ALTERNATIVE FUTURES FOR WORLD FOOD IN 1985

VOLUME 1, WORLD GOL MODEL ANALYTICAL REPORT

ALTERNATIVE FUTURES FOR WORLD FOOD IN 1985—VOLUME 1, WORLD GOL MODEL ANALYTICAL
REPORT. Anthony Rojko, Donald Regier, Patrick O'Brien, Arthur Coffing, and Linda
Bailey. Foreign Demand and Competition Division of the Economics, Statistics, and
Cooperatives Service, U.S. Department of Agriculture. Foreign Agricultural Economic
Report No. 146.

ABSTRACT

This volume reports on analysis and general results of the world grain-oilseeds-
livestock (GOL) model. The results point up the importance of the strong
interrelationships tying together the world commodity sectors. Projections rest on
a number of alternative sets of assumptions about world economic growth, trade, and
food policy conditions. Under most of the tested alternatives, the world has
sufficient capacity—whether measured in details of physical potential or economic
feasibility—to meet grain and overall food needs of an expanding, more affluent
population at real prices somewhat above base 1970 levels but below 1972-74 highs.

However, the projections indicate that regional food distribution problems are
likely to persist. Moreover, the alternative which assumes lower grain yields and
deteriorating climate and weather suggests the possibility of serious pressures on
resources and increases in price of grain imported by the developing countries. As
a whole, the developing countries' grain imports are projected to increase faster
than imports in the rest of the world. Imports in 1985 are projected to range from
49 million tons under the alternative which assumes a continuation of present
agricultural and trade policies, to 91 million tons under the high import demand
alternative; both compare with recent levels of 30-35 million tons. Rising demand
for meat and livestock products is projected under all alternatives. Growth in the
commercial sectors of the world meat economy ranges from one-third to one-half above
1970 base levels.

Key words: Agricultural projections, alternative assumptions, economic model,
agricultural commodities, grains, oilseeds, oilseed products, livestock products,
international trade.

FOREWORD
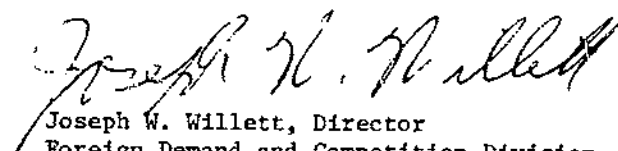
The Economics, Statistics, and Cooperatives Service (ESCS) is working on a continuing basis on projections of changes in world export markets, population, income, and resource and environmental constraints and of their impact on the U.S. agricultural sector. The affected U.S. variables include production, consumption, trade, prices, farm costs, and farm incomes.

Major components of the projections program are world, regional and country projections of production, demand, trade, and prices of major commodities important in agricultural trade. These projections are useful in evaluating the broad issues of future world food prospects.

The projections are made within the framework of a mathematical world grain-oilseeds-livestock (GOL) model. The model is designed to capture the main economic relationships of the three groups of commodities and to test the impact of different economic and policy assumptions on projected quantities and values.

Projections of U.S. agricultural exports generated by the GOL model are not official ESCS projections of U.S. trade in agricultural commodities. Rather, they are presented to aid users in evaluating the impact of different assumptions on world trade.

Results of the GOL model are being reported in this volume. Subsequent volumes provide model documentation. The GOL model is one analytical tool along with other ESCS computer programmed mathematical models analyzing future food and agricultural trade prospects.

Joseph W. Willett, Director
Foreign Demand and Competition Division
Economics, Statistics, and Cooperatives Service

i

PREFACE

This study reports on one phase of an ongoing research effort aimed at generating and maintaining up-to-date price, production, consumption, and trade projections for agricultural commodities in the major countries and regions of the world. The study assesses alternative world food prospects, through the use of a mathematical model of the world's grain-oilseeds-livestock economies (GOL model).

The study is being published in several volumes. The present analytical report, which summarizes the GOL projections to 1985, is volume 1 of four volumes. Volume 2 will contain detailed country and regional supply-distribution tables and related price and growth rate tables. Volume 3 will describe and present the mathematical equations used in the GOL model. Volume 4 will be a users manual.

This research effort requires substantial ongoing teamwork from members of the Commodities Program Area working with others in the Foreign Demand and Competition Division (FDCD) of ESCS and with other ESCS divisions in the area of econometric model development and country-specific analyses. Under the overall direction of Anthony S. Rojko, significant inputs have been made by Donald Regier (livestock and derived feed), Patrick O'Brien (grains), Arthur Coffing (oilseeds), Robert Barry (rice), Myles Mielke (dairy), and Linda Bailey. Several people have helped to develop the computer programs, beginning with Francis Urban in the early stages, Hilarius Fuchs during the main development stage, and Fenton Sands and Martin Schwartz in the later stages. The contribution of Angela Wray in organizing the formulation and presentation of the materials in this volume is also acknowledged.

While it is impossible to cite all the individuals in FDCD who contributed, special recognition is given to Wayne Denny, Gene Hasha, John Link, and John Parker for their inputs to the productivity aspects of the developing world. Recognition is also given to James B. Johnson, Leroy Quance, and Allen Smith for their part in the work on the U.S. sector.

CONTENTS

iii

TABLES

Table

FIGURES

SUMMARY

The results of the world grain-oilseeds-livestock (GOL) model presented in this report point up the strong interrelationships tying together the world's grain, oilseed, and livestock sectors and their importance in shaping future world food balances. The mathematical model reported on in this study makes alternative projections to 1985 of production, consumption, trade, and prices of grains, oilseeds, and livestock products. Projections are also included for grain and oilseed area and yield, and for grain food and feed use. Projected values are contrasted with 1970 base period levels, as well as with 1973-75 levels.

The projections rest on a number of alternative sets of assumptions, designed to evaluate the impact of different combinations of world economic, trade, and food policy conditions. These alternative sets of assumptions trace out the impacts of a continuation of recent policies, of a shift toward high world import demand with high income and more liberalized trade, of a shift toward low import demand and more stringent trade restrictions, and of different levels of agricultural productivity in developing countries.

The alternative tracing out the effect of a continuation of recent policies around the world and the alternative assuming more liberalized trade policies and higher income growth are considered as having higher likelihoods of occurring than the alternative assuming slowed income growth and low import demand. The alternative tracing out the effects of low income growth and more restricted trade demonstrates, however, the importance of world prosperity to world trade.

All of the alternatives discussed above assume the absence of any major climate change, either favorable or unfavorable, that could change future grain and oilseed yields substantially. The 1975 drought in the Soviet Union, the 1976 drought in Western Europe, and recent weather problems in the United States have reactivated concern about the possibility of deterioration in the world's climate and its implications for future world food production. Separate computer runs were made to estimate the effect of lower grain yields on the world food supply-demand balance and resulting pressure on resource availability. Separate runs were also made to capture the effects of more frequent weather-induced crop shortfalls than occurred in the two decades prior to 1972; results of these runs were used to determine the production needed to build adequate stocks in "good" years to maintain consumption in "bad" years.

Grain

Under most of the alternatives tested, the world has sufficient capacity--whether measured in terms of physical potential or economic feasibility--to meet the grain and overall food needs of an expanding, more affluent population at real prices somewhat above base 1970 levels, but below 1972-75 highs.

However, the projections indicate that regional food distribution problems are likely to persist. Moreover, the alternative that assumes lower grain yields indicates that deteriorating climate and weather could pose serious, possibly generalized, pressures on resources and prices.

The developed countries as a group--particularly the United States, Canada, and Australia--have the capacity to increase grain production to meet projected foreign and domestic demand. Their own use of grain is forecast to increase by over a third by 1985, largely because of increased demand for products from grain-fed livestock.

Foreign demand for their grain is likely to increase at least 75 percent, and possibly as high as 125 percent, as a result of both stronger feed demand in the richer importing countries and stronger food demand in the developing countries.

Under the policy continuation alternative, the exporters as a group would probably face problems of restraining production, given the assumption that the major exporters continue to adapt their production policies to changing global supply and demand conditions. Production in the United States and Canada in particular was assumed to adjust downward so as to prevent the accumulation of large, price-dampening stocks and upward so as to take advantage of growth in world import demand—be it either long-term growth related to population and income changes, or short-term growth related to production shortfalls.

Grain deficits in the developed importing countries as a whole are forecast to increase significantly, possibly doubling by 1985 from base 1970 levels under the high import demand alternatives. Substantial growth in grain import demand is expected in Japan. Growth in Western Europe will depend considerably on the European Community's Common Agricultural Policy, and possible expansion of the Community membership or the adoption of similar policies by other European countries. Imports by Eastern Europe are expected to expand significantly, and the Soviet Union's imports are projected to be about or somewhat higher than the 6- to 8-million-ton level of the USA-USSR agreement negotiated in 1976. Under the high import situation, the Soviet Union's net grain imports exceed 11 million tons.

Grain imports of the developing countries as a whole are projected to increase appreciably faster than imports in the rest of the world, with 1985 imports ranging from 49 million tons under the policy continuation alternative to 71 million tons under the high import demand alternative. This range compares with 18 million in the 1970 base and recent levels of 30-35 million tons. Wheat comprises the bulk of the grain imported; the largest purchasers are the more affluent countries of North Africa, the Middle East, and East Asia, as opposed to the poorer countries of Central Africa and South Asia. The developing countries' 1985 imports could be as low as 34 million tons, however, under the increased productivity alternative. Boosting growth in productivity by only the .4 or .5 percent per year implied in expanded use of physical inputs and agricultural technology could well lower the developing countries imports below base 1970 levels—while keeping per capita consumption growth at roughly twice the annual trend rate of .4 percent registered in the 1960's and early 1970's.

Projected increases in grain yields to 1985 differ widely by individual grain and by region. Overall growth, however, is expected to exceed the rates of the last half decade and to approach or exceed—depending on the model alternative—the rates of the 1950's and 1960's. Growth is postulated on the assumption that developed countries expand use of existing technologies. Yield increases are also likely in the developed countries as existing but still unadopted technology spreads to the less advanced countries of the temperate zone.

The largest potential for yield increases is in coarse grains—particularly corn. However, continued emphasis in many of the developing countries on improvements in wheat and rice yields, and on allocation of the most productive resources to the production of wheat and rice, are likely to keep increases in coarse grains yields well below increases in other grains.

Livestock

Strong and rising demand for meat and livestock products occurs under all alternatives. Growth in the commercial sector of the world meat economy ranges from one-third to one-half above the base period level. In no case is a decline projected in world per capita consumption of meat. It stagnates in developing countries under the effects of low income, but rises in all other alternatives.

Important considerations bear on this outlook. While meat consumption is bolstered by growth in income and population, national policies for production and trade also determine meat consumption levels and world trade patterns. Present policies imply continuation of high domestic prices and import barriers in the most important meat-consuming regions. Heavy balance-of-payments disbursements on fuel imports, feed inputs, and on finished meat imports may cause restrained meat consumption.

The commercial sector of the world meat economy holds to historical patterns in the projections. The United States and the European Community (EC) continue to be the major producing and consuming areas, with Canada, Mexico and Central America, and Other Western Europe sharing in the growth. Japan becomes a major world consumer. Argentina and Oceania remain the principal suppliers of long-distance meat to Western Europe, which continues to be a major importer as well as producer. If the EC were to lower meat import barriers, world trade would be stimulated, leading to higher levels of world production, expanded consumption even in the EC, and possibly exportation of ordinary beef by the United States (in addition to high-quality beef). Western Europe, rather than the United States, could thus measure as the world's largest meat importer.

Feed costs are projected to be higher relative to livestock product prices than they were in 1969-71. Thus, the degree of expansion in meat production will hinge on greater efficiencies in the structure of production and marketing.

The GOL model also indicates the crucial importance of developments in the livestock sectors. The extent to which the developed countries expand grain-fed livestock sectors, and the developing countries build up such sectors, will be a major determinant of grain prices and hence of world food problems in 1985. With a moderate rise in consumption of grain-fed livestock products in the developed countries and a continuation of largely cereal-based human diets in the developing countries, the projections indicate that exporters would have no problem meeting both food and feed demand for grain at reasonable prices. Even if grain demand grows more rapidly as a result of modest increases in feed use in developing countries, production should be sufficient to keep real grain prices below the high 1972-74 levels.

Grain prices could be pushed up substantially, however, if income in the lower income developed countries grew rapidly and generated stronger demand for livestock products. If Japan or the poorer countries of Western Europe were to adopt U.S. grain feeding techniques, grain prices could rise substantially as food demand bids against feed demand. Strong economic growth concentrated in the developed countries and the higher income developing countries could make it difficult for the poorer developing countries to raise per capita grain consumption levels faster than .3 to .4 percent a year.

Oilseeds

Demand for oilmeals will continue to grow with increased production of livestock and livestock products. Under the policy continuation alternative, commercial

demand increases 3.6 percent annually on a global basis. The increase under the high income alternatives is more rapid. To match these increases in demand, supply increases are projected under all alternatives. The largest supply changes are projected for the United States and Brazil, where soybean production continues to expand. Trade in oilmeals continues to expand rapidly, in some cases doubling the rate of production expansion. One implication is that both producers and consumers will tend to become even more dependent on world markets.

Real oilmeal prices are projected to advance significantly. Under the high import demand alternative, the rise is comparable to the increase projected for pork prices and only a little higher than the increase projected for coarse grain prices.

Because of the diversity of crops involved, it is harder to generalize with respect to yields of oilseeds and, consequently, oilseed meals. At one extreme, sunflower yields have increased rapidly in many areas of the world. At the other, soybean yields have been constant or have trended upward only slightly. Probably the greatest yield potential lies in peanut production in South Asia and West Africa. However, since soybeans account for the largest share of world meal production, and since efforts to improve yields have been largely unsuccessful, the area component will continue to account for a significant portion of the total increase in production.

Climate and Weather

To estimate the impact of possible long-run changes in climate, reductions in growth in yields of 5 to 15 percent were postulated for the major areas of the world subject to wide weather fluctuations historically. The impact under the lower income and consequently lower demand alternative is moderate; the major producers, particularly exporters, are able to expand area, thus offsetting slower growth in their own yields and slower production growth in regions where area expansion is more difficult.

However, lower grain yields combined with the higher demand alternative could pose serious problems. The major developed exporters would need to expand area considerably, but only at higher costs per unit of output and reduction of area in other crops. The higher grain prices projected could discourage some growth in the livestock industry. For example, a move to more restrictive trade policies and a return to higher levies in both meat and grains could be expected in much of Western Europe. The net effect, however, would be to increase U.S. coarse grain exports from 62 million tons under the original high demand alternative to 77 million tons given lower grain yields and high demand. The increase in U.S. exports of wheat is considerably less—from 50 million tons to 54 million tons. The assumptions of the poor climate scenario would result in reduced U.S. yields in the present major wheat belt and some shift in wheat production eastward to areas with more moisture. However, this move would be limited because of competition from coarse grains and soybeans. Harvested area in the United States for total grains and soybeans could be as high as 118 million hectares. This corresponds to a record in excess of 120 million hectares harvested in the 1975/76 period. Harvested area in Canada, Australia, and Argentina by 1985 would also approach or exceed recent highs on a regular basis.

World trade in beef and pork is also affected under the poor climate scenario. This scenario assumes low demand and recourse to trade protectionist practices. An increase in variable levies in the EC and limitations in Japan would make the market for low grade beef in United States more attractive than that in Europe. However,

Argentina and Australia would not be able to take full advantage of the high world prices of meat. Beef production in the United States, under the lower yield alternative, would be expected to shift to a greater extent east of the Mississippi—accelerating a trend that has been occurring in the last two decades. The United States could be a major exporter of pork as world prices of pork would likely increase substantially more than prices of beef.

For the developing countries, imports of grain increase to 82 million tons, compared with 70 million under the higher yield assumption. This import gap could not be met without massive food aid. Slowed production growth and high import demand, however, would be incompatible with high income growth and low agricultural productivity. Thus, a concerted effort to boost indigenous grain production probably would take place, thereby reducing the import gap.

Implications for the United States

Under each alternative, the U.S. share of world grain and oilseed exports is higher in 1985 than it was in 1961-71. The same is true for the U.S. share of world livestock product imports. However, under the policy continuation alternative, increased export availabilities in other major grain exporting countries reduce the U.S. share of the world grain market below 1972-74 highs. U.S. exports of wheat, coarse grains, and rice total 77 million tons in 1985, compared with an average of 40 million tons in 1969-71 and 73 million tons in 1974-76. The U.S. share of world grain exports is 54 percent, which compares with 51 percent in 1969-71 and as high as 60 percent in recent years.

U.S. wheat exports, projected at 34 million tons, are substantially above the 18-million-ton average of 1969-71 and the 30-million-ton average of 1972-74. Coarse grain exports, at 40 million tons, are double the 1969-71 average but marginally below the highs of 1972-74.

Under the high import demand alternative, U.S. grain exports in 1985 are 116 million tons, accounting for some 60 percent of world grain exports. Coarse grain exports increase to 62 million tons, with U.S. corn exports to livestock feeders in Western Europe accounting for about half of the increase because of the more liberalized trade policies assumed. Growth in world feed grain import demand under this alternative is almost twice the annual rate of the alternative assuming a continuation of current policies. The U.S. share of this larger market increases at the expense of the other major exporters because of greater U.S. production capacity. U.S. wheat exports increase to 50 million tons, with imports by the developing world accounting for most of the gain. The low-income developing countries account for about three-fourths of the 15-million-ton increase in wheat exports to the developing countries. These countries might find it difficult to purchase such amounts under the high import demand situation unless a greater proportion of imports are concessional than under the policy continuation assumption.

Model Format

The model's mathematical relationships are specified to capture the interaction of production, consumption, trade, and prices of grain, oilseed, and livestock products. Basic inputs include population and income growth rates, income

elasticities, direct and cross demand and supply price elasticities, supply variables, and assumptions about underlying economic trends and policy constraints.

Where possible, the model incorporates resource constraints and provides for changes in trends in yield growth, as well as changes in consumer preferences, such as shifts toward livestock products or shifts out of feed grains into wheat and rice products. The model covers the world in up to 28 country or regional aggregations for grains and 14 for the commercial, trade-oriented meat economies.

ALTERNATIVE FUTURES FOR WORLD FOOD IN 1985

VOLUME 1, WORLD GOL MODEL
ANALYTICAL REPORT

By

Anthony Rojko, Donald Regier,
Patrick O'Brien, Arthur Coffing, and Linda Bailey
Foreign Demand and Competition Division
Economics, Statistics, and Cooperatives Service

INTRODUCTION

The wide fluctuations in food supplies of the last few years—from surplus to shortage and back to surplus—have focused attention on a number of longer term world food problems that had been submerged during most of the last two decades. The most important of these problems has been the increasing dependence of the developing countries on the developed countries for imports of food. A second problem has been the sporadic but increasingly large grain purchases of the centrally planned economies. Still another problem arises from the increasing use of grain and other concentrate feeds in the production of meat and other livestock products.

Until 1972, the impact of these problems was largely mitigated by the extensive stocks held by the major grain exporting countries, particularly the United States. The increasing dependence of the developing world on both commercial and concessional imports, the increased import demand of the centrally planned countries, and the expansion of grain-fed livestock production in the developed world permitted the exporting countries to reduce surpluses resulting from farm income support programs. But the use of concessional food aid shipments as part of the exporters' surplus management program, and the low food price policies made possible by the developing countries' concessional imports, dampened incentives to produce food in a number of developing countries. The stock drawdown policies and tighter production controls implemented by the United States and the other major exporters in the late 1960's and early 1970's reduced their grain stocks even further, made more grain available to food importers, and encouraged more extensive use of grain in livestock production in the feed importing countries.

Production shortfalls in the USSR in 1972, followed by the Soviet's decision to import enough grain to maintain high consumption levels, combined with shortfalls in other parts of the world, depleted world stock reserves. Production shortfalls in the United States in 1974 and in the Soviet Union again in 1975 could not be made up through stock drawdowns. The world was consequently left dependent on annual production to meet current food needs.

Marked improvements in production in 1975/76 and again in 1976/77 virtually reversed the world food situation by the beginning of 1977/78. With world supplies up and consumption lagging, world stocks of grain hit a decade high, while stocks in the United States hit a 15-year high. This pronounced shift back toward abundance has not solved the problems that generated the world's 1972/73-1975/76 food crisis. Recent short-term improvements in world food supplies could well worsen the world food problem in the longer term by making supply management in the exporting countries more difficult and by disguising problems in the deficit areas of the world as opportunities to dispose of excess supplies.

The recent phenomenon of widely fluctuating food prices and uncertain food supplies that arose out of this combination of weather related production shortfalls, policy changes, and long-term trends raises the following important issues:

--Will the developing world continue to increase its dependence on the developed world for food imports?

--What will be the balance between the developed and developing world? Imports of food versus imports of agricultural inputs and technology?

--What will be the pattern of adjustment forced on the world's commercial meat economy by rising grain prices?

--What will be the relationship between grain use for food and grain use for feed and how will it differ among regions?

--Do the major exporters of grain have the long range capacity to meet the world's growing demand at reasonable prices?

This publication addresses these and other questions through the use of a mathematical model to project world production, consumption, trade, and prices of grains, oilseeds, and livestock products to 1985 under several different alternatives.[1] These projections should not be interpreted as forecasts of the future. The probability that a particular set of projections will materialize depends on the likelihood of its specific assumptions and the basic relationships underlying the projections. Moreover, long-range projections or basic assumptions and relationships can be invalidated over time, particularly if the attention they draw to developing disequilibria is followed by corrective action.

The major alternative sets of projections evaluated in this study can be summarized as follows:

--Alternative I assumes a modified continuation of trends and basic agricultural and trade policies around the world. International trade is somewhat restricted by protectionist national economic policies, but not all trade restrictive goals are met.

--Alternative I-A assumes the successful implementation of alternative I's protectionist policies in the developed countries and slowed economic growth in the developing countries.

---

[1] For other studies concerned with these problems see pp. 79-83.

2

--Alternative II assumes high income growth rates that generate substantially higher levels of world import demand.

--Alternative III quantifies the effects of generalized slowed income growth and low world import demand in conjunction with alternative I-A's restrictive trade policies.

--Alternative IV tests out the case of moderately higher productivity in the developing countries in the context of high income growth rates and strong world import demand.

--Alternative IV-A tests out the case of accelerated productivity in the developing countries in the context of high income growth rates and strong world import demand.

In addition, separate runs were made to capture how adverse longrun climatic change, as reflected by lower grain yields, might affect the world grain supply-demand balance and resources availability. Separate runs were also made to capture the effects of more frequent crop production shortfalls, caused by bad weather, than occurred in the two decades prior to 1972. Results of this analysis were used to determine the amount of additional productive capacity needed to build stocks in the "good" years to maintain consumption in "bad" years. In both cases, these parametric runs were tested using each of the alternative I, II, and IV assumptions.

ANALYTICAL FRAMEWORK

The research reported on in this study is based on a formal mathematical model used to project key economic variables in the world's grain, oilseed, and livestock sectors. This report concentrates on the model's projections to 1985. 2/ Mathematical relationships underlying the model were specified to capture the interaction of production, consumption, trade, and prices of grain, oilseed, and livestock products.

These mathematical relationships may be grouped into nine major components:

1. Demand block--livestock

2. Supply block--livestock

3. Demand block--feed

4. Demand block--food grains

5. Supply block--crops
   Area
   Production

6. Price linkages within regions

2/ This model builds upon the world grain model by Rojko, Urban, and Naive (167) and the approach used has been influenced by model development of Bawden (1007), Takayama and Judge (1069), (1070), and others.

3

7. Regional equilibrium

8. Price equations linking regions

9. World equilibrium equations for each commodity

Each component of the model may be thought of as consisting of two basic parts: a driving and a responding part.

The driving part of the model is made up of those variables whose levels are determined outside of the model. Included here are the usual demand shifters, such as population and income growth rates, and consumer preference variables, which are usually expressed as trend values. Also included are the usual supply shifters, including technology variables, statements on the availability and cost of basic agricultural inputs, factors related to national commercial and agricultural policies and practices, and basic growth rates for yields derived from analyses of data for the 1950's, 1960's, and early 1970's. The specific equations of each of the model's components specify the levels of the driving variables, as well as the extent to which changes in these levels affect the variables in the responding part of the model.

The responding part of these components are 930 interacting variables that are being projected and are contained in 930 equations specifying supply-demand balances for up to 14 separate commodities in 28 regions of the world. In general, the parameters defining the interrelationships do not vary between alternative projection runs. The demand blocks consist of direct and cross demand-price elasticities. The demand block for feed also includes physical input-output coefficients relating it to the supply block for livestock products. The supply block for livestock contains direct and cross supply-price elasticities. The supply block for crops distinguishes between area and production and allows for area allocation between crops subject to total area for these crops. The production equation allows for yield response to changes in relative prices. The price linkage and the equilibrium components relate the model within regions and among regions. This responding part of the model is solved simultaneously for given levels of the driving variables and is essentially unconstrained. Base data centered on the year 1970 were provided for the interacting variables and their counterpart values were projected for 1985.

The parameters for the model's mathematical relationships were synthesized from either statistical analyses or the judgment of experts. The model could not be a product of a direct statistical fit because of its size. Instead, to facilitate comparisons and permit evaluation of different alternatives, the model was built as an integrated framework of synthesized coefficients describing the behavior of the world's grain-oilseed-livestock sectors. The synthesized coefficients used in the model's equations were developed from numerous sources and adjusted when necessary to reflect relationships among the variables. Data for 1969/70-1971/72 were used to determine the value of the constants in the equations. But while the 3-year average 1969/70-1971/72 was used as base for projections to 1985, developments through 1975/76 were used to evaluate model inputs and projection outputs.

The mathematical model, with the aid of a computer program, projects a set of equilibrium values for production, consumption, trade, and prices of grains, oilseeds, livestock, and livestock products; area, yield, and food and feed use values are also projected for grains and oilseeds. The computer program solves a set of simultaneous equations consistent with the specific alternative under consideration. The equations are specified by commodity, by region, and according to economic function. They consequently constitute quantified descriptions of the world's grain-oilseed-livestock economy. The equations, as well as the supply

4

distribution tables for the individual alternatives, are being published in separate volumes. The parameters underlying the equations--that is, direct and cross supply and demand price elasticities and income elasticities of demand--are presented in a later section of this report.

The scope and organization of economic relationships contained in the model are shown in table 1 and figures 1-2. The variable patterns for each of the model's regions are laid out in table 1. Grains and oilmeals are modeled in all 28 regions of the world (see p. 9). Table 2 lists the countries included in each of the model's regions. Production and acreage equations were not developed for all regions; for instance, only international trade relationships were developed for the three centrally planned regions. Fuller representation of the centrally planned regions will be incorporated in future modeling phases. Minor departures from full coverage in the other 25 regions are deliberate and reflect judgments about the relative importance of a commodity in a specific region and the availability of data.

Modeling of the livestock economy has concentrated, at this stage, on representing the commercially important part of the world's livestock economy. The focus has been on beef and on the developed countries and Latin America. Attention has also been given to other meats and dairy products as competing and complementary products and as close substitutes in consumption.

Figures 1 and 2 present schematic views of (1) a region with both a crop and livestock sector, and (2) a region containing a crop sector only. Differences in the modeling approach can be summarized by highlighting the treatment of the animal sector. Where there are complete crop and livestock sectors, separate production, consumption, and trade balances are calculated for both the crop and livestock sectors, with production of livestock products linked technically to the quantities of a specific crop produced for livestock feed. As a result, world trade for the crops as well as for the livestock commodities is calculated. In regions containing only a crop sector, factors explaining the consumption and production of livestock products are considered to operate directly on the derived demand for crops used as livestock feed. In such regions, no livestock balance and no foreign trade in livestock commodities are calculated.

ASSUMPTIONS

Each alternative projection set has its own bundle of assumptions concerning key economic variables and policy considerations. These are discussed in detail on pages 32-62, where the results of the alternative projection sets are presented. Assumptions general to all projection sets are discussed below. As is usual, the projections assume the absence of major wars and natural disasters that would change the underlying factors affecting future supply and demand prospects.

Population

Population is a key variant in the model's projection of growth in demand for agricultural products. The United Nations' "medium" variant population projections, as reassessed in 1974, were used for all regions except the United States, for which the lower Series III figures of the Department of Commerce were used (table 3 and fig. 3).

5

World Grain-Oilseed-Livestock Economy

Region with
Full Livestock Sector

Figure 1

6
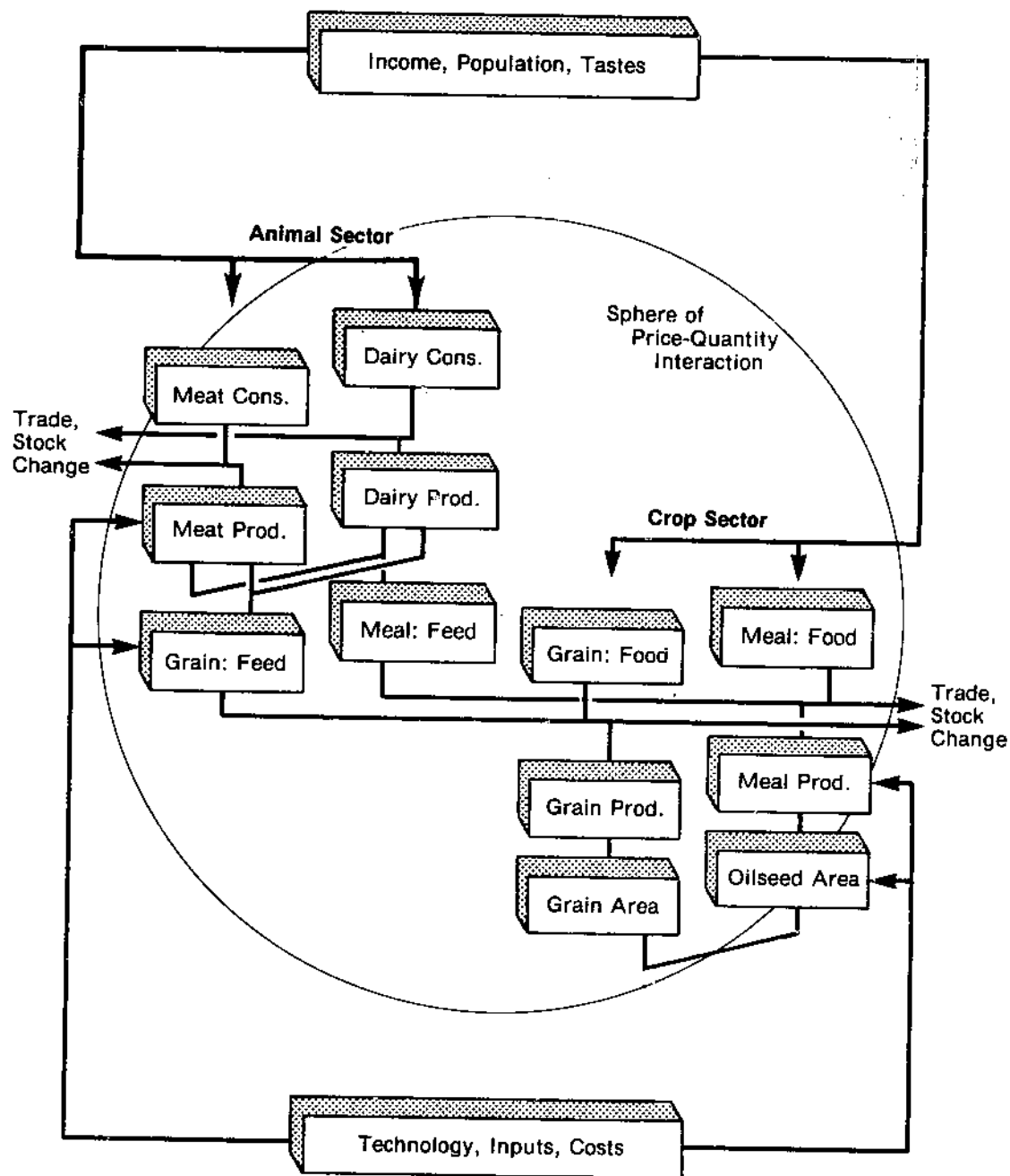
World Grain–Oilseed–Livestock Economy

Region with
Collapsed Livestock Sector

Income, Population, Tastes

Sphere of
Price-Quantity
Interaction

(Animal Sector)   Crop Sector

Grain: Feed   Meal: Feed   Grain: Food   Meal: Food

Trade,
Stock
Change

Grain Prod.   Meal Prod.

Grain Area   Oilseed Area

Technology, Inputs, Costs
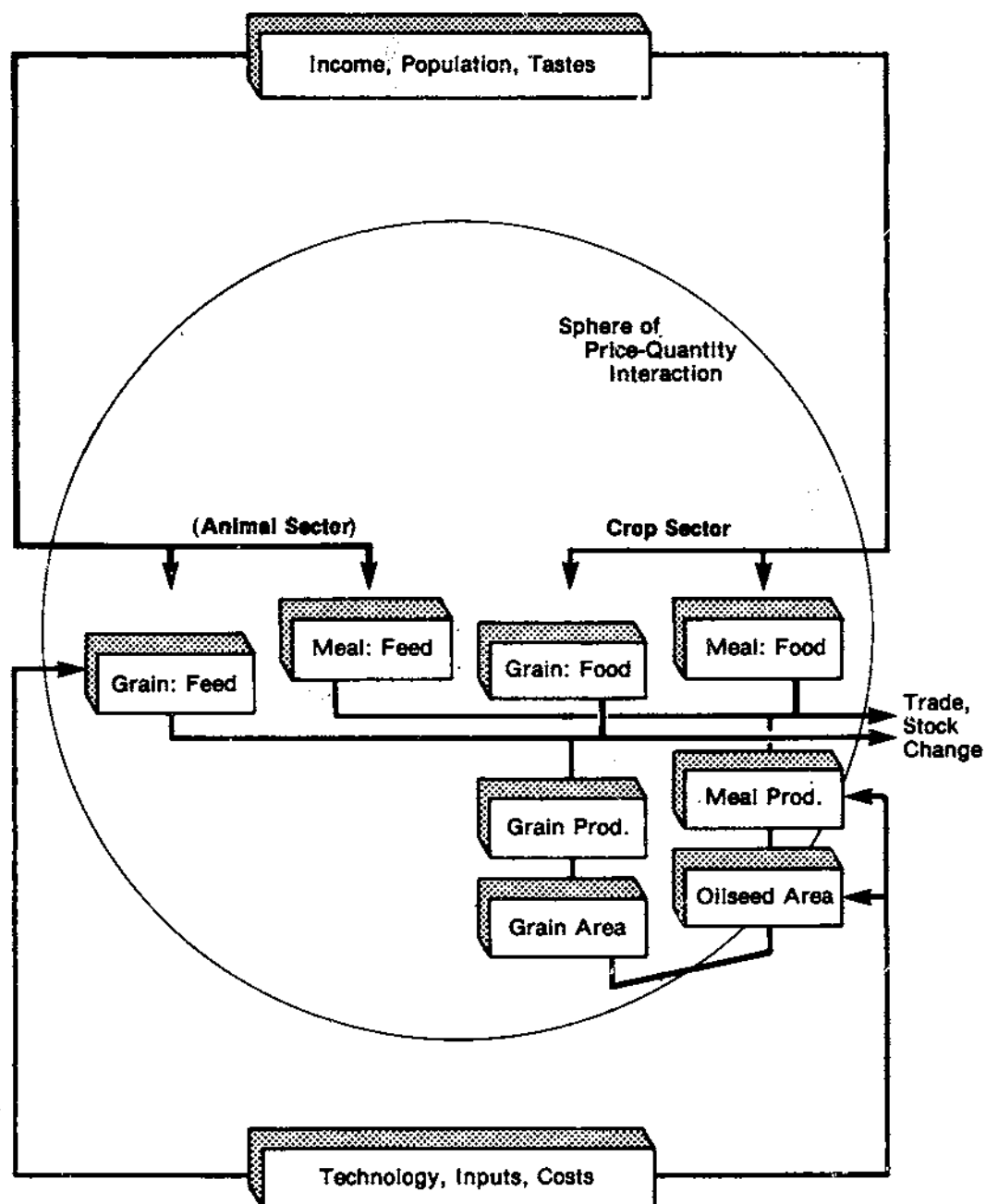
Figure 2

Table 1--Variables used in world grain-oilseeds-livestock model

Region	Wheat	Rice	Coarse grain	Oilseed meal	Milk	Cheese	Eggs	Beef cuts	Beef products	Pork	Poultry	Mutton & lamb
Developed countries:												
United States	DF PA	D PA	DF PA	F PA	D S	D S	P	D P	D P	D P	D P	D
Canada	DF PA	D	DF PA	F PA	D S	D S	P		D P	D P	D P	
EC-6	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	
EC-3	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	D P
Other Western Europe	DF PA	D PA	DF PA	F PA	D S	D S			D P	D P	D P	D P
Japan	D PA	DF PA	DF PA	DF PA	D S	D S	P		D P	D P	D P	D P
Australia/New Zealand	DF PA	D PA	DF PA	F PA	D S	D S	P		D P	D P	D P	D
South Africa	D PA	D	DF PA	F S		D S			D P	D P	P	D P
Centrally planned countries:												
Eastern Europe	T	T	T	T					T	T		
Soviet Union	T	T	T	T				T				
China	T	T	T	T						T		
Developing countries:												
Middle America	DF PA	D PA	DF PA	F PA					D P	D P		
Argentina	D PA	D PA	DF PA	F PA					D P	D P		
Brazil	D PA	D PA	DF PA	F PA					D P	D P		D P
Venezuela	D PA	D PA	DF PA	F PA								
Other South America	D PA	D PA	DF PA	F PA								
High-income North Africa & Middle East	D PA	D PA	DF PA	F								
Low-income North Africa & Middle East	D PA	D PA	DF PA	S								
East Africa	D PA	D PA	DF PA									
Central Africa	D S	D S	D S	T								
India	D PA	D PA	DF PA	F PA								
Other South Asia	D PA	D PA	D PA									
Thailand	D	D PA	DF PA									
Other Southeast Asia	D	D PA	DF S									
Indonesia	D	D PA	D PA	D PA								
High-income East Asia	D PA	D PA	DF PA	F PA								
Low-income East Asia	D	D PA	DF PA	S								
Rest of world							T		T	T		T

D = Demand, total or nonfeed
F = Derived demand for feed

P = Production
A = Area

S = Supply
T = Foreign trade, net

Table 2--Country composition of regions in the world grain-oilseeds-livestock model

Regions	Composition
I. Developed countries:	
United States	United States
Canada	Canada
EC-6	Belgium, France, West Germany, Italy, Luxembourg, Netherlands
EC-3	Denmark, Ireland, United Kingdom
Other Western Europe	Austria, Finland, Greece, Iceland, Malta, Norway, Portugal, Spain, Sweden, Switzerland
Japan	Japan
Oceania	Australia, New Zealand
South Africa	Botswana, Lesotho, Namibia, Republic of South Africa, Swaziland
II. Centrally planned countries:	
Eastern Europe	Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Yugoslavia
Soviet Union	Soviet Union
China	People's Republic of China
III. Developing countries:	
Middle America	Mexico, Bahamas, Bermuda, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, British Honduras, Jamaica, Nicaragua, Panama, Trinidad & Tobago, Other Caribbean Islands
Argentina	Argentina
Brazil	Brazil
Venezuela	Venezuela
Other South America	Bolivia, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Surinam, Uruguay

Continued--

9

Table 2--Country composition of regions in the world grain-oilseeds-livestock model
--Continued

High-income North Africa and Middle East	Algeria, Bahrain, Cyprus, Iran, Iraq, Israel, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates
Low-income North Africa and Middle East	Egypt, Jordan, Lebanon, Morocco, Sudan, Syria, Tunisia, Turkey, Yemen (Aden), Yemen (Sana)
East Africa	Kenya, Malagasy Republic, Malawi, Mozambique, Rhodesia, Tanzania, Uganda, Zambia
Central Africa	Angola, Burundi, Cameroon, Central African Empire, Chad, Congo, Ethiopia, Djibouti, Benin, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritana, Mauritius, Niger, Nigeria, Reunion, Rwanda, Senegal, Sierra Leone, Somalia, Togo, Upper Volta, Zaire
India	India
Other South Asia	Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka
Thailand	Thailand
Other Southeast Asia	Burma, Cambodia, Laos, South Vietnam 1/
Indonesia	Indonesia
High-income East Asia	Hong Kong, Singapore, South Korea, Taiwan, Brunei
Low-income East Asia	Malaysia, Philippine Islands
Rest of world	North Korea, North Vietnam 1/, Mongolia, Cuba, Pacific Islands, Papua-New Guinea

1/ The model was designed before the reunification of North and South Vietnam into the People's Republic of Vietnam.

Table 3--World population and growth rates, average, 1969-71, and projected, 1985

Region	Population levels		Compound annual growth rates
	1969-71 average	1985 projection	
	- - - - Thousands - - - - -		Percent
Developed countries:	700,346	792,229	.836
United States	204,880	228,360	.726
Canada	21,030	26,045	1.436
EC-6	188,084	205,127	.580
EC-3	63,381	67,393	.410
Other Western Europe	82,021	89,921	.615
Japan	104,330	122,443	1.073
Australia/New Zealand	15,320	19,929	1.769
South Africa	21,300	33,011	2.964
Centrally planned countries:	1,126,189	1,377,782	1.354
Eastern Europe	125,629	139,486	.700
Soviet Union	242,760	283,010	1.028
China	757,800	955,286	1.556
Developing countries:	1,734,192	2,591,070	2.680
Middle America	78,844	124,691	3.103
Argentina	24,160	29,173	1.265
Brazil	94,660	144,245	2.848
Venezuela	10,788	16,681	2.948
Other South America	61,780	92,940	2.760
High-income North Africa & Middle East:	62,752	101,018	3.225
Low-income North Africa & Middle East	116,479	177,518	2.849
East Africa	57,534	90,027	3.030
Central Africa	179,755	270,382	2.759
India	564,810	814,420	2.470
Other South Asia	172,100	269,024	3.023
Thailand	37,160	60,458	3.298
Other Southeast Asia	56,000	79,505	2.364
Indonesia	119,720	177,000	2.641
High-income East Asia	50,280	67,154	1.948
Low-income East Asia	47,370	76,834	3.277
Rest of world	46,740	(66,964)	(2.426)
World	3,607,467	(4,828,045)	(1.9454)

World Population Growth

Absolute Levels

Bil. People

[chart showing World, Developing market economies, Centrally planned economies, Developed market economies from 1960 to 85]

Compound Annual Growth Rates

Percent

[chart showing Developing market economies, World, Centrally planned economies, Developed market economies from 1960/1955 to 85/70]
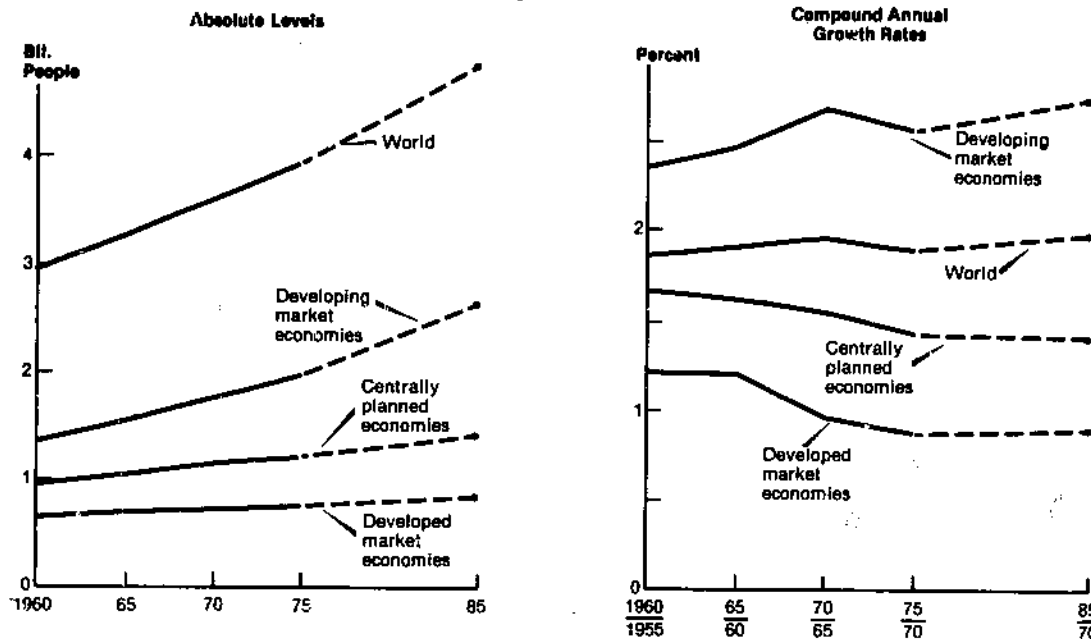
Figure 3

Over the projection period, 1969-71 through 1985, population is expected to increase at an annual rate of 0.8 percent in the developed market economies and 2.7 percent in the developing market economies. Earlier USDA projections used higher rates for the developed countries and somewhat lower rates for the developing countries. At the world level, the 1.9-percent U.N. growth rate used in the model is somewhat lower than rates used in earlier publications of the USDA.

Income

Income is another key variant in growth in demand for agricultural products. With given levels of population, prices, and other factors, the rate of increase in income largely determines the level, pattern, and variation in per capita consumption of agricultural products. While population may be the most important demand factor in developing countries, income is the most important factor in developed countries.

Where available, estimates of real per capita private consumption expenditures were used as income variables or demand shifters. For countries where these data were not available, either per capita gross domestic product or net material product was used (table 4 and fig. 4). In all cases, however, the implicit prices are those of 1970.

Income growth rates assumed in alternative I are the projected "trend" income values published in the Food and Agriculture Organization's 1974 Assessment of the World Food Situation, Present and Future. For the developing countries, these "trend" income projections were arbitrarily boosted by FAO to roughly 150 percent of the growth rates of the 1960's.

12

Table 4--World per capita private consumption expenditures and growth rates, average, 1969-71, and projected, 1985

Region	Private consumption expenditures per capita		Compound annual growth rates
	1969-71 average	1985 Alt. I projection	
	- - U.S. dollars - -		Percent
Developed countries:	1,747	2,803	3.202
United States	3,026	4,660	2.921
Canada	2,237	3,490	3.009
EC-6	1,463	2,368	3.263
EC-3	1,374	1,846	1.989
Other Western Europe	1,008	1,858	4.161
Japan	966	2,142	5.452
Australia/New Zealand	1,596	2,455	2.913
South Africa	502	715	2.385
Centrally planned countries:	439	792	4.010
Eastern Europe	1,024	1,988	4.521
Soviet Union	1,202	2,422	4.782
China	113	161	2.388
Developing countries:	155	251	3.255
Middle America	449	696	2.964
Argentina	724	1,149	3.125
Brazil	268	633	5.893
Venezuela	535	796	2.687
Other South America	311	414	1.925
High-income North Africa & Middle East:	261	614	5.864
Low-income North Africa & Middle East	188	306	3.301
East Africa	117	148	1.579
Central Africa	96	133	2.220
India	73	89	1.364
Other South Asia	95	101	.409
Thailand	130	248	4.392
Other Southeast Asia	83	99	1.182
	79	114	2.500
Indonesia	255	578	5.607
High-income East Asia	241	251	.271
Low-income East Asia			
Rest of world	181	232	1.669
World	560	834	2.691

World Per Capita Private Consumption Expenditures
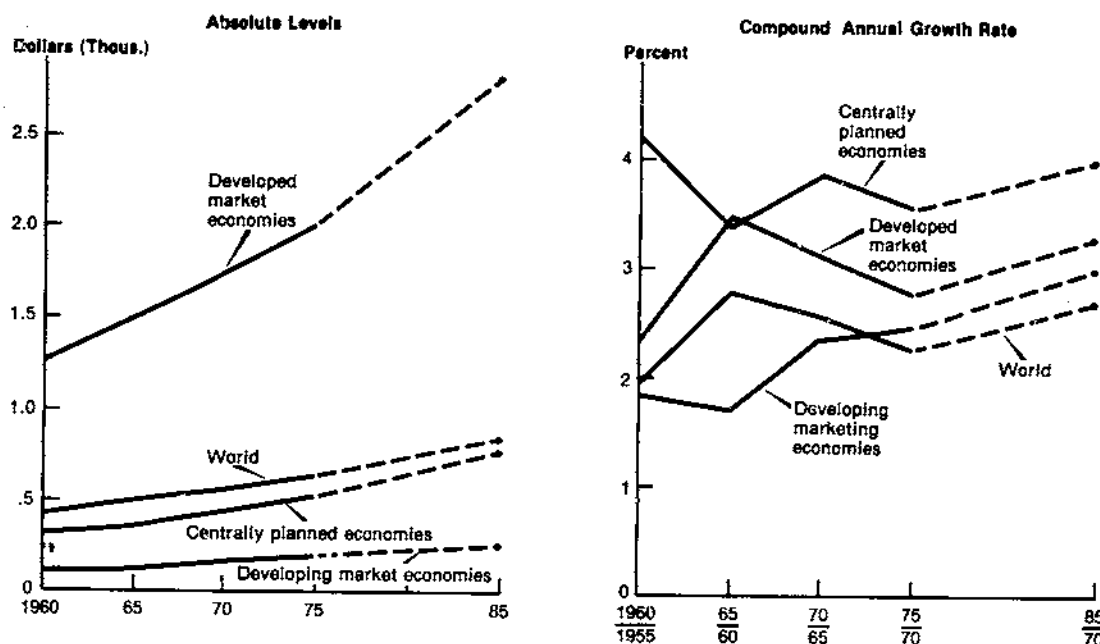
Figure 4

Alternative I-A uses the same "trend" income assumptions of alternative I for the developed and centrally planned countries. For the developing countries, however, alternative I-A uses rates of increase close to those of the 1960's. These same slower growth income projections are also used for the developing countries in the low demand alternative III.

Alternative III assumes income growth rates to be one-third lower than in alternative I in all areas of the world, postulating that world inflation and economic stagnation would result in a worldwide low demand situation. For the developing countries, this corresponds roughly to the growth rates experienced during the 1960's. The high demand alternatives--II, IV, and IV-A--assume more rapid income growth rates; for the developed countries, the growth rates are roughly 20 percent higher than in alternative I, and for the developing countries, roughly 50 percent higher (table 5).

Prices

Demand, production, and trade quantities are projected simultaneously with major commodity prices in the grain-oilseed-livestock model. Commodity prices in each projection set differ, depending on the projected supply and demand balance. All prices are projected in real 1970 dollars because of recent high inflation rates and uncertainty as to the future purchasing power of money. Where utilized or implied, exogenous prices are also expressed in terms of 1970 dollars.

14

Table 5--World per capita private consumption expenditures and growth rates,
by alternative, average, 1969-71, and projected, 1985

Region	1969-71 Base	1985 projection under alternative				
		I	I-A	II	III	IV & IV-A
		Real 1970 U.S. dollars				
World	560	834	814	915	730	915
Developed countries	1,747	2,803	2,803	3,075	2,553	3,075
Centrally planned countries	439	792	792	792	652	792
Developing countries	155	251	214	317	214	317
		Compound annual growth rates, percent 1/				
World	2.7	2.7	2.5	3.3	1.8	3.3
Developed countries	3.3	3.2	3.2	3.8	2.6	3.8
Centrally planned countries	3.6	4.0	4.0	4.0	2.7	4.0
Developing countries	2.0	3.3	2.2	4.9	2.2	4.9

1/ Growth rates under 1969/70-1971/72 base are computed from 1960 to 1970. Growth rates for 1985 are computed from base 1970.

Exchange Rates

For about four decades prior to August 1971, the United States maintained a
stable dollar in foreign exchange markets. During that period, the U.S. dollar
could be used as a numeraire for purposes of international currency value
comparisons. This is no longer so confidently true. Since then, the dollar has
been devalued twice and has been floating with respect to other currencies; gold has
been removed from the central position in international monetary calculations and
been replaced by the SDR--Special Drawing Rights--unit. For this reason, variables
in the GOL model are expressed in local currency or in "dollar equivalent" terms.
For the base period, 1970 exchange rates or average foreign currency conversion
rates are used. For subsequent years foreign exchange conversion factors were
adjusted to those shown in table 6. The use of these rates in the projected period
is valid provided intervening exchange rate adjustments fully reflect changes in
relative price levels in countries. The model does not project foreign exchange
rates. Exchange rates depend upon many factors not included within the model. It
is assumed that projected changes in region-to-region ratios of real prices would be
reflected in changes in exchange rates.

Table 6--Currency and exchange rate specifications 1/

Region	Currency and exchange rates
Developed countries:	
United States	U.S. dollar
Canada	1 Canadian dollar = 1 dollar equivalent
European Community	1 unit of account = 1 dollar equivalent
Other Western Europe	Dollar equivalent
Japan	357.600 yen = 1 dollar equivalent
Australia/New Zealand	.897 Australian dollar = 1 dollar equivalent
South Africa	Dollar equivalent
Centrally planned countries::	
Eastern Europe	Dollar equivalent
Soviet Union	Dollar equivalent
People's Republic of China:	Dollar equivalent
Developing countries:	
Argentina	3.75 new peso = 1 dollar equivalent
Others	Dollar equivalent

1/ Exchange rates as of July 1972. Dollar equivalent = 1 U.S. dollar.

Technology and Inputs

The GOL model treats technology and inputs, and their effect on productivity, as crucial supply shifters. Technological advances and improvements in both the quantity and quality of inputs used in the production of food affect not only immediate crop and livestock yields, but also the agricultural resource base. The continued evolution of technology along the lines of the recent past would be expected to expand the supply and improve the quality of resources to be used in food production. Perhaps the most obvious examples of this secondary effect of technology and inputs on the size and quality of the agricultural resource base are to be found in the impact of irrigation, the development and spread of pesticides and fertilizers, and the use of improved seeds and livestock strains.

The technology and inputs assumed in the GOL model either exist currently or are in the process of being developed. The availability of improved technology and the availability of inputs are consequently not assumed to be major impediments to future increases in food production. Accelerating the transfer of technology to the developing countries, adapting technology developed in the temperate countries to the needs of tropical countries, and encouraging adoption of technology and use of improved inputs by the small developing farmer, however, are likely to be significant bottlenecks. The GOL model assumes some advances are made in these areas. Full use of existing technology in the developing countries, however, would require a significant reorganization of the agriculture of much of the developing world.

The projections assume that the developed countries, and to a lesser extent the developing countries, will continue to take advantage of oncoming technological innovations and that limitation on the rate of adoption will depend mainly on the relative cost of inputs.

Several recent studies on land availability have concluded that at least twice as much of the world's land is suitable for crop production as is presently used. Nevertheless, there are serious regional problems resulting from a combination of population pressure on land and the difficulties of increasing agricultural production with prevailing technologies. As with other resources and economic opportunities, arable or potentially arable land is quite unequally distributed among the world's developing countries. This affects the options available to different groups and to different countries. A very large proportion of the world's people live in areas where possibilities for expanding the area cultivated are very limited. Bangladesh and Egypt, for example, must apply even more intensive, land-conserving methods of production to increase food output. The same is true, but with less extreme urgency, for Japan and Europe. Latin America and Africa have both intensive and extensive possibilities, as do Canada and the United States.

Except for Africa and Latin America, however, increases in land area will probably make progressively smaller proportionate contributions to future food supplies. The consensus of recent studies of world food production is that yield-increasing techniques will be the primary source of future growth in output, even in the developing countries (fig. 5).

Fertilizer is a key factor in yield increases, although it must be combined with other inputs, such as improved varieties of seeds and improved management practices, if it is to have its full potential impact on yields. Assumptions regarding fertilizer use are treated in greater detail in the discussion of alternatives IV and IV-A.

In addition to concern about the availability of land and fertilizer aroused by recent food shortages, some analysts question whether technological improvements will permit increases in crop yields in the future at the rates achieved in the

Grain Area
Mil. Hectares

Figure 5

17
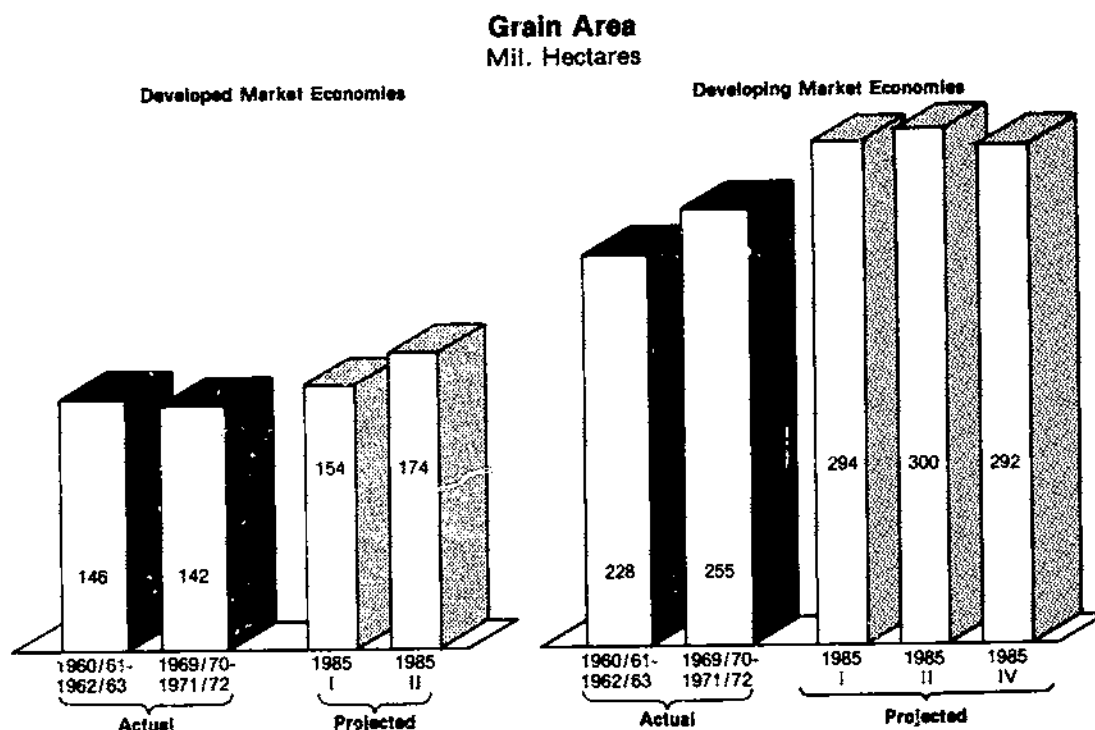
past. Attention has been focused on an apparent slowdown in the rate of production of some crops in some developed countries, and on the apparent loss of momentum of the Green Revolution in developing countries. The projections model assumes continued growth in grain yields in the developed countries but at rates below the highs of the 1960's. For the developing countries, the model assumes grain growth rates marginally above those of the 1960's.

Weather Variability and Stock Levels

Stock level assumptions are essentially part of broader production and trade policy assumptions. They are treated separately here, however, because of their importance in the current world food situation.

Assumptions about weather variability affect assumptions about stock levels, and vice versa. Assumptions about both affect the degree of price variability and, in turn, the projected levels of supply and trade. In general, less price variability occurs when growth in supply tends to be greater than growth in demand, resulting in a tendency to accumulate stock levels; the burdensome effect of the tendency to accumulate stocks, in turn, is mitigated by the frequency of droughts. Separate runs were made to study the relationship between short-term production shortfalls, longer term production levels, and stock levels.

Policy Assumptions

The production and trade policies of major food exporting and importing countries can have as much impact on future production and consumption patterns as can the interactions of economic variables. In the model, assumptions about government policies are included either explicitly in the mathematical formulations or implicitly in the coefficients used in the equations. For example, equations for the European Community (EC), provide explicitly for import levy variables. The equations for projecting grain area in the major grain exporting countries, on the other hand, have very responsive price coefficients to implicitly reflect the capability of government programs to readily adjust area to changed supply and demand situations.

Two important considerations of the policies of major grain exporting countries are basic to the assumptions of this study. The first is price maintenance at reasonable levels. The second is market share maintenance. It is not always possible to achieve both of these objectives at the same time. During periods of heavy world supplies, for example, prices cannot be maintained unless importers as well as exporters curtail production.

Price stability in periods of short supply can only be achieved if stocks are available. It is assumed that the major exporters will maintain sufficient stocks and implement production policies designed to maintain relative price stability in the longer run. In the shorter run, however, stocks would likely be kept below the levels needed to meet a series of successive production shortfalls similar to those of recent years. Implementation of such a policy could also be achieved through international cooperation. Thus, the meaning of the expression "continuation of policies" in the major exporting countries, such as the United States, is that they will follow production policies to keep the world grain supply in relative balance rather than permit continual appearance of sizable surpluses and deficits.

U.S. policies are important in establishing world price levels of many commodities. It is assumed that f.o.b. prices for these commodities in the United States and the appropriate c.i.f. prices abroad can be used as indicators of world supply and demand conditions.

An underlying feature of the import and domestic food production policies of major developed importing countries is that they attempt to at least maintain current self-sufficiency ratios. Japan would be a major exception, since her self-sufficiency ratio seems destined to decline. For all other major developed importing countries, it is assumed that recent food and fiber policies will be continued. Some modifications are provided for where it appeared that continuation of a particular policy would be untenable. Likewise, modifications, as well as the essentials of assumed food and fiber policies, can be different for the different alternatives.

The European Community is expected to continue its policy of enlargement. This means that the countries of the EC-3--the United Kingdom, Ireland, and Denmark--will continue through a transition period to become fully integrated economically with the EC-6 continental countries--France, Germany, Italy, Belgium, Luxembourg, and the Netherlands. It was assumed that the EC will continue to use variable levies and export subsidies to control the flow of imports and exports. High import levies, of course, limit trade, while low import levies increase trade. Levy and subsidy levels, however, differ under each alternative in order to be consistent with the food and fiber policy specified. It is also assumed that price policies of non-EC countries in Western Europe result in price levels similar to those in the Community. While Japan does not have specific import levies, its internal price and marketing structure is such that the effect is the same.

It is assumed that the longrun level of trade with the USSR, China, and Eastern Europe will be affected more by political factors than economic factors. The import policies of the centrally planned countries, particularly the USSR, will be influenced considerably by overall trade relations with the United States, as well as with other exporters. Actual trade levels will also depend on the extent to which the United States and other exporters are willing to absorb year-to-year variability in Soviet grain production.

Foot-and-mouth disease (hereafter called "aftosa") will continue to strongly influence livestock trade patterns. Since livestock in both Europe and South America already have aftosa, it was assumed that trade in fresh and frozen meat between these two continents will continue. Livestock in Oceania and the United States do not have aftosa, so it was assumed that these regions can export to the whole world, but will not import fresh or frozen meat from any of the aftosa areas. It was assumed that distances between Argentina and Europe are not too great to exclude trade in fresh beef on refrigerated ships.

Quotas on imports of beef into the United States were assumed to continue. If the projected imports obtained from the model are less than the quota, they become the imports.

It is also assumed that dairy product imports will continue to be limited by quotas in most countries. Butter imports into the United States are excluded and some growth in cheese imports is permitted if needed. Because of the continuation of health regulations and other policy and natural factors, fresh milk will not be traded. Primary adjustments in dairy markets between countries will take place in butter and cheese. It is assumed that prices of butter and cheese can be used as a barometer to measure degree of price pressures in the international dairy situation.

19

OVERALL RESULTS AND IMPLICATIONS

The following section presents the overall results and implications of the model common to all the alternatives and applicable to broad regional aggregates. Two more detailed discussions follow--the first dealing with results specific to individual alternatives, and the second dealing with results specific to the United States.

All of the model's projections of 1985 production, consumption, and trade emphasize the importance of technical and economic interrelationships in the grain-oilseed-livestock sectors of the world. The following factors will have a strong impact on the way demand and production patterns evolve over the next decade and beyond:

  --Growth in demand for meat and livestock products,
  and the impact of such growth on the use of grain and
  oilseeds in livestock feeds.

  --The relationship between affluency and the rate of shift
  from grains to animal products as a source of protein in
  diets.

  --The improvement in cereal diets in the developing
  countries.

  --The growth of indigenous livestock economies in the
  developing countries.

The projections suggest that the nature of food problems facing the world over the next decade will depend on the extent to which the developed countries expand, and the developing countries build up, grain-fed livestock sectors.

World grain balances could tighten if the lower income developed countries were to accelerate their growth in consumption of livestock products and adopt the grain-intensive feeding techniques of the United States. Consumption of livestock products in the lower income developed countries in general is low, and if increases in income were to strengthen growth in demand for grain-fed livestock products substantially, world grain and oilseed prices could be pushed up as food users in developing countries were forced to bid inputs away from feed users. Feed demand in the lower income developed countries, however, could not be expected to increase substantially unless grains and oilcake were reasonably priced relative to livestock products.

If diets in the developing countries continue to be based primarily on grains, and if consumption of grain-fed livestock products in the developed countries rises only moderately, the world's grain and oilseed productive capacity in 1985 should be sufficient to keep world grain prices, in real terms, below the high 1973/74-1975/76 levels but above the low 1969/70-1971/72 levels. A modest increase in feed use of grains in developing countries does not alter this projection. However, the alternative that assumes lower grain yields due to deteriorating climate and weather could put pressures on prices and resources under the high demand alternative.

Meeting a substantial increase in demand for grain in the developing countries--whether for food or for feed use--would, however, require a sharp increase in these countries' own grain production, and this, in turn, would require an accelerated transfer of technology and inputs from the developed to the lower income developing

countries. Progress in improving diets in the developing countries, particularly increasing consumption of animal proteins, would also depend on the extent to which these countries implement restraints on population growth. The whole complex of income growth, population growth, technological change in food use, and growth in agricultural and industrial production is closely interrelated. Any projection beyond 1985 would warrant endogenously rather than exogenously determined population, income, and productivity growth rates.

Meat

Continued growth in economic activity throughout the world would generate a strong and growing demand for meat and livestock products under all alternatives. While demand expansion could not occur without growth in income and population, production and trade policies are likely to be the more important factors determining levels of demand and trade in meats (tables 7-8). Such policies are particularly important in Western Europe and Japan. Continuation of restrictive policies would point toward high internal prices and import barriers. Moreover, a continuation of high oil import costs may cause policymakers in some developed countries to have second thoughts about permitting per capita meat consumption to grow to levels now experienced in the United States, particularly at the cost of importing large quantities of feed inputs or finished meat products. For the United Kingdom, Ireland, and Denmark, joining the European Community has meant higher food prices. It is in the meat sector, more sensitive to income and price effects than the crop sector, that adverse impacts of EC membership show up most clearly.

Availability of grain at reasonable prices is another important factor in growth in meat demand. The expansion of the livestock industry in the developed countries in the 1960's was made possible largely because of relatively low feed costs. All of o.: projections indicate that higher feed costs relative to prices received for livestock products are likely in 1985. These higher feed costs could dampen expansion of meat production somewhat unless economies were made in feed usage, or in the marketing and production structure of the livestock sectors.

With the United Kingdom, Ireland, and Denmark expected to be fully integrated into the European Community by 1985, world trade patterns for meat are likely to be significantly different from those of the early 1970's. In general, Australia is projected to lose much of its market in Great Britain, but this loss is likely to be offset by larger exports of meat to the United States, Japan, and other developed countries outside the EC.

The projections show the commercial sector of the world meat economy holding to recognizable historical patterns while expanding in a range of one-third to one-half above the base period level, depending on the alternative being considered. The United States and the European Community continue to be the major producing and consuming areas, with Canada, Middle America, and Other Western Europe sharing in the growth. Japan grows to be a major world consumer. Other regions show strong growth. Australia, New Zealand, and Argentina continue to provide the principal complements of long-distance meat to the United States and Western Europe, which remain the major importers while retaining lead positions as producers.

Under alternative I, the United States has the least restrictive trade policy of the meat importers and continues to be a stronger import market than Western Europe, primarily because of EC trade restrictions. A less restrictive approach by the EC (that is, lower import levies) could provide considerable stimulation to world trade in meat, leading to higher world production, expanded consumption even in the EC,

21

Table 7—World meat production, consumption, and net exports, and growth rates, average, 1969-71, and projected, 1985

Region	1969-71	1985 I	1985 II	1985 III	1985 IV
		1,000 metric tons			
Developed countries: 1/					
Production	46,617	66,379	68,340	63,426	69,562
Consumption	47,293	65,940	68,011	62,513	68,793
Net exports	-818	15	-93	534	218
Developing countries: 2/					
Production	6,531	10,414	11,292	9,660	11,196
Consumption	5,562	9,808	10,618	9,566	10,886
Net exports	966	596	663	84	300
Total listed:					
Production	53,148	76,793	79,661	73,086	80,758
Consumption	52,855	75,748	78,629	72,079	79,679
Net exports	148	611	570	618	518
		Compound annual growth rates, percent			
Developed countries: 1/					
Production		2.4	2.6	2.1	2.7
Consumption		2.2	2.5	1.9	2.5
Developing countries: 2/					
Production		3.2	3.7	2.6	3.7
Consumption		3.9	4.4	3.7	4.6
Total listed:					
Production		2.5	2.7	2.1	2.8
Consumption		2.4	2.7	2.1	2.8

1/ Excludes South Africa.
2/ Includes Middle America, Brazil, and Argentina.

and possibly to some U.S. exports of ordinary meat (in addition to high-quality trade beef). Under these circumstances, the traditional exporting countries would find the market in Western Europe more encouraging than the market in the United States.

Dairy Products

World prospects for dairy products to 1985 suggest an ample supply situation, primarily because of continued production increases in the EC and a continued decline in demand for milk-fat products throughout Europe. Full integration of the

Table 8—World per capita meat production, consumption, and net exports, and growth rates, average, 1969-71, and projected, 1985

Region	1969-71 average	1985			
		I	II	III	IV
		Kilograms			
Developed countries: 1/					
Production	66.6	83.8	86.3	80.1	87.8
Consumption	67.5	83.2	85.8	78.9	86.8
Net exports	-1.2	---	-.1	.7	.3
Developing countries: 2/					
Production	33.0	34.9	37.8	32.4	37.6
Consumption	28.1	32.9	35.6	32.1	36.5
Net exports	4.9	2.0	2.2	.3	1.0
Total listed:					
Production	59.2	70.4	73.1	67.0	74.1
Consumption	58.9	69.5	72.1	66.1	73.1
Net exports	.2	.6	.5	.6	.5
		Compound annual growth rates, percent			
Developed countries: 1/					
Production		1.5	1.7	1.2	1.9
Consumption		1.4	1.6	1.0	1.7
Developing countries: 2/					
Production		.4	.9	-.1	.9
Consumption		1.1	1.6	.9	1.8
Total listed:					
Production		1.2	1.4	.8	1.5
Consumption		1.1	1.4	.8	1.5

1/ Excludes South Africa.
2/ Includes Middle America, Brazil, and Argentina.

United Kingdom, Ireland, and Denmark into the EC aggravates both the supply and demand situation for dairy products in the Community, since projected price increases at all levels within the three countries stimulate production and retard consumption. With the United Kingdom becoming a high-priced butter market and receiving most of its supply from other EC members, world trade in butter (excluding intra-Community trade) is substantially reduced. In addition, the dairy/beef linkage in the EC will continue to force milk output up as increased demand for beef continues to provide incentives for beef production. Although the linkage will weaken by 1985, the strong demand for beef and continued increases in milk yields may lead to chronic surpluses of milk.

New Zealand continues to be a major exporter of butter, even though its exports drop substantially because of loss of the U.K. market. Partially offsetting this

decline in butter exports is a substantial increase in cheese exports. World demand for cheese is projected to grow substantially. In addition to New Zealand, Western Europe will continue to be an important exporter of cheese. The United States will continue to import substantial quantities of foreign-type cheeses. Australia, which was a major butter exporter, is expected to withdraw from the market for butter, but continue to export some cheese.

Crops

For grains and oilseeds, all of the alternative sets of projections point to the following general conclusions.

Over the next decade, the world is capable of producing enough grain and oilseeds, at real prices somewhat above those of the base period but below 1972/73- 1975/76 highs, to meet demand in both the developing and developed countries. Growth in production and consumption is likely to increase at appreciably faster rates in the developing countries than in the developed countries. The developing countries' faster growth, however, will be from a substantially lower base (tables 9-11).

Contrary to previous USDA projections which assumed a continuation of the low input costs and low product prices of the late 1960's and early 1970's, the GOL projections assume higher input prices and project higher product prices. Continued high energy costs would be expected to reverse the downturn in crop prices of the 1960's and early 1970's, except under the low demand alternative III (table 12).

Pre-1972/73 trends in the production of individual grains and oilseeds are expected to continue (see tables 9-11). Wheat is likely to continue to account for slightly less than a third of total grain production, while coarse grains are expected to increase slightly, at the expense of rice, to roughly three-fifths of the total. Oilmeal production is expected to grow somewhat faster, from about 6 percent of base grain tonnage to over 7 percent of the tonnage projected for 1985.

Approximately two-thirds of the increase in grain production projected under alternatives I, II, and III is expected to result from improved yields, with the remaining one-third resulting from increases in area (figs. 5-7). The importance of yield improvements varies between the developed and developing countries, with over three-fifths of the increases in the developed countries and slightly over half of the increase in the developing countries.

Projected increases in grain yields to 1985 differ widely by individual grain and by region. Overall growth, however, is expected to exceed the rates of the last half decade and to approach or exceed--depending on the model alternative--the rates of the 1950's and 1960's. Growth in wheat and rice yields is postulated on the assumption that developing countries expand use of the technology and improved strains developed at research centers such as the International Center for Improvement for Corn and Wheat (CIMMYT) and International Rice Research Institute (IRRI). Advances in wheat yields are also likely in the developed countries if cultivation of higher yielding utility wheat spreads in countries such as Canada and in countries of Western Europe and as general strain improvements continue in the other countries of the temperate zone.

The largest potential for yield increases, however, is in coarse grains-- particularly corn. Accelerating growth in coarse grain yields, however, will depend on more concerted national and international research and extension efforts. Continued emphasis in many of the developing countries on improvements in wheat and

24

Table 9--World grain production, consumption, and net trade, and growth rates,
recent averages, and projected, 1985

Region	1969/70-71/72	1973/74-75/76	1985 I	1985 II	1985 III	1985 IV
			Million metric tons			
World:						
Production	1,082.1	1,184.1	1,569.8	1,642.0	1,507.6	1,652.2
Consumption	1,080.7	1,185.3	1,569.8	1,642.0	1,504.4	1,649.1
Trade	---	---	---	---	---	---
Developed countries:						
Production	401.7	438.9	559.7	618.5	505.3	588.2
Consumption	374.3	381.7	491.3	520.2	453.2	527.9
Imports	38.1	68.3	48.7	64.1	37.2	70.8
Exports	70.3	130.3	117.2	162.5	89.3	131.2
Net exports	32.2	62.0	68.4	98.5	52.1	60.4
Centrally planned countries:						
Production	401.1	443.6	578.0	578.0	578.0	578.0
Consumption	406.6	469.1	597.4	605.8	585.9	601.0
Imports	10.8	31.1	20.8	29.6	11.6	26.9
Exports	5.7	9.8	1.4	1.8	3.7	3.9
Net imports	5.1	21.3	19.4	27.8	7.9	23.0
Developing countries:						
Production	279.3	301.2	432.1	445.4	424.3	486.0
Consumption	299.7	334.5	481.0	516.0	465.3	520.1
Imports	31.7	52.0	73.7	98.8	64.8	65.8
Exports	13.7	17.4	24.8	28.3	23.8	31.6
Net imports	18.0	34.2	48.9	70.6	41.0	34.2
			Compound annual growth rates, percent 1/			
World:						
Production		2.8	2.5	2.8	2.2	2.9
Consumption		2.8	2.5	2.8	2.2	2.9
Developed countries:						
Production		2.6	2.2	2.9	1.5	2.6
Consumption		2.0	1.8	2.2	1.3	2.3
Centrally planned countries:						
Production		3.2	2.5	2.5	2.5	2.5
Consumption		3.5	2.6	2.7	2.5	2.6
Developing countries:						
Production		2.6	3.0	3.2	2.8	3.8
Consumption		2.9	3.2	3.7	3.0	3.7

1/ Growth rates under 1973/74-75/76 are historical rates based on the period
1960/61-1975/76. Growth rates for 1985 are computed from base 1970.

Table 10--World per capita grain production, consumption, and net trade, and growth rates, recent averages, and projected, 1985

Region	1969/70-71/72	1973/74-75/76	1985 I	1985 II	1985 III	1985 IV
			Kilograms			
World:						
Production	299.3	303.8	325.3	340.2	312.4	342.3
Consumption	298.9	304.1	325.3	340.2	311.7	341.7
Trade	---	---	---	---	---	---
Developed countries:						
Production	571.0	599.6	702.2	776.1	633.9	738.0
Consumption	532.0	521.5	616.4	652.7	568.6	662.3
Imports	54.1	93.3	61.1	80.3	46.6	88.8
Exports	99.8	178.0	146.9	203.9	112.0	164.6
Net exports	45.7	84.7	85.8	123.5	65.4	75.7
Centrally planned countries:						
Production	355.4	371.5	418.8	418.8	418.8	418.8
Consumption	360.5	392.8	432.8	438.9	424.5	435.4
Imports	9.6	26.0	15.0	21.4	8.3	19.4
Exports	5.0	8.2	1.0	1.3	2.6	2.8
Net imports	4.5	17.8	14.0	20.1	5.7	16.6
Developing countries:						
Production	160.8	152.9	167.3	172.5	164.3	188.2
Consumption	172.5	169.6	186.2	199.8	180.1	201.4
Imports	18.2	26.3	28.5	38.2	25.1	25.4
Exports	7.9	8.8	9.5	10.9	9.2	12.2
Net imports	10.3	17.3	18.9	27.3	15.8	13.2
		Compound annual growth rates, percent 1/				
World:						
Production		1.0	.6	.9	.3	.9
Consumption		1.0	.6	.9	.3	.9
Developed countries:						
Production		1.6	1.4	2.1	.7	1.7
Consumption		1.1	1.0	1.4	.4	1.5
Centrally planned countries:						
Production		1.7	1.1	1.1	1.1	1.1
Consumption		2.0	1.2	1.3	1.1	1.3
Developing countries:						
Production		.2	.5	.5	.1	1.1
Consumption		.5	.5	1.0	.3	1.0

1/ Growth rates under 1973/74-75/76 are historical rates based on the period 1960/61-1975/76. Growth rates for 1985 are computed from base 1970.

Table 11—World total and per capita consumption of grain and oilmeal and production of meat, 1970, and projected, 1985

Total and per capita		Total grains	Food grains		Feed grains		Oilmeals			Meat		
			DC	LD	DC	LD	Total	DC	LC	Total	DC	LD
Total:						Million metric tons						
1970	Base	674	121	270	253	29	42	36	6	70	50	20
1985	I	971	134	427	359	51	71	60	11	(100)	66	(34)
	I-A	947	132	416	349	49	73	62	11	(99)	66	(33)
	II	1,034	132	454	390	58	75	64	11	(103)	68	(35)
	III	918	134	417	319	48	66	55	11	(96)	63	(32)
	IV	1,048	135	461	393	59	73	62	11	(105)	70	(35)
	IV-A	1,056	135	466	394	60	73	62	11	(105)	70	(35)
Per capita:						Kilograms						
1970	Base	276.8	172.8	155.7	361.3	16.7	19.3	51.4	3.5	28.7	71.4	11.5
1985	I	287.0	169.1	164.8	453.2	19.7	21.0	75.7	4.2	(29.6)	83.3	(13.1)
	I-A	279.9	166.6	160.6	440.5	18.9	21.6	78.3	4.2	(29.3)	83.3	(12.7)
	II	305.6	166.6	175.2	492.3	22.4	22.2	80.8	4.2	(30.4)	85.8	(13.5)
	III	271.3	169.1	160.9	402.7	18.5	19.5	69.4	4.2	(28.4)	79.5	(12.4)
	IV	309.8	170.4	177.9	496.1	22.8	21.6	78.3	4.2	(31.0)	88.4	(13.5)
	IV-A	312.1	170.4	179.8	497.3	23.2	21.6	78.3	4.2	(31.0)	88.4	(13.5)

Table 12—World grain and meat trade prices, recent averages, and projected, 1985

Year and alternative	Wheat	Coarse grain	Rice	Oilmeal	Beef	Pork
	Real 1970 dollars per metric ton					
1969/70-1971/72	58.73	57.08	153.00	98.30	1,289	1,568
1973/74-1975/76	122.80	85.08	308.63	113.60	1,314	1,829
1985:						
I	63.96	61.21	213.09	112.07	1,468	1,735
I-A	60.47	59.87	201.77	110.59	1,392	1,640
II	77.66	71.14	240.11	138.30	1,811	2,151
III	58.41	56.26	201.22	99.36	1,173	1,359
IV	67.46	64.44	194.57	120.56	1,746	2,029
	Real 1977 dollars per metric ton					
1969/70-1971/72	91.62	89.04	238.68	153.35	2,011	2,160
1973/74-1975/76	191.57	132.73	481.47	177.22	2,050	2,853
1985:						
I	99.78	95.49	332.42	174.83	2,290	2,396
I-A	94.33	93.40	314.76	172.53	2,172	2,265
II	121.15	110.98	374.57	215.75	2,825	2,971
III	91.12	87.77	313.90	155.00	1,830	1,877
IV	105.24	100.53	303.53	188.07	2,724	2,802

Commodities quoted on the following basis:
  Wheat—U.S. No. 1 Ordinary Protein, Gulf Ports quoted in base
  Coarse grain—U.S. No. 2 Corn Yellow, Gulf Ports
  Rice—Thai White, 5 percent Broken, FOB Bangkok
  Oilmeal—U.S. Soybean Meal, 44 percent protein, Gulf Ports
  Beef—U.S. Cow Beef, imported frozen, 90 percent lean Chicago
  Pork—U.S. hams, shoulders, canned, average import unit value, carcass weight

Grain Yields
Metric Tons Per Hectare

Developed Market Economies

2.17	2.83	3.63	3.57	
1960/61-1962/63	1969/70-1971/72	1985 I	1985 II	
Actual		Projected		

Developing Market Economies

.94	1.10	1.47	1.48	1.66
1960/61-1962/63	1969/70-1971/72	1985 I	1985 II	1985 IV
Actual		Projected		
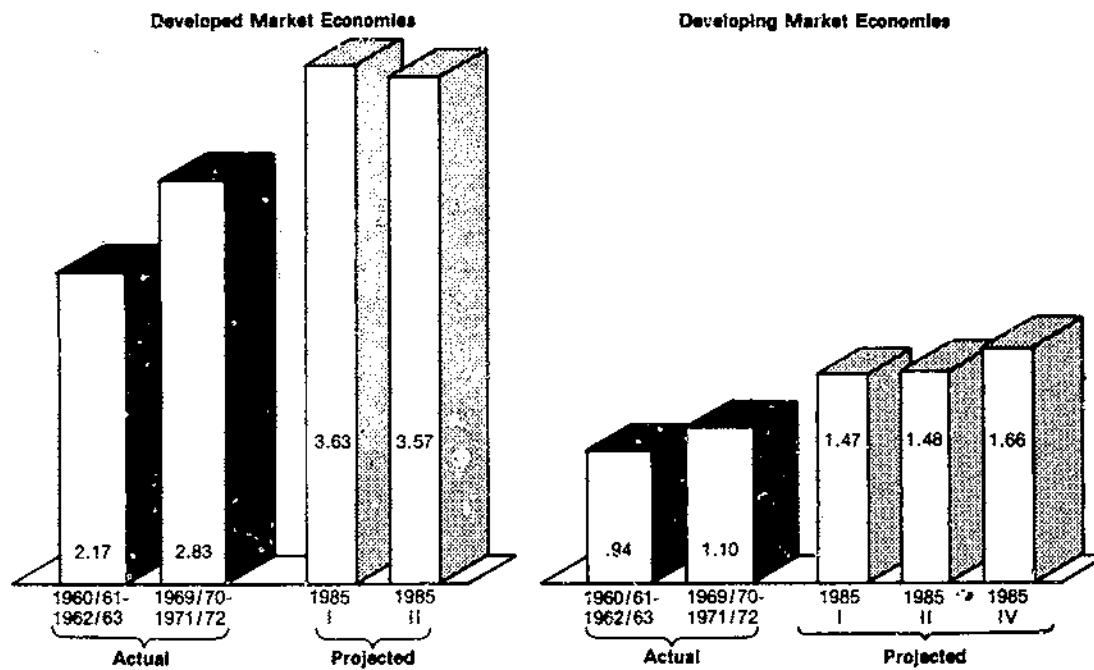
Figure 6

Grain Production
Mil. Metric Tons
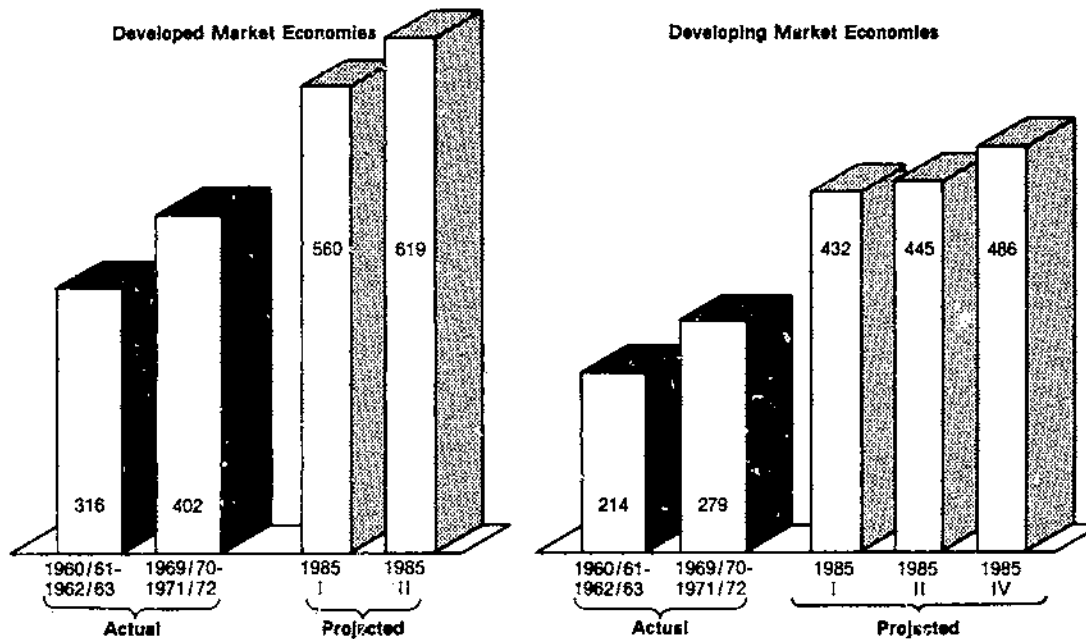
Developed Market Economies

316	402	560	619	
1960/61-1962/63	1969/70-1971/72	1985 I	1985 II	
Actual		Projected		

Developing Market Economies

214	279	432	445	486
1960/61-1962/63	1969/70-1971/72	1985 I	1985 II	1985 IV
Actual		Projected		

Figure 7

29

rice yields, and on allocation of the most productive resources to the production of wheat and rice are likely to keep increases in coarse grain yields in developing countries well below increases in other grains despite the greater coarse grain potential. Coarse grain yields in the developed countries are expected to increase because of wider use of improved strains, improvements in farm management techniques, and switches out of lower yielding into higher yielding coarse grains, particularly in areas suitable to corn production.

Because of the diversity of crops involved, it is harder to generalize with respect to yields of oilseeds and, consequently, oilseed meals. At one extreme, sunflower yields have increased rapidly in many areas of the world. On the other hand, soybean yields have been constant or have trended upward only slightly in most regions. Probably the greatest yield potential lies in peanut production in South Asia and West Africa. However, since soybeans account for the largest share of world meal production, and since efforts to improve yields have been largely unsuccessful, area increase will still account for significant portions of the total increase in production.

Importing and exporting countries in the developed and centrally planned economies will continue to be the major producers and consumers of grain, particularly wheat and coarse grains. Despite substantial increases in production and imports, the developing countries are likely to continue to account for about one-third of world consumption of grain while accounting for over half of the world population. The traditional grain exporting countries--the United States, Canada, Australia, Argentina, South Africa, and Thailand--are projected to continue to supply the deficit countries with well over three-fourths of their import requirements. Roughly half of this trade would be in wheat, with coarse grains accounting for slightly less, and with rice accounting for about 4 to 5 percent. More specific conclusions regarding the developed and developing countries follow.

Developed Countries

The projections indicate that the developed countries have the capacity to increase grain production sufficiently to meet world grain import demand under most of the alternatives--even after meeting a more than 33-percent increase in domestic demand. Under the conditions specified in the low demand alternatives, major exporters might need to restrict production in order to avoid stock buildups or dampened trade prices. However, the alternative that assumes lower grain yields due to weather and climate changes could pose serious upward pressures on prices and resources.

Grain production in the developed countries will continue to take advantage of capital-intensive techniques and technological innovations, even though input costs are projected to be about a third higher in real terms than costs in the 1970 base period. Growth in area from the base period to 1985 is likely to account for less than one-fifth of the increase in production, with higher wheat and rice, and particularly coarse grain, yields accounting for the other four-fifths (figs. 5-7).

The big factor in the growth in demand for grain in the developed countries will be feed demand generated by expanding grain-fed livestock production. Very little growth in demand for food grain is projected for the developed countries. Per capita demand for wheat in Japan will continue to grow as wheat is substituted for rice. Rice demand in the other high-income countries is expected to increase, but not fast enough for rice to become an important factor in the Western diet. Per capita food consumption of grain in the developed countries as a group is projected to be at or below its 1969-71 level of 170-175 kilograms.

Developing Countries

Grain production in the developing countries is expected to shift toward greater emphasis on growth in grain yields through increased use of improved technology and high productivity inputs. Growth in area would still contribute as much as two-thirds of the growth in production. Grain area could consequently be expected to increase from 36 to 38 percent of total arable area in the late 1960's and early 1970's to as high as 42 percent by 1985 (figs. 5-8).

The increased world production and trade under all alternatives would generate improvements in the availability of calories from grains, oilseed, and livestock products in the developing market economies. Total per capita consumption of grains is projected to rise from 173 kilograms in the 1970 base to 186 kilograms in 1985 under alternative I and to as high as 201 under the high-demand, high-productivity alternative IV.

The composition of grain consumption in the developing countries will depend more on productive capacity and import prices than on income and population growth or consumer preference. Gaps between grain production and demand in developing countries would be met primarily with added imports of wheat. Developing countries with limited foreign exchange would be forced to give priority to imports of grain for food, and particularly to wheat rather than higher priced rice. Those with abundant foreign exchange could afford imports of feed grains and rice as well as wheat.

Our analysis suggests that the food problems facing the developing countries will also depend to a large extent on a number of demand factors in the developed countries. The amount of grain available to the developing countries over and above their own production—be it in the form of commercial or concessional imports—hinges on the degree to which the developed countries—particularly the lower income

Developing Market Economies' Arable and Grain Area
Mil. Hectares

	1960/61-1962/63	1969/70-1971/72	1985 I	1985 II	1985 IV
Arable Area	635	670	711	716	722
Cereal Area	228	255	294	300	292
	36%	38%	41%	42%	40%
	Actual		Projected		

Figure 8

31
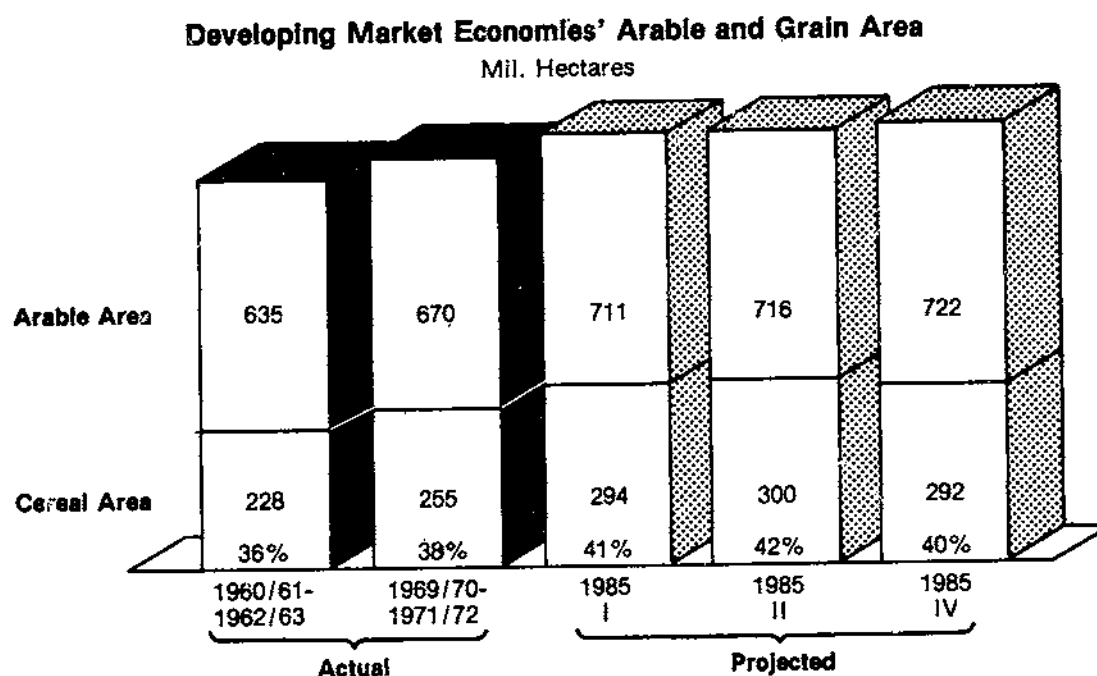
developed countries outside the United States, Japan, and the EC—build up or expand grain-feed livestock sectors. Food production capacities and income levels are such in the developed countries that there is no question that adequate diets in excess of 2,800 calories per day would be maintained. What is in question is what proportion of these calories will come from grain-fed livestock products.

Consumption of livestock products in the lower income developed countries is well below levels in the higher income countries. If income grows rapidly in these countries and is translated into stronger demand for livestock products, and if these countries adopt the grain-feeding production techniques of the United States, demand for feed would tighten available world grain supplies.

Under these circumstances, grain available from the surplus developed countries—particularly as food aid or as concessional imports—would be much more limited. Grain prices could be pushed up as food demand bids against feed demand. Some developing countries would find the opportunity cost of improving low consumption levels at home too high relative to exporting grain to more affluent developed countries. The poorest of the food-deficit developing countries could find the prices the more affluent countries are willing to pay for feed too high to pay for all but the most crucial food imports. Much the same case would also be true if the European Community or Japan attempted to raise their per capita livestock protein consumption to the levels approaching those prevailing in the United States. In either case, a very affluent developed world could make it harder for the poorer developing countries to raise per capita grain consumption levels faster than .1 or .2 percent per year implied in growth in indigenous production.

The adverse effects of livestock feeders in the developed countries buying up grain or bidding up the grain prices paid by the developing countries must be weighed against a number of positive effects. Feed use of grain has acted in the past not only to stabilize the world grain market in periods of surplus, but also to provide a hedge or added margin of reserve above and beyond conventional grain stocks in periods of shortages.

Over the last 15 years, feed demand for grain was also more price elastic than food demand for grain; adjustments in food usage in periods of marked surpluses or deficits were consequently minimized by appreciably larger adjustments in feed use. Over the last 4 years of high prices and short supplies, food usage in the developing countries fell below the trend of the previous 10 years an average of 3 million tons, or 1 percent each year. Feed usage in the developed countries, on the other hand, fell below trend an average of 17 million tons, or more than 4 percent a year.

RESULTS AND IMPLICATIONS BY ALTERNATIVE

The model incorporates a number of alternative sets of assumptions to quantify their effect on world production, consumption, prices, and trade of grains, oilseeds, and livestock. Each set was designed to evaluate the impact of a specific combination of assumptions rather than to predict probable production, consumption, prices, and trade. To evaluate the full implications of alternatives, some sets of assumptions were used that were not necessarily internally consistent in a broader economic context.

For example, the high income growth in the developing countries assumed under alternative II also assumes the same agricultural productivity as alternative I. However, this combination of high income growth and alternative I agricultural

productivity would require a highly unlikely growth rate in the industrial sector of the developing countries. Given no marked improvement in indigenous agricultural productivity, sizable exports of nonagricultural products would be necessary to pay for large food imports. With the agricultural sector generally accounting for a large proportion of the economy in developing countries, it would be more consistent to associate rapid income growth with higher agricultural productivity and consequently lower imports. Thus, alternative IV, which connects high income with increased agricultural productivity in the developing countries, may be a more plausible alternative than alternative II.

Alternative II does quantify, however, the level of potential demand implied in the higher income growth rate. It also underlines the improbability of realizing any sharp increase in consumption in the developing countries without increased domestic production or without food aid transfers appreciably larger than the record levels of the mid-1960s.

. The following sections present the different assumptions and results of the various alternatives. For each alternative, population for the United States is projected according to the U.S. Department of Commerce Series III figures. For the rest of the world, the United Nations' "median" variant population projections are used with some modifications.

Emphasis is on alternatives I and II, which can serve as the basis for comparison with the other alternatives. Each alternative set of projections has its own bundle of assumptions regarding key economic variables and policy considerations. Not all of the alternatives have an equal probability of occurring. Nor is the likelihood of one alternative to be considered superior to another in the context of a forecast. Alternatives I and II, however, can be considered as having somewhat higher probabilities than the others.

Alternative II, reflecting high U.S. exports, appears the more plausible in a setting of strong world import demand and widespread production shortfalls— providing U.S. production remains relatively stable or sufficient stocks are maintained, or, as in 1975, adjustments are made in U.S. livestock feeding in order to maintain export levels.

On the other hand, several years of relatively "good weather," making it possible for other countries to come closer to fulfilling their goals of self-sufficiency, could make alternative I appear the most likely. But the important consideration is that while basic agricultural policy may remain the same, much of a country's or region's import and export behavior is conditioned by actions beyond its control.

Alternative I

In general, this alternative assumes a continuation of basic policies around the world. International trade is somewhat constrained by self-serving national policies, but not all trade restriction goals are met. The following assumptions are employed: —Income is projected according to the "trend" income projections of the Food and Agriculture Organization of the United Nations. These projections

foresee a continuation of the trend of the 1960's for the developed countries and a boosted trend, higher than the trend of the 1960's, for the developing countries:

Population and income, compound annual growth rates

	Base 1/		Alternative I 2/	
	Population	Income	Population	Income
	Percent			
World	1.9	2.7	1.9	2.7
Developed countries	1.1	3.3	.8	3.2
Importers	.9	4.3	.7	3.7
Exporters	1.5	2.3	1.1	2.8
Developing countries	2.5	2.0	2.7	3.3
Importers	2.5	2.0	2.7	3.4
Exporters	2.5	2.3	2.6	2.7

1/ Growth rates are for 1960-70.
2/ Growth rates for 1985 are computed from base 1970.

--Continued growth in world import demand is somewhat constrained by high internal prices and national food policies designed from local viewpoints. --The European Community continues its policy of enlargement. For the United Kingdom, Ireland, and Denmark, EC membership means higher prices. --The Soviet Union, Eastern Europe, and China implement policies gradually liberalizing their foreign trade. --Not all trade restriction goals are met. Countries with a history of active participation in international trade are treated as likely to continue trading actively. --Technological response to agricultural inputs--using fertilizer as a proxy for a number of basic inputs such as irrigation, pesticides, and hybrid seed--is set at the basic rates comparable to recent trends.

Meat

Under alternative I, the grain available for livestock feed is sufficient to permit continued substantial growth in world production of meat and other livestock products. Per capita meat consumption in the commercially important part of the world meat economy (consisting of 14 of the 28 regional breakdowns) rises to an annual average of 70 kilograms in 1985, as compared with 59 kilograms in the 1969-71 base. These estimates take into account over two-thirds of all world meat consumption and production: 81 percent of world beef (including veal), 86 percent of world pork, 56 percent of world poultry, and 35 percent of world mutton (including lamb and goat). Over the projection period, a 41 percent increase in the feed grain use in the developed countries is associated with a 42 percent rise in meat production. The quantity of grain allowed for feed in the developing world shows a 74 percent growth, which appears consistent with a 70 percent rise in meat production. This translates into roughly a 1 percent annual rise in per capita meat consumption in the developing countries. World trade in meat is somewhat reduced in volume as compared with base 1970 figures.

As the world's largest meat consuming region, the United States is projected to continue to account for a fifth of world meat consumption. Under alternative I, U.S. meat consumption per person during the 15 years rises less than 1 percent

annually from a base of 107 kilograms to 121 kilograms. Both beef and poultry register gains of 8 kilograms to levels of 60 and 30 kilograms, respectively. However, consumption of pork remains at relatively the same level of 31 kilograms.

With only modest increases in the U.S. population, U.S. meat production keeps pace with consumption. Net meat imports remain essentially at 1970 levels, with the decline in beef imports offset by pork imports.

In the European Community, the largest meat consuming area outside the United States, consumption of meat per person has been growing steadily and is projected under alternative I to continue its strong expansion--1.9 percent annually in the original EC-6 and 1.0 percent annually in the EC-3. The increase is from 64 kilograms in 1970 to 85 kilograms in 1985 for the EC-6 and from 73 to 84 kilograms for the EC-3.

For the EC-3, the projected rise in meat consumption is substantially less than for the EC-6 because of the inhibiting effect of the more rapid rise in meat prices in the EC-3 and also because of curtailed income growth under EC enlargement. Under the requirements of harmonization of agricultural prices within the EC, the EC-3 is expected to adjust to the substantially higher price levels of the EC-6.

At the same time, price effects stimulate livestock production among the EC-3 to such an extent that appreciable exports of livestock and meat develop for Denmark and Ireland. U.K. dependence on imported meat from outside the EC is likely to be appreciably reduced and what remains is largely expected to be taken care of within the enlarged EC.

Meat production within the EC-6 has been expanding also, but at a rate somewhat less than the growth of demand for meat. So, since the early 1950's, the growing gap has been filled by larger meat imports. East Germany and Poland furnish pork and pigs, while Denmark, Yugoslavia, and increasingly, South America, provide beef and cattle. The outlook, however, is for the production-consumption gap to gradually become narrower. But, periodic falling off (cyclical) of EC beef production could require larger imports. On the other hand, cyclical highs in production trigger the variable levy to shut out imports, as occurred in 1974, with the result that since then, meat imports have been at the minimum permitted under the General Agreement on Tariffs and Trade.

In the rest of Western Europe, growth in meat consumption is projected to outpace advances in production. The recent rapid rise in grain output there probably signifies a modernization of agriculture that embraces livestock. Alternative I projects that by 1985, the Other West European countries will have reached the per capita meat consumption levels which the EC-6 had in 1970. Imports are projected to more than double by 1985 to .5 million tons.

Japan is projected under alternative I to rapidly increase both production and consumption of meat. This is the most dramatic consumption transformation indicated by any of the projections, raising per capita meat consumption from 15 kilograms in 1970 to 38 in 1985. While production of pork and poultry is projected to keep pace with demand, output of beef and mutton is not. The result is that meat imports triple in the course of the 15-year period, reaching .8 million tons by 1985.

With per capita meat consumption among the world's highest, Argentina nevertheless exports the meat from one beef animal in every four grown domestically. It is generally considered that the high meat consumption constitutes a national reserve which can be drawn down as opportunities appear for increased exports. Exports, however, are not steady. Supply-demand conditions in the EC-6 and in the United Kingdom have been the major factors affecting the foreign demand for

35

Argentine beef. The EC variable levy on meat operates directly on Argentina's most lucrative export stream; after 1974, exports were reduced to token amounts. Spain, Brazil, and Chile are also important market outlets. Fresh meat from Argentina is not imported by the United States because of aftosa, but canned and frozen-cooked beef are being shipped to the United States in growing volume. Internal conditions in Argentina also produce dislocations in the steadiness of the meat supply. Pasturing is typically dense and exposed to drought. The economy is growing only at a slow rate (in real terms), partly because of continued high domestic inflation. These internal conditions have necessitated frequent foreign exchange devaluations over the last two decades which, in turn, have contributed instability to price and cost calculations in the export sector, which is importantly a beef exporting activity. It is not realistic to foresee an end to domestic economic difficulty. The combined effect of these domestic and foreign factors precludes exuberant growth of beef exports while they continue to operate. A modification of EC import policy or changed social circumstances within Argentina could modify this expectation. Modest expansion is more likely.

In Oceania, a strong upsurge in meat production, mainly beef, is projected under alternative I. Systematic development of the water supply in Australia's dry hinterland is underway. Cattle ranching is being intensified. With domestic per capita meat consumption expected to remain stable at present world-record levels, domestic production is projected to grow far beyond domestic needs, thereby generating large additional exports.

In recent years, about 60 percent of Australian beef and veal exports have been shipped to the United States, accounting for over 50 percent of total U.S. beef and veal imports. The lucrative U.S. market is limited by quota, so under Australia's implementation of the voluntary restraint scheme, shippers must export to other less lucrative markets as a condition for qualifying for supplying the U.S. market. It has been estimated that Australia could expand its beef exports threefold by 1985. But it remains to be seen whether pastures can permanently sustain the beef herds being built up to achieve these levels.

Alternative I indicates some interesting changes in traditional trading patterns. Because of increased livestock production in Ireland, the EC-3 becomes a strong net exporter of beef, while imports of the other six countries combined double. Other Western Europe would be a strong importer. The net effect of these changes is that Western Europe as a whole is importing somewhat less beef in 1985 than in 1970 on a net basis. In Japan, beef imports rise from fairly small amounts to levels as high as the amounts projected for Other Western Europe for 1985. In other words, Japan's patterns of meat consumption become increasingly Western. Argentina ups its beef exports by over a third, while Australia and New Zealand nearly double theirs. The United States lowers its dependence on imported beef by a quarter. In terms of total meat, the United States remains the world's leading producer, with output up a fifth over that of the European Community.

Dairy Products

The world dairy situation under alternative I shows ample supply of dairy products to 1985, primarily because of substantial production increases in the European Community and the continued decline in demand for milk-fat products throughout Europe. Full accession of the EC-3 aggravates both the supply and demand situation in the Community, since price increases at all levels within the EC-3 stimulate production and retard consumption. With the United Kingdom becoming a higher priced butter market and receiving most of its supplies from other EC members, world trade in butter is substantially reduced if intra-EC trade is excluded.

In addition to the pressure within the European Community to be self-sufficient in dairy products, the dairy/beef linkage forces milk output up. Although the linkage weakens by 1985, the strong demand for beef and continued increases in milk yields may lead to chronic milk surpluses. Substantial exports of butter in 1985 are projected for the EC-6.

Although the loss of the U.K. market reduces New Zealand's butter exports substantially, New Zealand continues to be the world's major exporter of butter. Partially offsetting the decline in butter exports is a substantial increase in cheese exports. Milk production in New Zealand slows considerably from historical growth rates. Cow numbers decline as milk production per cow increases.

The shrinking of the foreign market for butter accelerates the shift away from dairy in Australia. Australia, which was a major exporter of butter, withdraws from the export market for butter but continues to export some cheese. On balance, milk production in the Australia-New Zealand group is expected to decline somewhat.

Grains

Alternative I projections of world production, consumption, and trade in grains and oilseeds point up the following general conclusions: A 2.5 percent average annual increase in world demand for grain through 1985 is well within the productive capacity of the world's grain economy. Growth in output in both the developed and developing exporters is projected to be within the growth rates of the last 15 years:

Alternative I's grain demand and supply growth factors 1/

	Demand growth	Supply growth		
		Productivity	Resource	Supply
	Percent			
Base:				
World	2.4	2.1	.6	2.6
Developed countries	2.0	2.4	.2	2.6
Importers	1.7	2.2	.4	2.6
Exporters	2.4	2.9	.2	2.6
Developing countries	2.9	1.6	1.0	2.6
Importers	3.6	1.4	2.0	3.3
Exporters	2.9	1.6	1.0	2.6
Alternative I:				
World	2.5	1.7	.8	2.5
Developed countries	1.8	1.7	.6	2.2
Importers	1.9	2.0	.1	2.0
Exporters	1.7	1.6	.8	2.3
Developing countries	3.2	2.0	1.0	3.0
Importers	3.3	2.1	.9	3.0
Exporters	2.3	1.1	1.7	2.8

1/ Compound annual growth rates calculated using actual 1969/70-71/72 and projected 1985 data. Demand rates calculated using total grain consumption data; productivity rates calculated using yield data; resource rates calculated using harvested area data; supply rates calculated using production data.

World grain prices (in real terms) are projected to average above low 1967/68–1971/72 levels, but below the high 1973/74–1975/76 levels, largely because of higher production costs. Compared with the base period, these costs in real terms would average about one-quarter higher in the developed countries and somewhat less in the developing countries.

Gross world grain trade is projected to increase some 25 percent above the base period and to match 1972/73–1975/76 highs on a regular year-to-year basis. The bulk of the increase is projected to be in wheat and coarse grain rather than rice. The United States continues to account for over half of the wheat, rice, and coarse grain traded on the world market. Substantial growth also occurs in Thai and Brazilian exports. The developing countries and Japan account for over two-thirds of the increased imports. Any further increase in trade would likely be constrained by the continued use of domestic support programs and restrictive trade policies in the richer grain-deficit countries as well as in the poorer countries committed to maximizing self-sufficiency.

Developed Countries.—Grain production in the developed countries is projected to increase 2.2 percent per year, with a large part of the increase generated by high support prices in the European Community and Other Western Europe. Growth in the major grain exporting countries—the United States and Canada in particular—would average below the growth rates for 1960/61–1972/73 (during most of this period, growth in the exporter's grain production was consciously slowed). Even after providing for a doubling of exports, production programs could become necessary under alternative I if gains in production in the major exporting countries out-distanced growth in effective domestic and foreign demand.

Grain consumption is also projected to rise 2.0 percent per year, with the bulk of the increase expected in grains used for livestock feed (coarse grains and soft and/or utility wheat). Growth would be marked in the European Community, where increases in livestock support prices would raise feed consumption over 40 percent above base levels. As table 13 indicates, EC-6 livestock-feed price ratios under alternative I would be appreciably more favorable than in the base period, particularly with regard to pork, poultry, and beef. Increases comparable to those in the EC are expected in Other Western Europe and, to a lesser extent, in Eastern Europe. Feed use of grain in Japan would more than double. But even with these increases, feed use in these countries would still be roughly half the base per capita level in the United States and Canada. Livestock-feed ratios are also projected to improve for exporting countries, particularly in the beef, pork, and poultry sectors as opposed to the dairy sector (fig. 9 and table 14). Continued use of producer grain and livestock price supports is likely to keep prices high in a number of the developed importing countries, consequently limiting demand growth. The developed countries exports of grain would exceed the record high levels of 1973/74–1975/76 largely because of growth in import demand in the developing regions. The gross wheat, rice, and coarse grain imports of the deficit developed countries are expected to be appreciably higher than in the 1969/70–1971/72 base period but only slightly above the record levels of 1973/74–1975/76. Restrictive trade policies used in conjunction with domestic support programs would tend to limit imports, except in periods of production shortfalls.

Developing countries.—Alternative I projects a 3.0-percent average annual increase in grain production in the developing market economies—somewhat higher than their projected population growth rate of 2.7 percent annually (tables 15–16). The developing countries' mix of grain production is not expected to change drastically. A continued shift of resources out of coarse grains into wheat is likely, but rice will continue to dominate among the individual grains, followed by corn and wheat. Production increases are projected to be strongest in the regions with large reserves of arable or potentially arable land—for instance, Brazil,

38

Table 13—Price ratios of selected products, recent averages, and projected, 1985

Region and price ratio	1969/70-71/72 base	1973/74-75/76 average	1985 alternatives	
			I	II
United States:				
Beef cattle-corn	12.74	9.20	13.84	15.10
Pork-corn	8.91	8.68	9.40	10.48
Poultry-corn	12.00	8.81	12.82	13.24
Milk-corn	2.39	1.70	2.10	1.95
Beef cattle-milk	5.33	5.42	6.59	7.73
Pork-milk	3.72	5.12	4.48	5.36
Beef cattle-pork	1.43	1.06	1.47	1.44
Canada:				
Beef cattle-corn	12.83	10.47	13.92	15.16
Pork-corn	13.06	12.28	13.81	15.47
Poultry-corn	8.34	7.54	8.68	9.68
Milk-corn	2.28	2.14	2.10	1.92
Beef cattle-milk	5.63	4.90	6.63	7.88
Pork-milk	5.73	5.75	6.58	8.05
Beef cattle-pork	.98	.85	1.01	.98
Oceania:				
Beef cattle-corn	17.79	7.98	18.77	19.41
Pork-corn	16.45	13.70	24.90	23.39
Poultry-corn	---	---	---	---
Milk-corn	1.23	1.15	1.29	1.66
Beef cattle-milk	14.48	6.94	14.54	11.72
Pork-milk	13.39	11.91	19.29	14.12
Beef cattle-pork	1.08	.58	.75	.83
EC-6:				
Beef cattle-corn	8.47	9.48	9.24	9.65
Pork-corn	8.20	8.32	9.10	9.70
Poultry-corn	5.33	5.23	5.91	6.90
Milk-corn	1.12	1.09	1.18	1.23
Beef cattle-milk	7.55	8.69	7.86	7.86
Pork-milk	7.32	7.66	7.74	7.90
Beef cattle-pork	1.03	1.13	1.02	.99
EC-3:				
Beef cattle-corn	13.77	15.03	15.01	15.74
Pork-corn	13.66	16.15	10.95	11.73
Poultry-corn	9.15	9.53	8.22	9.60
Milk-corn	1.55	1.39	1.18	1.23

Continued--

Table 13--Price ratios of selected products, recent averages, and projected, 1985--Continued

Region and price ratio	1969/70-71/72 base	1973/74-75/76 average	1985 alternatives I	1985 alternatives II
EC-3--Continued:				
Beef cattle-milk	8.87	10.80	12.77	12.81
Pork-milk	8.80	11.61	9.31	9.55
Beef cattle-pork	1.01	.93	1.37	1.34
Japan:				
Beef cattle-corn	16.99	18.51	17.24	16.21
Pork-corn	10.62	8.65	10.14	10.10
Poultry-corn	7.64	5.94	8.49	11.80
Milk-corn	1.92	1.74	1.79	1.94
Beef cattle-milk	8.84	10.66	9.61	8.35
Pork-milk	5.53	4.98	5.65	5.20
Beef cattle-pork	1.60	2.14	1.70	1.61

parts of Southeast Asia, and the low-income countries in East Asia (tables 17-18). Projected yield increases for these regions are somewhat less than those projected for the land-tight regions such as South Asia, North Africa/Middle East, and Middle America. Of the remaining regions, production would lag well behind population in high-income East Asia, Central Africa, East Africa, Venezuela, and Other South America.

Consumption is projected to increase 3.2 percent per year, slightly below the growth rate of the 1960's, but fast enough to push net imports in 1985 up to 49 million tons--approximately double the base period level and over 50 percent above the record high 1973-75 levels. The developing market economies would be roughly 90 percent self-sufficient in 1985 under this first alternative, as compared with 94 percent in the base period and 92 percent in 1973/74-1975/76.

On a per capita basis, only Central Africa would be expected to show a declining per capita grain consumption level (tables 19-20). None of the currently grain-deficit developing countries, however, are projected to have lower grain import requirements in 1985 than in 1969/70-1971/72 (table 21). The most marked increases in import requirements, however, are projected for the higher income countries--especially those of East Asia and North Africa/Middle East--and to a lesser extent those countries other than Central Africa facing declining per capita production levels.

Oilmeal

Projected increases in demand for meat and other livestock products imply a rapid increase in usage of oilmeals, especially in the developed countries where most of the increased meat production will arise. Under alternative I, world oilmeal consumption is projected to expand by 29.7 million tons, from an average of 42.2 million tons in 1969-71 to 71.9 million tons in 1985. The developed countries account for 84 percent of the increase. The largest regional changes are projected

World: Grain/Meat and Oilmeal/Meat Feed Conversion

Grain

Oilmeal

Kilograms of Grain Fed

Kilograms of Oilmeal Fed

1970   1985

1970   1985

DV Developed Countries

W World Average

LD Less Developed Countries

Base - 1970

Alternative I

Alternative II

One Kilogram of Meat
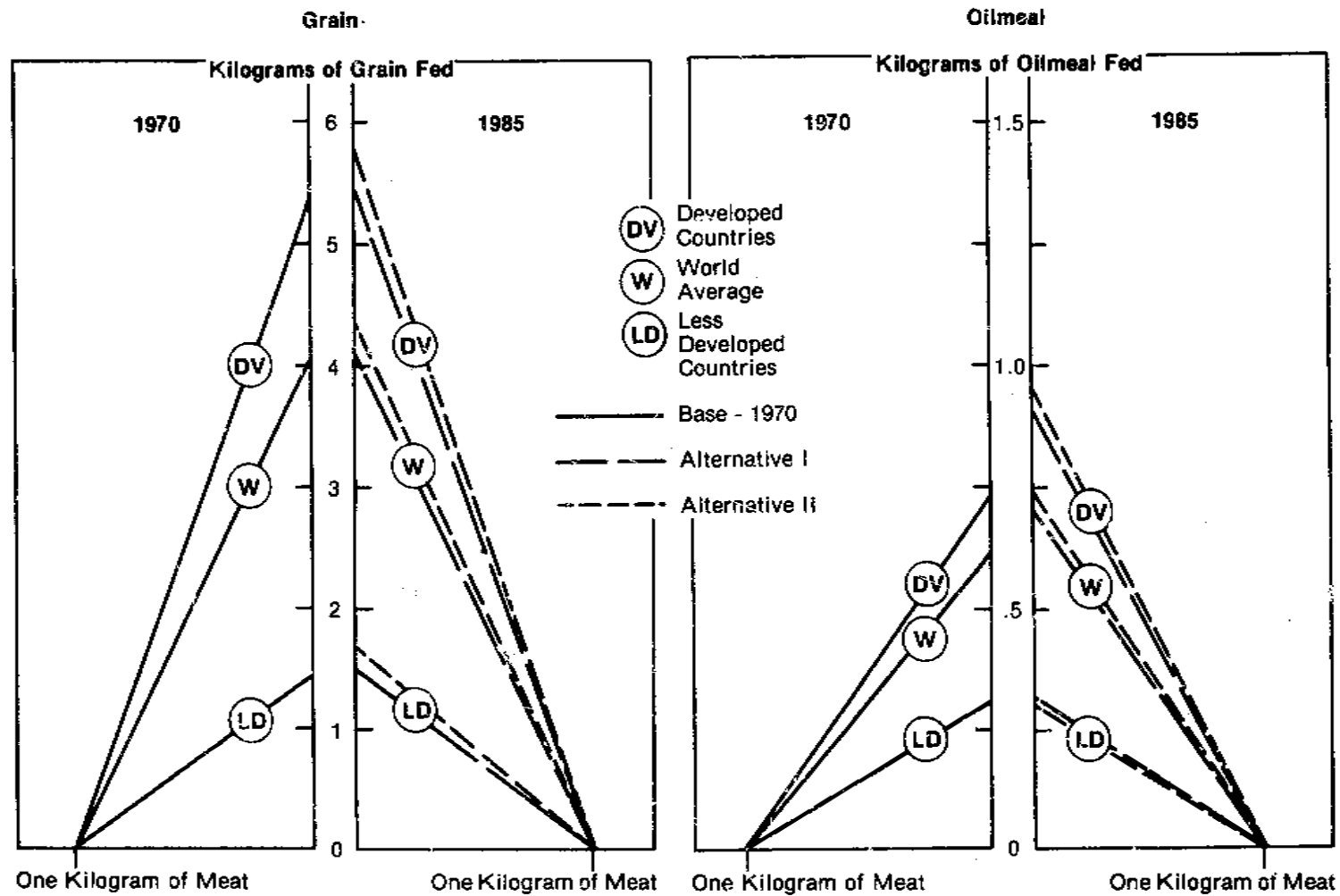
Figure 9

Table 14--World grain and meat trade prices relative to coarse grain prices, 1970, and projected, 1985

Year	Wheat	Oilmeal	Beef I	Beef II	Pork	Wheat	Oilmeal	Beef I	Beef II	Pork
				Ratio					Index	
1970 base	1.03	1.72	22.6	18.2	27.4	100	100	100	100	100
1985:										
I	1.04	1.83	24.0	19.9	28.3	101	106	106	109	103
I-A	1.02	1.87	23.4	19.3	27.7	99	109	104	106	101
II	1.09	1.94	25.5	21.9	30.2	106	113	113	120	110
III	1.04	1.77	20.8	16.4	24.2	101	103	92	90	88
IV	1.05	1.87	27.1	23.2	31.5	102	109	120	127	115

42

Table 15--Production and consumption of total grains, developing countries, recent averages, and projected, 1985

Region	1969/70-71/72 base		1973/74-75/76		1985									
					I		II		III		IV		IV-A	
	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption
	Million metric tons													
Latin America:	63.8	61.2	70.2	69.8	101.8	101.6	107.6	108.0	98.3	96.6	116.6	107.6	124.7	107.9
Middle America	15.7	16.9	16.2	20.2	24.3	28.7	25.1	29.6	23.9	28.1	28.6	29.7	30.8	29.8
Argentina	19.2	10.8	21.2	12.1	27.6	12.8	29.4	12.9	26.0	12.5	28.5	13.0	28.0	13.1
Brazil	21.1	22.6	24.4	24.9	38.5	41.6	41.6	46.2	37.1	38.6	45.9	46.5	50.6	46.6
Venezuela	.8	1.9	.8	2.1	1.2	3.4	1.2	3.6	1.2	3.1	1.7	3.4	2.0	3.4
Other South America	6.9	9.0	7.6	10.5	10.1	15.1	10.3	15.7	10.1	14.3	11.9	15.0	13.3	15.0
Africa and West Asia:	52.2	64.0	57.5	72.6	75.7	104.4	77.5	108.6	74.8	101.7	85.7	108.0	92.0	107.6
High-income North Africa/Middle East	9.8	14.2	9.8	16.3	15.0	27.9	15.3	30.7	14.8	26.2	18.8	30.8	21.0	30.9
Low-income North Africa/Middle East	29.0	35.3	31.8	38.6	42.7	53.5	43.4	54.7	42.3	52.7	47.8	53.6	51.4	52.9
Central Africa	6.4	7.4	7.8	9.4	8.6	11.2	8.7	11.3	8.5	11.2	8.5	11.6	8.3	11.8
East Africa	7.0	7.1	8.1	8.3	9.5	11.8	10.1	11.9	9.2	11.7	10.6	12.0	11.3	12.0
Other Developing Asia:	163.2	174.5	174.2	190.3	254.6	275.0	260.4	299.4	251.2	267.0	283.7	304.6	303.0	310.8
India	87.0	91.0	33.3	90.4	135.8	140.5	137.2	154.2	134.9	136.9	154.1	160.1	167.9	164.3
Other South Asia	23.7	25.9	32.3	35.3	37.0	40.5	37.3	46.2	36.8	40.1	41.6	47.6	44.9	48.6
Thailand	10.8	7.6	12.6	9.1	18.1	13.1	19.5	13.5	17.3	12.9	18.5	13.6	18.1	13.7
Other Southeast Asia	11.9	11.7	12.0	12.4	19.0	17.5	19.8	17.5	18.5	17.4	19.5	17.7	19.5	17.9
Indonesia	14.6	15.5	17.9	19.6	23.2	29.1	24.3	32.3	22.5	25.7	25.1	29.4	25.5	29.8
High-income East Asia	8.7	14.6	8.5	14.5	9.5	21.2	9.6	22.1	9.4	20.6	11.2	22.3	12.1	22.4
Low-income East Asia	6.5	8.2	7.6	9.0	12.1	13.2	12.8	13.6	11.7	13.2	13.8	13.9	15.0	14.1
Developing countries total	279.3	299.7	301.9	332.7	432.1	481.0	445.4	516.0	424.3	465.3	486.0	520.1	519.6	526.0

Table 16--Compound annual growth rates for production and consumption of grain, developing countries, projected, 1985

Region	1985									
	I		II		III		IV		IV-A	
	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption	Pro-duction	Con-sumption
	Percent									
Latin America	3.2	3.4	3.6	3.9	2.9	3.1	4.1	3.8	4.6	3.9
Middle America	3.0	3.6	3.2	3.8	2.8	3.5	4.1	3.8	4.6	3.9
Argentina	2.5	1.1	2.9	1.2	2.0	1.0	2.7	1.2	2.5	1.3
Brazil	4.1	4.2	4.6	4.9	3.8	3.6	5.3	4.9	6.0	4.9
Venezuela	2.7	4.0	2.7	4.4	2.7	3.3	5.2	4.0	6.3	4.0
Other South America	2.6	3.5	2.7	3.8	2.6	3.1	3.7	3.5	4.5	3.5
Africa and West Asia	2.5	3.3	2.7	3.6	2.4	3.1	3.4	3.6	3.9	3.5
High-income North Africa/Middle East	2.9	4.6	3.0	5.3	2.8	4.2	4.4	5.3	5.2	5.3
Low-income North Africa/Middle East	2.6	2.8	2.7	3.0	2.6	2.7	3.4	2.8	3.9	2.7
Central Africa	2.0	2.8	2.1	2.9	1.9	2.8	1.9	3.0	1.7	3.2
East Africa	2.1	3.4	2.5	3.5	1.8	3.4	2.8	3.6	3.2	3.6
Other Developing Asia	3.0	3.1	3.2	3.7	2.9	3.9	3.8	3.8	4.2	3.9
India	3.0	2.9	3.1	3.6	3.0	2.8	3.9	3.8	4.5	4.0
Other South Asia	3.0	3.0	3.1	3.9	3.0	3.0	3.8	4.1	4.4	4.3
Thailand	3.5	3.7	4.0	3.9	3.2	3.6	3.7	4.0	3.5	4.0
Other Southeast Asia	3.2	2.7	3.5	2.7	3.0	2.7	3.4	2.8	3.3	2.9
Indonesia	3.1	4.3	3.5	5.0	2.9	3.4	3.7	4.4	3.8	4.5
High-income East Asia	0.6	2.5	0.7	2.8	0.5	2.3	1.7	2.9	2.2	2.9
Low-income East Asia	4.2	3.2	4.6	3.4	4.0	3.2	5.2	3.6	5.7	3.7
Developing countries total	3.0	3.2	3.2	3.7	2.8	3.0	3.8	3.7	4.2	3.8

64

Table 17--Per capita production and consumption of total grain, developing countries, recent averages, and projected, 1985

Region	1969/70-71/72 base Pro-duction	Con-sumption	1973/74-75/76 Pro-duction	Con-sumption	1985 I Pro-duction	Con-sumption	II Pro-duction	Con-sumption	III Pro-duction	Con-sumption	IV Pro-duction	Con-sumption	IV-A Pro-duction	Con-sumption
								Kilograms						
Latin America	236.1	226.5	232.9	231.6	249.7	249.2	263.9	264.9	241.1	236.9	286.0	263.9	306.1	264.9
Middle America	199.7	214.3	181.8	226.7	194.9	230.3	201.0	237.1	191.7	225.4	229.4	238.2	247.0	239.0
Argentina	795.6	447.9	834.5	476.3	947.6	437.3	1007.2	442.3	891.2	428.5	976.9	445.6	959.8	449.0
Brazil	222.6	238.9	230.4	235.1	267.2	288.5	288.8	320.6	257.2	267.6	318.2	322.4	350.8	323.1
Venezuela	77.0	173.0	66.0	173.3	72.4	202.6	73.3	217.0	71.9	185.8	101.9	203.8	119.9	203.8
Other South America	111.4	146.1	110.3	152.4	109.1	162.0	110.6	168.9	108.7	153.9	128.0	161.4	143.1	161.4
Africa and West Asia	125.3	153.7	123.2	155.5	118.5	163.4	121.3	170.0	117.1	159.2	134.1	169.0	144.0	168.4
High-income North Africa/Middle East	156.6	226.4	137.6	228.8	148.1	276.5	151.4	303.5	146.5	259.4	186.1	304.9	207.9	305.9
Low-income North Africa/Middle East	249.2	303.2	244.0	296.2	240.4	301.4	244.6	308.1	238.3	296.9	269.3	301.9	289.5	298.0
Central Africa	35.8	41.1	38.9	46.9	31.7	41.5	32.2	41.7	31.4	41.4	31.4	42.9	30.7	43.6
East Africa	120.9	122.6	124.9	128.0	105.4	131.1	111.8	132.5	102.2	130.0	117.7	133.3	125.5	133.3
Other Developing Asia	155.8	166.6	150.0	163.8	164.9	178.1	168.6	193.9	162.7	172.9	183.7	197.2	196.2	201.2
India	154.0	161.1	133.8	145.2	166.7	172.6	168.4	189.4	165.6	168.1	189.2	196.6	206.2	201.7
Other South Asia	137.9	150.4	166.6	182.1	137.4	150.6	138.6	171.9	136.8	149.1	154.6	176.9	166.9	180.7
Thailand	291.8	204.5	297.8	215.1	299.2	216.7	322.3	222.8	286.2	213.4	306.0	225.0	299.4	226.6
Other Southeast Asia	213.2	209.8	195.2	201.7	239.0	219.7	249.0	220.1	232.7	218.9	245.3	222.6	245.3	225.1
Indonesia	122.0	129.7	134.7	147.5	131.0	164.3	137.2	182.6	127.1	145.2	141.8	166.1	144.1	168.4
High-income East Asia	173.6	291.1	156.5	267.0	141.2	315.5	142.5	329.0	140.0	306.8	166.8	332.1	180.2	333.6
Low-income East Asia	137.6	172.1	141.0	167.0	157.6	171.4	166.3	176.5	152.3	171.8	179.6	180.9	195.2	183.5
Developing countries total	161.1	172.8	156.5	172.4	166.8	185.6	171.9	199.2	163.8	179.6	187.6	200.7	200.5	203.0

Table 18--Compound annual growth rates for per capita production and consumption of grain, developing countries, projected, 1985

Region	1985									
	I		II		III		IV		IV-A	
	Production	Consumption	Production	Consumption	Production	Consumption	Production	Consumption	Production	Consumption
	Percent									
Latin America	0.4	0.6	0.7	1.1	0.1	0.3	1.3	1.0	1.7	1.0
Middle America	-0.4	0.5	0.0	0.7	-0.3	0.3	0.9	0.7	1.4	0.7
Argentina	1.2	-0.2	1.6	-0.1	0.8	-0.3	1.4	1/	1.3	1/
Brazil	1.2	1.3	1.8	2.0	1.0	0.8	2.4	2.0	3.1	2.0
Venezuela	-0.4	1.1	-0.3	1.5	-0.5	0.5	1.9	1.1	3.0	1.1
Other South America	-0.1	0.7	-0.1	1.0	-0.2	0.4	0.9	0.7	1.7	0.7
Africa and West Asia	-0.4	0.4	-0.2	0.7	-0.5	0.2	0.5	0.6	0.9	0.6
High-income North Africa/Middle East	-0.4	1.3	-0.2	2.0	-0.4	0.9	1.2	2.0	1.9	2.0
Low-income North Africa/Middle East	-0.2	1/	-0.1	0.1	-0.3	-0.1	0.5	1/	1.0	-0.1
Central Africa	-0.8	0.1	-0.7	0.1	-0.9	0.1	-0.9	0.3	-1.0	0.4
East Africa	-0.9	0.5	-0.5	0.5	-1.1	0.4	-0.2	0.6	0.2	0.6
Other Developing Asia	0.4	0.5	0.5	1.0	0.2	0.3	1.1	1.1	1.5	1.3
India	0.5	0.5	0.6	1.1	0.5	0.3	1.4	1.3	2.0	1.5
Other South Asia	1/	1/	1/	0.9	-0.1	-0.1	0.8	1.1	1.3	1.2
Thailand	0.2	0.4	0.7	0.6	-0.1	0.3	0.3	0.6	0.2	0.7
Other Southeast Asia	0.8	0.3	1.0	0.3	0.6	0.3	0.9	0.4	0.9	0.5
Indonesia	0.5	1.6	0.8	2.3	0.3	0.8	1.0	1.7	1.1	1.8
High-income East Asia	-1.4	0.5	-1.3	0.8	-1.4	0.4	-0.3	0.9	0.2	0.9
Low-income East Asia	0.9	1/	1.3	0.2	0.7	1/	1.8	0.3	2.4	0.4
Developing countries total	0.2	0.5	0.4	1.0	0.1	0.3	1.0	1.0	1.5	1.1

1/ Less than 0.1.

Table 19--Net grain trade, developing countries, recent averages, and projected, 1985 1/

Region	1960/61–1962/63	1969/70–1971/72	1973/74–1975/76	1985 I	1985 II
			Million metric tons		
Latin America	+1.0	+3.3	-.2	+.3	-.4
Middle America	-.9	-1.0	-4.1	-4.4	-4.5
Argentina	+5.2	+8.2	+9.0	+14.9	+16.5
Brazil	-1.9	-.8	-1.2	-3.1	-4.6
Venezuela	-.4	-1.0	-1.2	-2.2	-2.4
Other South America	-1.0	-2.1	-2.7	-4.9	-5.4
Africa and West Asia	-6.1	-10.1	-15.9	-28.7	-31.2
High-income North Africa and Middle East	-2.0	-3.8	-6.4	-13.0	-15.4
Low-income North Africa and Middle East	-3.5	-5.3	-7.0	-10.8	-11.3
Central Africa	-.7	-.7	-2.3	-2.6	-2.6
East Africa	+.1	-.3	-.2	-2.3	-1.9
Other Developing Asia	-6.4	-11.1	-16.1	-20.5	-39.0
India	-4.1	-3.2	-5.7	-4.8	-17.0
Other South Asia	-2.1	-2.4	-3.6	-3.5	-9.0
Thailand	+2.0	+3.2	+3.3	+5.0	+5.0
Other Southeast Asia	+1.9	+.2	-.5	+1.5	+2.3
Indonesia	-1.1	-1.1	-2.0	-5.9	-8.0
High-income East Asia	-1.8	-6.0	-6.0	-11.7	-12.5
Low-income East Asia	-1.2	-1.8	-1.6	-1.1	-.8
Developing countries total	-11.5	-17.9	-32.2	-48.9	-70.6

1/ Net imports shown as -; net exports shown as +.

47

Table 20--Effects of accelerated growth in fertilizer use on grain production in the developing countries

Region	Added fertilizer applied	Physical response coefficient	Fertilizer effects on products	Price effect on		Change in net imports
				Production	Consumption	
	1,000 metric tons	Grains/ fertilizer	- - - - - - - - Million metric tons - - - - - - -			
Latin America:						
Middle America	705	5.7	4,045	-540	+167	-3,338
Brazil	914	7.3	6,694	-2,486	+120	-4,088
Venezuela	59	7.7	456	-13	+18	-425
Other South America	280	6.5	1,809	-135	+107	-1,567
Africa and South Asia:						
High-income North Africa and Middle East	470	8.1	3,798	-299	+158	-3,341
Low-income North Africa and Middle East	700	7.4	5,173	-723	+404	-4,046
East Africa	126	7.7	971	-401	+25	-545
Other Developing Asia:						
India	2,265	8.6	19,458	-2,136	+5,766	-11,556
Other South Asia	529	8.8	4,652	-492	+1,461	-2,699
Thailand	106	10.4	1,103	-1,881	+132	+910
Other Southeast Asia	97	11.6	1,125	-1,026	+224	+125
Indonesia	304	9.7	2,956	-1,829	+543	-584
High-income East Asia	411	4.6	1,873	-184	+193	-1,496
Low-income East Asia	245	9.1	2,221	-1,029	+271	-921
Total above 1/	7,211	7.8	56,334	-13,174	+9,589	-33,571

1/ Excludes Argentina and Central Africa.

Table 21--Effects of longrun climatic change on 1985 trade in grains 1/

Region	Alternative I		Alternative II		Alternative IV	
	Original 2/	Low yield	Original 2/	Low yield	Original 2/	Low yield
	Million metric tons					
Developed countries	68.5	101.4	98.5	127.6	63.4	103.6
Importers	-48.0	-53.8	-64.0	-65.5	-70.1	-77.4
Exporters 3/	116.4	155.2	162.3	193.0	133.5	181.1
United States	76.4	117.5	116.0	152.9	93.2	141.7
Centrally planned countries	-19.4	-33.2	-27.8	-41.0	-28.9	-42.8
Developing countries	-48.9	-68.1	-70.6	-86.5	-34.4	-60.7
Importers	-68.8	-88.1	-93.1	-108.8	-55.0	-81.1
Exporters 4/	19.9	20.0	22.5	22.3	20.7	20.4

1/ As measured by a reduction in yields.
2/ Original projections for alternatives I, II, and IV are discussed in earlier sections of this report.
3/ United States, Canada, Oceania, South Africa.
4/ Argentina, Thailand.

66

for the EC-6, where consumption is up 7.0 million tons; the United States, up 6.9 million tons, and Japan, up 4.0 million tons. Among the developing countries, only Brazil and India are projected to have over 1-million-ton increases in total usage. Growth in Brazil is especially rapid, projected at nearly 9 percent annually over the period. High-income North Africa/Middle East, and high-income East Asia, are projected to have consumption growth rates comparable to those of the developed countries, generally between 3.5 and 4.0 percent annually.

Large production increases for oilmeals are projected for the United States and Brazil, both based on soybean meal. Annual growth rates for the two countries are 3.8 and 15.3 percent, respectively. Production in Other South America, based largely on fishmeal, is projected to grow only slowly, since the 1971-75 period indicates that prospects for a larger fishcatch are not promising. Production in Peru, the largest producer, has not returned to the levels that prevailed during 1969-71. Production of meal in India, largely based on peanut meal, is projected to have a rather modest 2.6 percent annual growth rate.

World trade in oilmeals is projected to more than double over the projection period. A substantial increase in imports is projected in the centrally planned economies as they attempt to expand production of animal products. Growth in oilmeal trade is projected to be more rapid than growth in world production because demand growth in some of the major producing countries is projected to be slower than in the major importing countries. Thus, the projections indicate an increased dependence on world markets to meet import demand and to provide export markets.

Large growth rates in imports are projected for Western Europe and Japan—growing at annual rates of 4.3 and 5.9 percent, respectively. Oilmeal exports of the United States and Brazil are projected to be up 11.7 million tons each over 1969-71. India, another major exporter, is projected to decrease rather than to increase exports because domestic use is projected to rise faster than production.

Alternative II

This alternative assumes high import demand. The following assumptions, which are in contrast to the assumptions of alternative I, were incorporated:

  --The income growth rates used in alternative I are
  multiplied by a factor of 1.2 for developed countries and
  1.4 for developing countries:

Alternative II's population and income compound annual growth rates 1/

	Population	Income
	Percent	
World	1.9	3.3
Developed countries	.8	3.8
Importers	.7	4.4
Exporters	1.1	3.3
Developing countries	2.7	4.9
Importers	2.7	5.0
Exporters	2.6	4.0

1/ Growth rates for 1985 are computed from base 1970.

--The Soviet Union and Eastern Europe attempt to increase
livestock production and consumption at a faster rate of
growth, even if this means expanded imports from Western
countries.

--China becomes more trade oriented and imports more grain.

--The enlarged EC adopts less restrictive trade policies,
lower internal price targets, and narrower margins thus
permitting a higher level of grain imports.

--Japan adopts policies permitting increased consumption of
meat and livestock products.

--The livestock economies, particularly poultry, of the
developing world grow faster, especially in countries with
enhanced petroleum revenues and higher rates of economic
growth.

These assumptions imply that demand for livestock products would be higher than
in alternative I and that this would thus generate a substantial increase in demand
for coarse grains and oilcake. Higher feed prices would encourage more feeding of
wheat in developed countries, particularly in Western Europe, where wheat competes
with barley for feed use.

In the developed countries, projected grain feeding of 388 million tons would be
30 million tons higher than in alternative I and 135 million tons above the 1970
base. In contrast, in the developing countries, grain feeding is projected at 58
million tons, 7 million above alternative I but double the 1970 base. The big
increase projected in the developing market economies is grain for food--458 million
tons, compared with 430 million under alternative I.

Net imports by the developing market economies could increase to 71 million tons
by 1985, which would compare with 49 million tons under alternative I, an average of
18 million in the base period, and an average of 33 million in 1973/74-1975/76.
However, this high level of imports would probably have to include a substantial
increase in concessional shipments from the developed countries, despite the overall
higher income growth rates assumed for developing countries and the increased
foreign exchange earnings in the oil-exporting countries. Under alternative II
assumptions, import policies would not prevent this trade, and appropriate growth in
nonagricultural sectors would facilitate it.

Meat

Consumption adjustments made in response to alternative II's higher levels of
meat production and trade differ for importers and exporters. The reduction of
variable levies in the European Community and the restructuring of consumption
controls in Europe and Japan would result in narrowed margins between international
and consumer prices. Consumer prices for beef and pork under alternative II would
be lower than under alternative I. The moderation of barriers to trade would be
expected to have price and business expansion effects. For some countries, the
postulated income effects under alternative II increase demand for meat sufficiently
to offset the price lowering effects of the reduced levies. Increased output of meat
would also be expected along with increased product prices relative to input prices.
In this alternative, again, price and income impacts of EC membership have adverse
effects on the meat sector in the EC-6.

On balance, an increase in meat imports is projected for both Western Europe and Japan, as well as for the centrally planned countries. Expanded world trade, higher international trade prices, and the resulting higher producer prices stimulate meat production in Argentina, Australia, New Zealand, and other main exporters while restraining somewhat their consumption levels. Boosted prices are also expected in the United States, restraining meat consumption, stimulating its production, and contributing to somewhat reduced meat imports. The United States could continue to import manufacturing quality but export some high-quality grain-fed beef.

Under alternative I, with Europe and Japan restricting imports of meat, the United States is the more lucrative import market. Under alternative II, the substantial increase in import demand in Western Europe and Japan makes those two markets more attractive, even though U.S. prices under alternative II are higher than under alternative I. The country to benefit the most from the policy changes defining alternative II is Argentina. Under prevailing world health regulations, aftosa precludes Argentina from exporting beef to the United States, the major world importer under alternative I, and aftosa-free. Under alternative II, the expanded markets of Europe and Japan, where aftosa is also a problem, confer major benefit to Argentina.

Dairy Products

In the developed world, the higher incomes postulated under alternative II have a smaller impact on consumption of milk products than on consumption of meat products because of the differential income effect among these products.

While the projected increase in milk consumption tends to raise milk prices, the impact of increased incomes on milk prices is less than on meat prices. In the United States and Canada, the beef-milk and pork-milk price ratios are higher under alternative II than under alternative I. Combined with lower milk-grain price ratios, lower levels of milk production are projected under alternative II. However, in the EC-3, these price ratios remain about the same to a little higher under both alternatives I and II than in the base period. But beef production is down somewhat adding to lower levels of milk production under alternative II because of the milk-beef production linkage.

On the other hand, increased overall competition for resources used in the livestock sector and higher projected input prices in general also have a price raising effect on milk and milk product prices. The net effect of these higher prices is lower per capita consumption of fluid milk and butter under alternative II than alternative I. But the income effect for cheese is strong enough to permit higher levels of cheese consumption under alternative II.

The projected increase in world trade of butter and cheese results in substantially higher export prices and exports for Oceania under alternative II, compared with alternative I. The substantial higher prices encourage higher levels of milk production even though milk prices become less favorable with respect to beef prices.

Grains

The assumptions of alternative II suggest the following general conclusions regarding grains: A 20 percent increase in growth in real per capita income in the developed countries and a 40 percent increase in the developing market economies, relative to the rates used in alternative I, would generate an additional .4 percent annual increase in world grain demand. A large part of this additional demand would

probably be met from increased production in the major exporting countries for consumption in the grain-deficit developed, centrally planned, and developing countries:

Alternative II's grain demand and supply growth factors 1/

	Demand Growth	Supply growth		
		Productivity	Resource	Supply
		Percent		
World	2.8	1.8	1.2	3.0
Developed countries	2.2	1.5	1.3	2.9
Importers	2.2	1.9	0.2	1.7
Exporters	2.3	1.5	2.0	3.5
Developing countries	3.7	2.0	1.1	3.2
Importers	3.8	2.1	1.0	3.1
Exporters	2.4	1.2	2.1	3.3

1/ Compound annual growth rates calculated using actual 1969/70-71/72 and projected 1985 data. Demand rates calculated using total grain consumption data; productivity rates calculated using yield data; resource rates calculated using harvested area data; supply rates calculated using production data.

World grain trade reaches its highest projected level under alternative II. This occurs because of the effects of accelerated income growth on food and feed demand in deficit areas and because of the effects of trade liberalization on the import demand of marginally self-sufficient as well as deficit countries. The projections indicate world grain exports could increase to over 193 million tons by 1985, compared with 143 million tons under alternative I and an average of 90 million tons in the 1969/70-1971/72 base period.

Real grain prices would range up to 15 percent above the alternative I level or up to 25 percent above the base level. This increase in real prices would result from higher input costs, but more importantly from demand pressure. But even under alternative II, real prices would be below the highs recorded in 1973/74 through 1975/76. However, a succession of widespread droughts of the type experienced in these years and resulting low stock levels would generate high prices similar to those of recent years.

Developed Countries.--The assumptions of alternative II provide for stronger demand for livestock products than under alternative I and consequently for substantially stronger demand for grains for feeding. In the developed countries, while virtually no added food demand for grain would be generated by increased per capita income, there would be marked increases in demand for grain-fed livestock products. Livestock-feed price ratios would be appreciably more favorable than in the base period or than under alternative I. Price ratio improvements would be strongest in the feed-intensive pork, poultry, and to a lesser extent, beef sectors. Some deterioration in the milk-corn ratio, however, would probably be likely as milk prices fell off relative to both feed input and finished livestock product prices. Ratio improvements would be strongest in the grain and meat exporting countries as compared with the importing countries. Importers would face the dilemma of importing

53

more higher cost finished livestock products or importing a larger volume of higher cost feed inputs.

Grain fed to livestock in the developed countries could consequently increase to 388 million tons—or some 135 million tons higher than in the base period and some 30 million tons higher than under alternative I. Higher coarse grain prices relative to wheat prices under alternative II would encourage more feeding of wheat in many of the developed countries, particularly if production of higher yielding soft and/or utility grades of wheat continues to expand. Soft and/or utility wheat would be expected to compete very favorably with feed barley in most of Eastern and Western Europe.

Developing Countries.--In the developing countries, demand for grain would increase at 3.6 percent per year because of growth in feed demand in a number of the higher income countries with indigenous feeding operations and because of growth in food demand in all of the lower income countries (table 15). Alternative II projections indicate that grain fed to livestock could reach as high as 58 million tons, or 7 million tons above the alternative I level and some 30 million tons above the base period level. This increase in feeding, however, would be concentrated in a few regions such as Brazil, Venezuela, parts of East Asia, and high-income North Africa/Middle East, as well as countries along the Asian rim.

The rest of the increase over alternative I grain demand—some 28 million tons—would be earmarked for direct consumption as food in the lowest income developing countries with high income elasticities of demand and low caloric intake levels. Chief among these would be the countries of Other South Asia, Indonesia, India, and the poorer parts of Central and East Africa and North Africa/Middle East.

Production in the developing countries is projected to increase at 3.2 percent per year under alternative II, or roughly .4 percent faster than population growth and some .3 percent more than under alternative I as a result of the effects of higher supply prices (see tables 18-20). As is to be expected, much of this growth would be concentrated in Argentina, Thailand, and Brazil, and in parts of low-income East Asia and East Africa, as unused or underutilized capacity is brought into production to meet higher domestic and expanded world demand. Only marginal increases in production would be forthcoming in resource-constrained Indonesia, India, Other South Asia, Middle America, and high-income East Asia.

If foreign exchange were available, the grain imports of the developing market economies could increase to 71 million tons in 1985, compared with 18 million tons in the base period, 49 million tons under alternative I, and an average of 33 million tons for the period 1973/74-1975/76. This level of imports, however, would depend to a large extent on increases in concessional shipments, despite alternative II's higher incomes since grain prices would be appreciably higher than in either the base period or under alternative I.

Alternative II's combination of generally stronger demand but limited increases in production put the grain-deficit developing countries in their weakest trade position of all the alternatives. Net Indian imports would be expected to reach the 17-million-ton level, while Indonesia and Other South Asia are projected to import over 8 and 9 million tons, respectively. The fastest growth in imports, however, is projected for high-income East Asia and North Africa/Middle East; these two regions alone are projected to account for imports of over 28 million tons. Gross grain imports of the developing countries as a group reach the 99-million-ton level, while the exports of the few surplus countries would hit a record 28 million tons (see table 19).

Oilmeals

Alternative II conditions—high income growth rates coupled with some freeing of trade for grains and livestock products—have definite and somewhat unexpected implications for oilmeals. As one would expect, the biggest changes are in Western Europe—especially in the EC-6, where liberalized trade policies are implemented to the greatest degree. Although feed use of grain in the EC-6 is projected to be 72 million tons, or 3 percent, above the alternative I level, oilmeal use is projected to decrease. In the EC-3 and Other Western Europe, grain use for feed is up 6.7 and 5.0 percent, respectively, while for oilmeals the same changes are -2.6 and -2.9 percent. In the United States, oilmeal and grain feeding under alternative II are roughly 12 percent above the alternative I levels.

At the world level, the net effect of the increased income and policy changes is to raise oilmeal usage 3.7 million tons, or 5 percent, above the alternative I level. Imports are projected to increase only slightly faster, moving from 44.5 to 47.1 million tons. The largest changes for imports are projected in Japan and the Soviet Union, with each projected to import over a million tons above the alternative I level.

Larger import demand leads to higher exports, mainly by the major exporters. Exports by the United States are projected to be nearly 1.5 million tons above alternative I, while Brazilian exports are projected to be up approximately 0.4 million tons. The higher prices for soybean meal relative to feed grains implies that in the United States, soybeans will be better able to compete with corn for acreage; on the other hand, such competition is less intense in Brazil.

Alternative I-A

As in alternative I, a continuation of basic policies around the world is assumed, but trade is more constrained. Income growth is the same as under alternative I for the developed countries, but for the developing countries, it is one-third lower. Growth of world import demand is more fully constrained. EC variable levies are set higher. Japan's imports are smaller. The Soviet Union resumes its traditional net export position in wheat, and its net imports of other commodities are lower than in alternative I. Eastern Europe substantially reduces its grain imports. Trade with China remains stagnant, as in the base. As a result of constraints on world trade, world per capita consumption is marginally off, compared with alternative I, while tending to higher levels in principal exporting regions. World prices tend to somewhat lower levels.

Meat

The projections show that price effects associated with trade restriction policies, such as increases in the EC's variable levies, would have a significant impact on patterns of world production and use of meat. Compared with alternative I, world meat production is substantially lower. With the exception of some countries, consumption also tends to be generally lower. Beef consumption in the EC-6 is up from base period levels as a consequence of higher imports, despite the higher levies on beef imports. But these beef imports are from the EC-3, now inside the Community. Consumption also holds up in Australia and Other Western Europe. Beef imports by Europe and the United States are higher. Pork consumption in Western Europe is curtailed to generate exports or reduce feed costs, and pork exports to the United States are higher. Mutton consumption tends to be higher because of increased Australian and Argentine production and exports.

Results of a comparison of alternatives I and I-A were instructive in indicating the sensitivity of the projections model to adjustments in the EC's variable levies and the interdependency of the factors in the model. The policies analyzed under alternative I-A deal harshly with the world pork economy but have important impacts on beef and mutton, in fact on all meats. If the variable levy increase for pork had been less than that for beef, consumption of beef would have been lower than under alternative I. Thus, the combination of increases in levies that would restrain consumption of both beef and pork might provide the more acceptable policy alternative as compared with that specified in alternative I.

Grains

The lower income growth rate assumed for the developing countries, combined with successful use of restrictive trade policies in the grain-importing countries, would generate growth in world grain production of less than 2.3 percent per year. The economic impact would be greatest for the surplus grain producers faced with sharply reduced export outlets. Growth in grain production in these countries would be considerably below the 1960-75 trend. Deficit producers enforcing trade restriction policies would produce more grain than under alternatives I and II, but appreciably smaller imports would keep total availability for domestic use lower than under the other alternatives.

World growth in grain consumption lags at 2.3 percent per year, or at its lowest projected rate. The lower incomes in the developing countries generate less food demand, and restrictions on imports, combined with generally higher internal prices in the deficit developed countries, reduce growth in feed demand. As a result, world import demand is below alternative I levels. The volume of grain moving in international trade is appreciably above the 1969-71 base levels, but at or below the high levels of 1972-75. The bulk of the grain would be food grains shipped to the developing countries, and combined food and feed grains shipped to Japan.

The restrictive trade policies of alternative I-A generate record increases in grain production in the EC-9 and in Other Western Europe. Offsetting these increases are reduced growth rates in the United States, Canada, Australia, Argentina, and South Africa. For the developed countries as a whole, increases in production slow to 1.9 percent per year.

Grain consumption in the developed countries also grows at the appreciably slower rate of 1.7 percent per year.

The internal price levels needed to generate self-sufficiency in most of the importing developed countries would prove too high to allow the expansion in feeding projected under the other alternatives. Growth in consumption in the exporting countries continues at about the same rate as under alternative I, with marginal increases in some countries as a result of lower domestic prices and readily available supplies.

Under alternative I-A, the developed countries would be net exporters of 50 million tons of grain, roughly four-fifths of which would be wheat.

In the developing countries, grain production grows at 2.9 percent per year, or roughly .2 percent faster than population. Growth in Brazil, Thailand, and Argentina, in particular, lags at roughly two-thirds the historic trend rate. Consumption of grain in developing countries grows 3.0 percent per year, compared with 3.2 percent under alternative I, because of the dampening effects of lower income growth. As a result, imports approach the lows of alternative IV, but at the cost of slowing consumption increases to approximately three-fourths the 1960-75 rate.

56

Oilmeals

World oilseed production under the more restrictive conditions of alternative I-A is less than half a percentage point above that of alternative I. World usage is about 2 percent higher because of heavier rates of meal feeding in Western Europe and Japan. In other areas of the world, including the United States, meal feeding is generally down from alternative I levels. For the developed countries as a whole, total usage is 3.0 percent above the alternative I level, with increases of more than 10 percent occurring in the three regions comprising Western Europe.

Nearly all of the increased utilization of oilseeds in these regions would come from imports. Thus, the overall trade restriction assumptions of alternative I-A would generate higher levels of trade in oilseeds. Meal trade is approximately 3 percent above the alternative I level.

Oilseed exports from the developing exporting countries are 1.4 million tons higher than under alternative I. Prices are slightly lower than alternative I levels, to the benefit of the developed importers. Production, total usage, and imports of oilmeals would be only marginally above alternative I levels. Surprisingly, exports from the region would increase only slightly--by approximately 100,000 tons.

Alternative III

This alternative represents a situation of low import demand in a context of trade restrictions. The assumptions are those of alternative I-A, except that rates of income growth for developed as well as developing countries are assumed to be one-third lower than in alternative I:

Alternative III's population and income compound annual growth rates 1/

	Population	Income
	Percent	
World	1.9	1.8
Developed countries	.8	2.1
Importers	.7	2.5
Exporters	1.1	1.9
Developing countries	2.7	2.2
Importers	2.7	2.3
Exporters	2.6	1.8

1/ Growth rates for 1985 are computed from base 1970.

A striking point of alternative III is its demonstration of the importance of world prosperity to world trade. World demand for grains drops to levels sharply below those of alternatives I and I-A. Prices (in real terms) also are lower. The sharpest drop in grain consumption occurs in feed use. Per capita demand for grains in the developing countries grows only slowly, and import demand is 7 million tons

below the alternative I level. Major exporters have the production capacity to expand concessional sales because of loss of grain markets in the developed countries.

The world livestock economy would also suffer, with per capita feed use of grain off 5 and 10 percent from alternatives I and II, respectively, and with little more than constant per capita expansion in the developing countries. World trade is at low levels, and meat consumption is high in the major meat exporting countries. Meat prices are below the 1970 base levels.

With per capita income growth rates one-third below the alternative I levels, only a 2.2 percent annual increase in world grain consumption is projected. This conservative estimate of growth in grain demand reflects projected slowdowns in growth in feed use in developed countries and, to a lesser extent, food use in developing countries:

Alternative III's grain demand and supply growth factors

| | Demand growth | Supply growth | | |
		Productivity	Resource	Supply
		Percent		
World	2.2	1.6	.5	2.2
Developed countries	1.3	1.8	-.3	1.5
Importers	1.5	2.0	1.0	2.5
Exporters	1.1	1.5	-.7	1.0
Developing countries	3.0	1.9	.9	2.8
Importers	3.0	1.9	.8	2.9
Exporters	2.2	1.2	1.3	2.5

1/ Compound annual growth rates calculated using actual 1969/70-71/72 and projected 1985 data. Demand rates calculated using total grain consumption data; productivity rates calculated using yield data; resource rates calculated using harvested area data; supply rates calculated using production data.

World grain production under this low-income alternative increases 2.2 percent per year, or at the lowest rate projected under all the alternatives. In the major exporting countries, most of the difference between alternative I and III production levels is due to an unfavorable export outlook and dampened domestic demand. Somewhat slower growth is also projected for the deficit countries, largely because of lower producer prices, except in those countries where domestic support programs are implemented.

World real grain prices are at their lowest projected levels under alternative III, reflecting lagging growth in demand and resultant excess productive capacity in the major exporting countries and in a number of marginally self-sufficient countries. Prices are still slightly above base 1970 levels. The rate of growth in world trade in grains is also the lowest under alternative III. World exports increase above the 1972/73-1975/76 levels but lag at 80 percent of the alternative I level and at 60 percent of the alternative II level.

Under alternative III, use of oilmeals is projected to be over 7 percent below the alternative I level. World imports are projected to change by approximately the same percentage. The lack of demand has a significant impact on projected real prices, dropping them to levels that prevailed in the base period.

Developed Countries

Lower incomes would generate no substantial change in food consumption of grains in developed countries. Slower growth in feed demand accounts for the lower growth rate of 2.2 percent per year in combined food and feed demand. Grain fed to livestock accounts for less than 70 percent of total consumption, as compared with 73 percent under alternative I and a high of 75 percent under alternative II.

Grain production in the developed countries increases 1.5 percent per year. As under alternative II, however, the bulk of the adjustment would be in the surplus producing countries--the United States, Canada, Australia, and South Africa--because of weak demand at home and abroad. Production in Western Europe actually reaches its highest level as support programs generate higher production levels and restrictive trade policies result in lower grain imports than projected under alternatives I and II.

Trade in the developed countries reaches its lowest projected levels under alternative III. The imports of the deficit countries increase only slightly from 1973/74-1975/76 levels; increases in Japanese purchases account for well over half of the growth in the developed country total. Exports from the surplus developed countries also grow slowly. For the developed countries as a group, exports are projected at 52 million tons, compared with 98 million tons under alternative II and 68 million tons under alternative I.

Under the conditions of alternative III, total use of oilmeal in the developed region falls 5 million tons, or about 8 percent, below the alternative I level. The lower prices for oilseeds relative to grain in the EC moderate the income effect in that region. Thus, use of oilmeal in the EC-6 is projected to be only 3.2 percent below alternative I levels. In contrast, total use in Japan drops 1 million tons, or about 12 percent. For Canada, the percentage decline is even larger.

Developing Countries

Growth in grain production lags at 2.7 percent per year, primarily because of the effect of weaker demand and consequently lower supply prices than under alternatives I and II. The projections indicate that while much of this slower growth would occur in Argentina, Thailand, and Brazil, even the grain-deficit developing countries would face reduced growth in production.

Growth in grain consumption in the developing countries lags at 3.0 percent per year, partly reflecting a slowdown in grain feeding in the countries with budding livestock operations. Slow growth in direct food consumption in the poorer developing countries with large populations, however, would make up the bulk of the lower grain consumption level.

Even given the situation of low import demand, alternative III projects that 1985 net grain imports in the developing countries would be well above the 1973/74-1975/76 levels. A large part of the developing countries' imports could possibly be purchased on concessional terms as the major exporters attempt to expand trade in the face of dampened world feed grain demand.

59

Under alternative III, total oilmeal utilization in the developing region is only about 2 percent below that of alternative I. Total imports change even less. The change in exports is projected to be less than 1 percent, indicating that the developed regions bear the brunt of the decrease in import demand. In India, the major consumer of oilmeals among the developing countries, the lower prices that alternative III generates more than offset the decline in income and result in a tiny increase in oilmeal consumption relative to that of alternative I.

Alternative IV

Alternative IV was designed to test the effect of expanding use of high-productivity inputs on grain production in the developing countries. The assumptions are the same as those of alternative II, with the exception that use of high-productivity inputs in the developing countries was assumed to increase 1.5 to 2.0 percent per year above the trend growth rates incorporated into alternatives I-III:

Alternative IV's grain demand and supply growth factors 1/

| | Demand growth | Supply growth | | |
		Productivity	Resource	Supply
		Percent		
World	2.9	2.1	.9	2.9
Developed countries	2.3	1.7	.9	2.6
Importers	2.3	1.8	-.3	1.6
Exporters	2.4	1.5	1.4	3.0
Developing countries	3.7	2.9	.9	3.8
Importers	3.8	2.9	.9	3.8
Exporters	2.5	1.3	1.7	3.0

1/ Compound annual growth rates calculated using actual 1969/70-71/72 and projected 1985 data. Demand rates calculated using total grain consumption data; productivity rates calculated using yield data; resource rates calculated using harvested area data; supply rates calculated using production data.

The model uses fertilizer as a proxy for a number of other inputs equally crucial in raising agricultural productivity. Although the composition of any particular bundle of high-productivity inputs would vary widely from region to region, fertilizers would play a crucial role in each. Fertilizer production, consumption, and trade data were also readily available for most of the regions of the world and physical response coefficients relating additional units of fertilizer used to additional units of output produced fit well into the supply framework of the projections model.

The fertilizer response coefficients used in alternative IV were derived from farm management studies and experiment station data or estimated in light of a region's resource endowment and level of technological development. The bulk of the information available pointed to theoretical physical output coefficients ranging up to 15 or 20:1—that is, an additional ton of fertilizer generating 15 to 20

additional tons of output. Wider field observations, however, suggest appreciably lower physical response coefficients ranging from as high as 10 or 11:1 to as low as 4 or 5:1. It also proved difficult to project changes in these physical response coefficients over time because of improvements in technology. The most relevant data for gauging future improvements are drawn from the short history of the Green Revolution. The longer term effects of these 5 to 7 years of technological advances, however, were disguised by poor weather in a number of the 1972/73-1975/76 crop seasons. Recently identified institutional and marketing constraints have also acted to blunt the beneficial effects of Green Revolution technology. The late 1960's and the early years of the 1970's were also years of generally low grain prices in both the developed and developing countries. Prices were also downturned on the world market, hence keeping developing country import prices low and export incentives for the few surplus producers quite weak.

As table 20 indicates, the physical response coefficients used in alternative IV assumed a long-term product input ratio of roughly 7.5:1. The strongest responses— 10 to 12:1—were assumed for the fertile, underdeveloped regions of Thailand, Other Southeast Asia, and Indonesia, where fertilizer use in 1969-71 averaged less than 4 kilograms per hectare of arable land and where grain yields averaged less than 1.3 tons per hectare. In short, the more primitive the state of agricultural technology and the better the resource endowment, the greater the potential increase in production. But in these high potential areas, the bundle of inputs associated with increased effective use of fertilizer would be extremely expensive. The bundle would include development of land and water resources, and investment in basic agricultural and rural infrastructure, as well as large expenditures on the conventional high-productivity inputs such as chemical pesticides and hybrid seeds. The resettling of large numbers of people would be needed. Long-term, ongoing expenditures would also be needed in many of these regions as the physical and chemical properties of tropical and subtropical soils pose serious soil fertility maintenance problems.

The weakest response—4.5 to 6.5:1—was used for those countries where—due generally to limited resources and population pressure on domestic food production capacities—the level of agricultural technology and fertilizer use is already high. Chief among these regions is high-income East Asia, where fertilizer use in 1969-71 averaged more than 25 kilograms per hectare of arable land and where grain yields averaged close to 3 tons per hectare. Also included among the weak response regions would be Middle America and Other South America. Substantial investment has been made in infrastructure in these two regions, and much of the initial gain to be made by increasing use of fertilizer and other high productivity inputs has already been realized for wheat and rice. Large gains are yet to be made, however, in subsistence farming areas where corn is the principal crop. Intermediate responses ranging from 7 to 8:1 were used for the majority of the other regions.

The results of alternative IV indicate that increasing fertilizer use 1.5 to 2.0 percent above the levels assumed under alternative I would reduce the 1985 grain import requirements of the developing market economies to 34 million tons, as compared with 71 million tons under alternative II and 49 million tons under alternative I.

Alternative IV projections suggest the following additional general conclusions: —If productivity in the developing market economies grew some .9 percent a year faster than in alternative I, as implied by the higher levels of input usage, growth in world grain production could reach 2.8 percent per year, or some .3 percent higher than under any of the other alternatives. The developing countries would account for three-fourths of this additional annual increase. The remainder would be generated in the major developed exporting countries, where use of the same high-

income growth rates assumed for alternative II would strengthen domestic and foreign demand for feed grain. --The high-income and liberalized trade assumption introduced in alternative II combined with the high-productivity assumption pushes alternative IV's consumption growth rate to over 3.0 percent per year, or well above any of the other alternatives. Once again, more than half of the alternative IV increase would be due to changes in the developing market economies as the effect of increased domestic supplies and lower prices encouraged faster growth in food and, to a lesser extent, feed use. --World grain trade would remain above 1969/70-1971/72 levels, but would fall below 1972/73-1974/75 levels. Increased domestic production in the developing market economies would be large enough to meet the demand generated by higher incomes and thus allow for some decrease in imports. The imports of the developed countries would be only marginally above the alternative II level because of alternative IV's somewhat lower trade prices.

The following more specific conclusions deal with the implications of increased fertilizer use in the developing market economies. The 2.8 to 3.1 percent annual increase in grain production in the developing countries projected under alternatives I and II assumes an 8.0 percent, or roughly 1.3 million ton average annual, increase in fertilizer use through 1985. In the 5-8 years immediately following the introduction of Green Revolution technology, growth in fertilizer use averaged appreciably higher. It is unlikely, however, that fertilizer consumption in developing countries could continue to grow at even the lower, longer term 1962-72 rate of 11-13 percent per year from a 1970 base of 9 million tons--particularly if the developing countries have to depend more and more on imported nutrients.

If the lower 8.0 percent annual growth rate assumed under alternative I can be maintained through 1985, fertilizer consumption is projected to reach 28 million tons in the developing countries. Fertilizer use would reach 36 million tons if, as assumed in alternative IV, the rate of increase were 1.5 to 2.0 percent, or .5 million tons per year, higher. Weighted physical response coefficients suggest that this additional 7 million tons of fertilizer--if used in conjunction with the proper package of inputs and improved management practices--would generate an additional 13 percent or 56 million tons of grain production.

This increase in indigenous supply, however, would dampen farm prices and discourage 13 million tons of production generated under the higher prices of alternative II. The net 43-million-ton increase in production would be divided between a 10-million-ton increase in consumption due to lower demand prices and a 33-million-ton decrease in imports due to added domestic availabilities. The regions benefiting most from the higher productivity generated under alternative IV would be the regions with intermediate response levels--regions such as India and Other South Asia--where much of the potential of modern technology has yet to be tapped and where the costs of the inputs associated with increasing effective use of fertilizer would not be prohibitively high. It should also be noted that alternative IV's assumption of increased fertilizer use does not provide for the increases in supply prices necessary to generate accelerated adoption of the high-productivity input package. Government intervention, either through subsidizing inputs or maintaining of a two-tier system of high producer prices and lower consumer prices, would be necessary if the higher growth rate in input usage were to be reached.

IMPACT OF CLIMATE AND WEATHER ON GRAIN PROJECTIONS

The 1975 drought in the Soviet Union, the 1976 drought in Western Europe, and the recent weather problems in the United States have reactivated concern about the possibility of a changing world climate and its implications for future world food

62

production, particularly grain production. These developments also raise questions about the impact of shortrun fluctuations in weather on longrun levels of grain production and related grain reserve and production policies.

Although there is a lack of agreement among experts on climatic change, they do agree generally that longrun climatic changes would result in lower grain yields. The impact of longrun changes in climate on yields would reflect a number of weather attributes--temperature, including levels and both seasonal and diurnal distribution effects, insolation, and moisture of both air and soil, including level and distribution.

By modifying assumptions concerning future growth in grain yields, the GOL model was used to estimate the impact of possible longrun changes in climate. The impact of shortrun fluctuations in weather on the frequency and magnitude of production shortfalls is examined in the GOL model in terms of the following question: will maintaining sufficient reserves to meet shortrun shortfalls require significantly higher levels of longrun production? The implicit assumption is that in many parts of the world--particularly in the developing countries--stocks accumulated in bumper years are considerably smaller than would be required to maintain trend consumption in years of major production shortfalls. Policy as well as economic issues would be involved in decisions about needed future production levels. Such decisions would need to recognize that longrun grain production levels and grain reserve levels are interrelated.

Effect of Longrun Climatic Change

In the recent controversy over climatic change, a number of theories have been advanced as to why the world's climate could be expected to change (1103) (1104) (1105) (1106) (1108) (1109) (1112) (1117) (1118) (1119) (1120) (1122) (1123). One theory is that a cooling trend in climate is occurring and that the trend will continue. Another is that a warming trend is likely in the future because of the increase in carbon dioxide (CO_2) in the air resulting from the burning of fossil fuels. A third theory suggests that there is a relationship between sunspot cycles and precipitation.

With respect to the cooling hypothesis, annual temperature data for the Northern Hemisphere shows a distinct rising trend from the 1880's to the 1940's, with a subsequent decrease to the 1970's. There is disagreement, however, as to whether this cooling trend is continuing. A continued cooling trend could have a serious negative impact on the northernmost agricultural areas of the United States and on agricultural areas in Canada and the USSR. The effect on production in the United States would be marginal, however, because there would be U.S. areas that might gain from a cooling trend.

With respect to the warming hypothesis, it is argued that the so-called "greenhouse effect" caused by emission of carbon dioxide is offsetting the cooling trend of recent decades. There has been speculation that the net effect of this warming would be a sharp decline in the productivity of much of the world's food-producing regions. But so far, no consensus has been reached.

With respect to sunspots, theorists suggest that a reoccurrence of a 1930's-type drought is "due" in the High Plains of the western United States in the mid-1970's. On a world basis, most drought conditions appear to occur at random, but the time and location on the U.S. High Plains appear to be an exception. Here, drought conditions have shown a marked regularity every 20 to 25 years, corresponding with sunspot cycles.

63

Virtually the same points have been raised where longrun projections of world grain production are concerned (1111) (1113) (1115) (1116) (1121). One position that has been taken is that no provision should be made for longrun changes in climate because of the uncertainty as to the direction of change, because of confusion as to measuring the impact of weather on grains, or because of basic belief in the random nature of weather variations.

The weather-related shortfalls in grain production of the past few years have also raised questions about longrun increases in grain yields. For the past 3 or 4 years, grain yields, particularly in the United States, have not kept pace with the trend of the previous two decades. One view contends that much of the increase in grain yields over the last several decades resulted from exceptionally favorable weather, and that growth in yields is slowing. An opposing view is that improved technology, through new seed varieties, increased fertilizer use, and better management practices, has greatly reduced the adverse effects of weather, particularly in the United States and Western Europe.

Several conferences have been held on the relationship between climatic change and food production (1107) (1109) (1110) (1118) (1120). At a December 1974 conference at Sterling Forest (1120), there was general agreement that the 1955-71 period represented a sequence of favorable growing seasons, particularly for the United States. The June 1976 conference in Bellagio, Italy, noted that while the sharpest increases in corn yields in the United States occurred after 1960, when nitrogen fertilizer became cheap and plentiful, the U.S. Corn Belt had unusually favorable weather from 1956 through 1973 (1118). The November 1975 conference in Toronto on "Living With Climatic Change" and subsequent seminars noted that "the remarkably consistent high productivity of North American agriculture from the mid-1950's to the early 1970's has been due to a combination of improved technology and exceptionally favorable weather..." (1107) (1109). It was argued that this unusual run of good years has given a false impression of stability and security, and that the climate of the preceding century was much more variable and was characterized by periods of either sustained drought or excess moisture.

Assumptions

In addition, several alternatives were run to test the effects of adverse longrun climatic change on world production, consumption, trade, and price levels of grain. Yield reductions of 5-15 percent from the 1985 levels were postulated for the major areas of the world subject to wide weather fluctuations historically. These lower yield growth assumptions were run for the lower demand alternative I; the higher demand alternative II; and alternative IV, which assumes the developing countries make a concerted effort to offset longrun climatic change by reorganizing their agriculture and upgrading their agricultural technologies.

Implications

The effect of lowering yields 5 to 15 percent from the levels projected for 1985 differ markedly for alternatives I and II (table 21). The impact under alternative I is moderate, primarily because the major producers are able to offset the decrease in yields by expanding area, thus compensating for slower growth in their own yields and slower growth in regions where area expansion is more difficult. Area expansion is limited in the developed importing countries; consequently, their grain import requirements are more than 20 million tons above the original alternative I level. Slower growth in grain production in the developing countries would likely slow down overall economic growth. This could make it difficult for some of the developing nations to accumulate sufficient foreign exchange earnings to meet this increased

gap. World wheat prices are as much as 20 percent higher than the original alternative I levels; coarse grain and rice price increases are somewhat smaller.

The 5 to 15 percent lower yields in 1985 combined with the higher demand assumptions of alternative II could pose serious problems. Under this alternative, the major developed exporters use an appreciably larger share of their productive capacity than under alternative I. Expansion of area can only come at higher costs per unit of output and at the expense of other crops.

Grain area expansion beyond alternative II levels under the poor weather assumptions is consequently limited, even though world prices of wheat increase to $100 per ton, up from $78 per ton in real 1970 dollars in the original alternative II projection, and coarse grain prices move from $71 to $91 per ton. Livestock prices also increase significantly. The lower pork-grain and beef-grain price ratios tend to discourage livestock production below alternative II levels. The higher feed costs could also be expected to result in policy changes in the EC, Other Western Europe, and Japan that would affect the grain-livestock mix. For example, a move to less trade liberalization and return to higher levies for both meats and grains would be expected. Higher internal prices for livestock products would tend to discourage consumption and expand production to compensate for lower yields and poor grasses. Another expected policy change would be a move by the EC to export more wheat, and to substitute corn for wheat for feeding. This would tend to raise the world level of coarse grain prices, but would mitigate the rise in wheat prices if minor adjustments were made in the feed use of wheat.

These changes generate U.S. coarse grain exports of 77 million tons--up from 62 million tons under the original alternative II. The increase in U.S. wheat exports is considerably less--from 50 million tons under the original alternative II to 54 million tons.

With a deterioration in climate, there would likely be reduced U.S. yields in the present major wheat belt and some shift in wheat production eastward to areas with more moisture. This move would be limited because of competition from coarse grains and soybeans. For these crops, production would also move eastward, where moisture tends to be higher. The net effect of the shift would be to mitigate the average loss in yield for the United States as a whole and permit expansion of grain area, but at the expense of other crops.

Total grain and soybean area for the United States under the poor climate scenario is projected at 118 million hectares in 1985. This corresponds to 93 hectares harvested in 1975/76. Harvested area in Canada, Australia, and Argentina by 1985 would also be above recent highs, but growth in both harvested area and exports would be proportionally smaller than for the United States because of these countries' limited ability to increase their productive capacities within the next decade.

World trade in beef and pork is also affected under the poor climate scenario. The increase in variable levies in the EC and trade restrictions in Japan would again make the market for low-grade beef in the United States more attractive than that in Europe. Livestock production in the major exporting countries is also affected, and Argentina and Australia cannot take full advantage of the high world prices for meat. Beef production in the United States would be expected to shift to a greater extent east of the Mississippi--accelerating a trend that has been occurring in the last two decades. The United States could continue to be a major exporter of pork, even though the world price of pork rose substantially more than the price of beef.

For some countries in the developing world, area expansion could be expected to accelerate because of substantially higher foreign and domestic prices. In Brazil, soybean production would be expected to expand. But area expansion could also be expected to exacerbate weather risks and yield variability. In land-constrained regions such as South Asia, the impact of lower yields could be quite serious unless appropriate action were taken to reorganize agriculture and improve the quantities and quality of inputs. For example, if we assume that production policies in these regions continue as assumed in alternatives I or II, then the import gap could not be met without massive food aid. Imports of grain are 85 million tons, compared with the original alternative II level of 70 million tons. Slowed production growth and high import demand, however, would be incompatible with high income growth and agricultural productivity.

However, it would be unrealistic to assume that under such circumstances a concerted effort to boost production, such as assumed in alternative IV, would not be undertaken. For example, if we test the impact of lower yields using the same assumptions to accelerate production as in alternative IV, the import gap in the developing world would shrink substantially and income growth and agricultural productivity would be in better balance.

Effect of Production Shortfalls

Assumptions

In any given year, the impact of a "production shortfall" on grain prices is determined by the proportion of the shortfall to be made up through imports and by the supplies of grain available to meet resultant changes in world trade. The longrun impact of shortfalls are reflected in the somewhat higher production levels required over time to maintain planned reserves. The size of this added production would depend on the frequency and magnitude of shortfalls and the policies planned to cope with them. Greater frequency in shortfalls than anticipated could well require additional catchup over several years.

A "shortfall" can be defined as the amount by which grain yields fall below historical trend. Using this definition and converting yield deviations into production equivalents, 5 major world shortfalls can be observed over the 1961-75 period--amounting to 34 million tons in 1961, 34 million tons in 1963, 32 million tons in 1965, 25 million tons in 1974, and 72 million tons in 1975 (table 22).

What is the likelihood of a major shortfall between now and 1985, or in 1985? What is the likelihood of three major shortfalls between now and 1985, or in 1985? Three major shortfalls occurred during 1950-70, suggesting a probability of about 15 percent in any given year. But if we had considered the period 1960 to date, we could expect 2 to 3 shortfalls per decade, or a probability of up to 33 percent that we have a shortfall in any particular year over the projected period. One could also speculate that the frequency and magnitude of shortfalls have increased from minor, generally localized disturbances in the 1950's to larger, regionalized shortfalls in the 1960's, and finally to world shortfalls in the decade of the 1970's.

While the 5 major shortfalls during 1961-75 had many attributes in common, the impact on trade and prices was strikingly different. The following are possible explanations.

The physical production shortfall is not always the relevant shortfall with respect to world trade. Many countries—particularly low-income countries or isolationst trading countries—make up only part of their shortfalls through imports

66

Table 22--Incidence of major yield deviations from trend, 1950-75, and their effect on grain production

Year	United States	Canada	EC-9	Other Western Europe	South Africa	Japan	Oceania	Eastern Europe	USSR	People's Republic of China	Mexico/ Central America	Brazil	Argentina
					Shortfall incidence								
1950		XX											
1951													
1952					XX								
1953						XX							
1954		XX						XX					
1955				XX									
1956								XX					
1957							XX		XX				
1958								XX			XX		
1959													
1960										XX			
1961		XX	XX							XX			
1962										XX			
1963						XX	XX						
1964													
1965								XX	XX				
1966			XX										
1967		XX											XX
1968					XX								
1969					XX								
1970			XX						XX				
1971							XX				XX	XX	XX
1972						XX	XX				XX		
1973				XX	XX							XX	
1974	XX	XX											
1975			XX						XX			XX	XX
					Million metric tons								
Shortfall frequency	1	5	4	2	4	3	4	4	4	3	3	3	3
Total shortfall tonnage	41.0	31.9	24.6	2.7	8.0	4.7	12.8	20.5	151.5	55.6	3.8	6.0	9.0
Average shortfall tonnage	41.0	6.4	6.2	1.4	2.0	1.6	3.2	5.1	37.9	18.5	1.3	2.0	3.0
Percent of base 1969/70-1971/72 production	19.6	19.2	6.6	4.9	19.6	12.4	21.3	7.1	23.0	11.3	8.0	9.5	15.6

Continued--

Table 22--Incidence of major yield deviations from trend, 1950-75, and their effect on grain production--Continued

Year	Other South America	N. Africa/ Middle East	East Africa	Central Africa	India	Other South Asia	South East Asia	East Asia	Sum of negative regional deviations		
									Shortfall Frequency	Shortfall Tonnage	Percent of base production
	- - - - - - - - - - - - - Shortfall incidence - - - - - - - - - - - - - - - -								- Million metric tons -		- - Percent - -
1950									1	5.7	.8
1951									--	---	---
1952								XX	2	2.7	.4
1953									1	1.9	.2
1954									2	11.1	1.4
1955						XX			2	2.6	.3
1956									1	4.4	.5
1957	XX				XX		XX		5	50.3	5.9
1958	XX								2	4.8	.5
1959									1	.8	.1
1960									1	25.6	2.8
1961		XX							4	35.9	3.9
1962									1	10.7	1.1
1963									2	39.0	4.0
1964									-	---	---
1965			XX		XX				4	57.7	5.7
1966				XX	XX	XX		XX	5	43.0	3.9
1967								XX	3	12.1	1.1
1968									2	5.6	.5
1969									1	1.7	.1
1970			XX						3	14.8	1.2
1971				XX					2	2.5	.2
1972			XX	XX			XX	XX	9	16.6	1.3
1973		XX		XX					4	11.7	.9
1974		XX			XX				5	79.6	5.9
1975									4	74.0	5.5
	- - - - - - - - - - - - - - Million metric tons - - - - - - - - - - - - -										
Shortfall frequence	2	3	3	4	4	3	2	3			
Total shortfall tonnage	.5	13.2	4.1	3.0	106.0	6.3	5.4	4.4			
Average shortfall tonnage	.3	4.4	1.4	.8	26.5	2.1	2.7	1.5			
Percent of base 1969/70-1971/72 production	3.6	11.3	19.7	11.7	30.5	8.9	11.9	9.8			

89

and compensate for the remainder by reducing consumption through direct or indirect price rationing. In 1963 and again in 1965, the USSR, through policies including a deliberate reduction in livestock numbers, made up about a third of their grain production shortfalls at home. But in 1972, the USSR imported a net of 25 million tons of grain in order to maintain growth in livestock production in the face of indigenous shortfall. The USSR might have imported less but for exceptionally low world market prices. In contrast, even though the USSR grain shortfall was much larger in 1974, world export availabilities were more limited, world market prices were appreciably higher, and Soviet imports were kept limited.

Table 23 compares U.S. grain exports, world grain trade, and world grain production shortfalls for major areas for selected years. In 1963 and again in 1965, the amount that U.S. grain exports were above trend was considerably below the grain production shortfall in the world excluding the United States. Specifically, the United States met one-third or less of the world shortfall even though it carried substantial stocks. But in 1972/73, the United States exported 22 million tons above trend, while the shortfall in the world was less than 20 million tons (or almost 10 million tons higher if USSR goals are included). In that year, U.S. exports met one-third or less of the shortfall in the developing world—about the historical share—while exports to the USSR exceeded the historical share. U.S. export levels again in 1973/74 were above previous trends even though world production was over 50 million tons above trend and world trade only 17 million above.

Implications

This section reports results of using the GOL model to test the impact of shortrun weather fluctuations on longrun grain production levels (table 24). As indicated above, the impact would reflect the frequency and size of production shortfalls, as well as the production and stock policies (national and international) adopted to meet shortfalls. These two sets of factors are highly interrelated.

In addition, the response of industry, particularly in the shortrun, could have an important bearing on price and market stability. The interaction of production policies, stock policies, and price fluctuations, and how producers, traders, and governments react to them, could determine whether there is a continuation of the historical, cyclical pattern of several years of shortages followed by several years of oversupply, or whether cyclical variations in supply can be minimized.

The reaction of traders, in terms of their management of private stocks, to production and stock policies would also have a bearing on the impact of shortrun production shortfalls. Two positions appear to be taken concerning trade response to production and reserve policies. One position is that if commercial traders were given complete assurance that there would be no government interference, the market mechanism would work in such a way that private business would accumulate sufficient stocks to meet the necessary contingencies. The reasons usually given are that at the world level, regional shortfalls tend largely to offset each other and the size of any shortfall to be met from stocks would be minimized if free trade were allowed to function.

The second position is that national and probably international stock policies are needed to meet such contingencies. In these discussions, some critical attributes that could affect response of the trade seem to be ignored. The profit motive suggests that business would consider (1) the size and frequency of shortfalls, (2) the cost of storage, and (3) the alternative income lost from investment of funds from delayed sale of stocks. The cost of storage is currently estimated at about $4.50 (1970 dollars) per ton of wheat. If an annual interest rate of 8 to 10 percent is applied to an alternative II purchase price, the value of the

Table 23--Grain trade and production shortfalls, selected years, 1961/62 – 1975/76

Year	U.S. grain exports			World grain exports			Production shortfalls		
	Actual	Trend	Deviations	Actual	Trend	Deviations	Summation of negative deviations 1/	Summation minus U.S.	World deviations 2/
						Million metric tons			
1961/62	35.9	34.0	+1.9	87.4	81.9	+5.5	-35.9	-35.9	-32.8
1963/64	41.1	37.0	+4.1	102.5	92.2	+10.3	-39.0	-39.0	-33.0
1965/66	50.0	42.0	+8.0	115.7	102.5	+13.2	-57.7	-57.7	-30.6
1972/73	78.9	57.0	+21.9	147.9	138.7	+9.2	-16.6	-16.6	+15.2
1973/74	75.2	61.0	+14.2	161.1	143.9	+17.2	-11.7	-11.7	+50.7
1974/75	65.2	64.0	+1.2	145.0	149.0	-4.0	-79.6	-38.6	-24.1
1975/76	83.1	67.0	+16.1	168.6	154.2	+14.4	-74.0	-74.0	-69.0

Note: The full trade effect of a production shortfall often runs over into the following year because of purchase-delivery lags and stock adjustments.

Note: 1972/73 shortfall would be in excess of 30 million tons if deviation in the Soviet Union was measured from plan rather than trend.

1/   Summation of the regional negative deviations appearing in table 22.

2/   World deviations based on summation of both negative and positive deviations calculated for table 22.

70

Table 24--Effects of short-term weather variations on trade levels, projected, 1985

Region/Country	Alternative I variations		Alternative II variations						
	Original 1/	Low yield	Original 1/	8 million ton stock accumulation 2/	16 million ton stock accumulation 2/	Low yield	8 million ton stock accumulation 2/	16 million ton stock accumulation 2/	40 million ton stock accumulation 2/
	Million metric tons								
Developed countries	68.5	101.4	98.5	105.4	112.3	127.6	127.0	134.0	155.0
Importers 3/	-48.0	-53.8	-63.9	-63.2	-62.5	-65.5	-58.0	-57.3	-54.7
Exporters 4/	116.4	155.2	162.3	168.6	174.8	193.0	185.1	191.3	209.7
United States	76.4	117.5	116.0	120.9	125.7	152.9	140.0	144.9	166.1
Centrally planned countries	-19.4	-33.2	-27.8	-27.6	-27.4	-41.0	-37.7	-37.5	-37.1
Developing countries	-48.9	-68.1	-70.6	-69.7	-68.8	-86.5	-81.1	-80.3	-77.8
Importers	-68.8	-88.1	-93.1	-92.4	-91.6	-108.8	-103.1	-102.5	-100.3
Exporters 5/	19.9	20.0	22.5	22.7	22.8	22.3	22.0	22.2	22.5

1/ Original alternative I and II taken from earlier sections.
2/ Assumes annual stock accumulations of 8, 16, and 40 million tons.
3/ EC-6, EC-3, Other Western Europe, Japan.
4/ United States, Canada, South Africa, Oceania.
5/ Thailand, Argentina.

delayed sale would be $7.50 per ton (1970 dollars), and prices in shortfall years would have to increase by this amount times the number of years between shortfalls to cover costs.

Changes in the frequency of production shortfalls could reduce the number of years necessary to hold the stock and reduce costs. Costs could also be reduced if the trade bought in periods of gluts and managed supplies so as to sell in periods of shortages. The historical reaction of the trade can be inferred from the stock levels of the four major exporters over the past two decades--stock levels that have ranged up to 160 million tons. If stock levels are around 130 million tons, the trade would argue that supplies and demand are in balance. On the other hand, when stock levels drop to substantially below 100 million tons, as they have in the recent period, the trade expresses considerable concern, and prices tend to rise more than normal response would suggest because of added speculative elements in the market. The speculative element tends to be reduced if the same stock levels continue for several years because the trade finds that adjustments can be made—as evidenced, for example, by the substantial drop in feed use in the United States from 1974 through the present. At the other extreme, when stock levels reach about 160 million tons, even though they may be held by the government with no cost to the trade, a price depressing effect may occur. The reason is that historical experience suggests that in any year of a major shortfall, the additional international trade in grains, particularly wheat, seldom exceeds 30 million tons. The above cost calculations thus would suggest that a shortfall of this magnitude would have to occur every 4 or 5 years for the trade to break even, excluding any return for increased risks. A factor often ignored is that the costs of government storage during the late 1950's and 1960's were financed at low interest rates.

In the GOL model, the impact of production shortfalls is estimated for the low demand alternative I and the high demand alternative II, and the analysis takes into account the considerations discussed above. Also, it is assumed that production and stock policies are managed to assure stock levels sufficient to meet the contingencies assumed in alternatives I and II.

The possibility that two major shortfalls do not occur successively is considered first. Under these circumstances, additional grain production of 80 million tons over a 10-year period, or 8 million tons of grain production per year, would be required. Raising annual production levels by this amount in either alternative I or alternative II has only a minimal effect on longrun average world grain prices or quantities traded. World trade prices for wheat, as expressed by U.S. export prices, are $80 per ton, up only slightly from $78 per ton in the original alternative II projection. However, if the frequency of the production shortfalls should double to reach four per decade, U.S. grain exports and world trade prices are likely to be even further above the original alternative II level. Thus, it can be concluded that if consistent production and stock policies were implemented, the impact of production shortfalls on longrun production levels would be minimal unless the size of shortfalls or their frequency increased substantially.

However, the above runs assumed alternative I and II yields and that a production shortfall would not occur 2 years in succession. The weather impact alternatives discussed below use the projections reflecting a slower growth of yield because of longrun climatic change, as analyzed in the previous section. In these weather impact analyses, the base is alternative II. Even though the weather impact by itself may be minimal, the impact may be significant if pressures against resources exist.

In the first parametric run using two production shortfalls per decade, world prices of wheat are as high as $102 per ton and coarse grain prices, while rising proportionately less, are $92 per ton. Grain exports by the United States, Canada,

Australia, and Argentina total 185 million tons, with U.S. exports at 140 million tons. If the shortfall frequency is set at four per decade, world prices of wheat and coarse grain rise to $105 and $93 per ton. In this situation, the major exporters export 191 million tons of grain, with U.S. exports at 145 million tons.

One parametric run could be described as a "disaster" case. It assumes that in 1984 all stocks have been depleted. An immediate attempt is made in 1985 to raise stocks levels by 40 million tons rather than build stocks at the average annual rates assumed in the earlier alternatives. In this instance, world prices would increase up to 20 percent. These prices reflect average longrun elasticities. Accelerated stock accumulation could generate higher levels, however, particularly if announcement of such a policy led to overoptimism as to true market demand or generated increased speculative demand.

However, normal crops in 1985 would probably result in price adjustments either late in the 1985 season or certainly in the following year, even under the low yield assumption. A real resource squeeze in a given year, as postulated in the above parametric alternative, would bring about higher prices and adjustments in grain use such as experienced in 1974. It is also quite likely that, given a series of years in which the world market price of grain continued at high levels, the developing countries would make a special effort to raise production levels through improvements in inputs and the social and institutional organization of agriculture to offset climatic and weather impacts. In this case, the "disaster" alternative probably would not create any more tightness than did the period 1972/73-1975/76.

IMPLICATIONS FOR THE UNITED STATES

The projections all indicate that the United States is likely to play an increasingly important role in the world's grain-oilseed-livestock economy in the years ahead.

The extent to which the U.S. agricultural economy grows in importance varies widely, however, under the different alternatives. But even under the slow growth alternatives I and III, the United States is projected to continue to be the world's largest producer and trader of agricultural products.

The United States is projected to continue to produce at least one-fifth of the world's grain, over one-third of the world's commercial output of meat, and approximately half of the world's commercial output of oilmeal (table 25).

U.S. exports of grains and oilseeds, and imports of livestock products, are projected to account for even larger shares of their respective world trade totals in 1985 than they did in 1969/70-1971/72. U.S. grain and oilmeal exports range from 50 to 60 percent of the world export total by 1985, depending on the alternative being considered. U.S. meat imports account for about 15 percent of the world import total under alternative I (tables 26-27).

All the projections point up the importance of strong growth in effective commercial import demand for grain and oilseeds if American agriculture is to produce anywhere near capacity or at levels commensurate with domestic farm and food policy goals. Specific U.S. production and trade implications of alternatives I and II are outlined below.

73

Table 25--Production and growth rates for grains, oilcake, and meat,
United States, recent averages, and projected 1985

Commodity	1969/70-71/72 base	1973/74-75/76	1985				
			I	I-A	II	III	IV
			Million metric tons				
Production:							
Wheat	40.0	51.1	58.4	49.9	74.4	45.9	64.8
Coarse grains	165.8	173.7	227.2	205.8	269.4	177.1	258.8
Total grains 1/	208.7	228.4	290.7	260.5	349.4	227.8	328.2
Oilcake	25.4	31.6	44.5	47.9	48.5	42.3	51.0
			1,000 metric tons				
Beef	10,063	10,222	13,070	12,913	13,529	12,455	13,689
Pork	6,227	5,666	6,875	6,718	7,309	6,198	7,433
			Compound annual growth rates, percent 2/				
Growth rates:							
Wheat			2.6	1.5	4.2	.9	3.3
Coarse grains			2.1	1.5	3.3	.4	3.0
Total grains 1/			2.2	1.5	3.5	.6	3.1
Oilcake			3.8	4.3	4.4	3.5	4.8
Beef			1.8	1.7	2.0	1.4	2.1
Pork			.7	.5	1.1	-.03	1.2

1/ Includes rice.
2/ Growth rates computed from base 1969/70-71/72.

74

Table 26—Grain, oilcake, meat, and cheese exports, United States, recent averages, and projected, 1985

Commodity	1969/70-71/72 base	1973/74-75/76	1985				
			I	I-A	II	III	IV
			Million metric tons				
Wheat	17.9	30.2	33.5	24.6	50.0	21.5	39.0
Coarse grain	20.3	41.8	39.4	22.1	62.0	12.3	49.2
Rice	1.7	1.9	3.5	3.2	4.0	3.2	3.0
Total grain	39.9	73.9	76.4	49.9	116.0	37.0	91.2
Oilcake	11.2	15.6	23.3	28.0	24.8	24.2	28.0
			1,000 metric tons				
Beef	-741	-792	-435	-752	-275	-938	265
Pork	-109	-140	-262	-583	-877	-1,533	785
Cheese	-55	-104	-48	-118	-252	-0.3	-206

75

Table 27--U.S. share of world market for grains and oilcake, recent averages, and projected, 1985 1/

Commodity	1969/70- 71/72 base	1973/74- 75/76	1985				
			I	I-A	II	III	IV
			Percent of world exports				
Wheat	39.2	56.3	51.6	42.1	57.5	36.6	52.9
Coarse grains	53.2	68.8	58.0	43.2	67.5	24.9	60.2
Total grains 2/	44.5	65.1	53.3	42.0	60.2	31.7	54.7
Oilcake	55.3	60.0	51.1	60.0	51.3	57.2	59.5

1/ Due to the GOL model's use of regional net trade rather than gross world trade, world exports are understated and the U.S. percentage is overstated.

2/ Includes rice.

Alternative I

Alternative I's base income growth rates, somewhat higher real input and product prices than in the base period, and restrictive trade policies in a number of importing countries generate only modest growth in world trade in grains, oilseeds, and livestock products. World grain trade is projected to increase through 1985 at somewhat less than 3.2 percent per year from the 1969/70-1971/72 base level. World import demand for grains is projected to be 143 million tons in 1985, which would compare with an average of 81 million tons in the base period but about 115 million tons in the recent 1973/74-1975/76 period and as high as 130 million tons in 1975/76.

U.S. grain exports are projected to account for 77 million tons of the 1985 world import total under alternative I, compared with an average of 40 million tons in the base period and 73 million tons in 1973/74-1975/76. In terms of market share, U.S. exports would account for 54 percent of the alternative I export total in 1985, compared with 45 and 63 percent, respectively, in 1969/70-1971/72 and 1973/74-1975/76. Increased export availabilities in the other major exporting countries are likely to reduce the U.S. share of the world grain market from the peak reached during recent years of strong world import demand and generalized short supplies. Somewhat stronger world import demand in 1985 than in 1969/70-1971/72, however, is likely to keep the U.S. share of the market from slipping back to the lower levels of the late 1960's.

Under alternative I, wheat and coarse grain continue to account for over 90 percent of the grain traded internationally and for roughly 95 percent of U.S. grain exports. U.S. wheat exports are projected to be 34 million tons in 1985, or substantially above the 18-million-ton average of 1969/70-1971/72 but only marginally above the 32-million-ton average of 1973/74-1975/76. In the case of coarse grains, U.S. exports are projected to be roughly double the 20-million-ton average of the base period but below the highs of 1973/74-1975/76. U.S. rice exports increase at a substantially faster pace than wheat and coarse grain exports, but from a relatively small base of only 1.7 million tons.

Alternative I's trade projections—as well as those of the other alternatives—do not provide for any wide year-to-year fluctuations in import demand along the lines of the 1972/73 or 1975/76 Soviet purchases. Consequently, any one year's export level might well fluctuate 20 million tons or more above the projected level. Meeting future fluctuations in world import demand generated by unexpected production shortfalls or any marked short-term increase in conventional demand will depend on the major exporters' ability to draw down stocks or adjust domestic feed use, as was done in the United States in 1973/74-1975/76. The productive capacity of the major exporters is such, however, that no problem is foreseen in meeting any of the long-term import demand levels projected under all the alternatives.

U.S. grain production in 1985 under this moderate growth alternative is projected at 291 million tons, substantially above the 209-million-ton average in the base, and moderately above both the 1973/74-1975/76 average of 229 million tons and the record 253 million tons reported in 1975/76. Growth would be strongest in wheat production, with annual increases averaging 2.5 percent. But wheat production in 1975—at 58 million tons—had already reached the level projected under alternative I. Because of the increases in yields expected over the next decade, less area would be required to produce alternative I's level of output than was harvested for the 1974, 1975, or 1976 crops. Some type of Government program might be needed to reduce wheat area if downward pressure on prices and accumulation of stocks were to be avoided. Under alternative I, coarse grain production in the United States increases 37 percent between the base and 1985, or more than 2 percent per year. Compared with 1975

levels, however, U.S. production in 1985 would be up less than 15 percent. Most of the expansion in output would likely result from higher yields. Some reductions in coarse grain area would also likely be necessary if downward price adjustments and stock accumulation were to be avoided. Adjustments in coarse grain area, however, would be appreciably smaller than likely wheat production adjustments.

Under alternative I, total grain production in other major exporting countries is expected to grow faster than in the United States. While total U.S. grain production under alternative I is projected to be 17 percent above the 1975 level, production in the other major exporting countries is projected at 34 percent above the 1975 level. Faster growth in production in the other exporting countries, however, depends on their ability to recover export markets lost in the tight supply situation of 1973/74-1975/76.

Alternative II

Alternative II's median population and high income growth rates, combined with liberalized trade policies in the developed importing countries, generate substantially stronger world demand and consequently appreciably higher U.S. production and trade levels.

Under this high import demand alternative, world grain import demand is projected to reach 192 million tons by 1985, with U.S. exports accounting for 116 million tons or some 60 percent of the total.

While much of this world increase would be generated by higher incomes, in both the developed and developing countries, liberalization of trade would also generate a significant share of alternative II's higher trade levels. Increases in world wheat and rice trade would be marked as higher incomes enabled the food-deficit developing countries to import more. In developed regions, trade liberalization measures under alternative II result in low prices for feeds. Thus, alternative II's stronger growth as compared with alternative I would be in trade in grains ultimately used for feed. Growth in world feed grain import demand under alternative II is almost twice the rate of alternative I, with U.S. corn exports to livestock feeders in Western Europe accounting for most of the increase. The U.S. share of this large market would increase at the expense of the other major exporters because of greater U.S. productive capacity. The other traditional exporters would likely have less additional productive capacity above and beyond the capacity used under alternative I to commit to the production of added coarse grain for export.

Alternative II's higher import demand levels generate an increase in U.S. grain production to some 349 million tons, or substantially above the 1975 record. U.S. wheat production is projected at 74 million tons, or 85 percent above the base period level and approximately 65 percent above current levels. Increases in production at the rate of the last 5 years, however, would be more than sufficient to raise production to these projected levels. U.S. coarse grain production in 1985 is projected to be 270 million tons, or 18 percent above the level projected under alternative I, 60 percent above base production, and some 55 percent above the 1973/74-1975/76 level. Yield increases combined with marginal expansion in coarse grain area would be more than sufficient, however, to reach this 270-million-ton production level.

REVIEW OF SOME RECENT PROJECTIONS STUDIES

The Food and Agriculture Organization (FAO) of the United Nations and the Economics, Statistics, and Cooperatives Service of USDA both analyze agricultural developments and project their implications over the long term on a regular basis. With less regularity, other organizations and individuals also study world food prospects. This section compares the GOL projections with those of five other recent world food studies. The discussion focuses on grain 3/ rather than meat or other components of the diet because of the key role grains play in the world food balance—particularly in countries where the food problem is most critical. The projected year of comparison is 1985 because it was common to all the studies reviewed.

The present GOL model was developed in the spring and summer of 1974. Aggregate regional results from the GOL model for 1985 were published in an ERS report (124) released in December 1974, with an earlier draft available for the World Food Conference in Rome in 1974. 4/

Major Projections Studies

The five other studies treated in this section appeared in the following order:

The Iowa State University study (1012) was published in 1973 amid considerable concern about the tight world food supply situation. The bulk of the study's analytical work was done in the late 1960's, a period of general concern over surplus disposal rather than tight supplies or food shortages. The first part of the study contains world (based on 96 countries) supply-demand projections. Projections to 1985 and to 2000 were made not only for grains but also for sugar, root crops, pulses, fruits and vegetables, oilcrops, meat, milk, and eggs. On the supply side, alternatives were run with high and low limits on the area of new land that could be developed. On the demand side, alternatives were based on three rates of population growth and two rates of income growth. The study does not estimate the prices required to balance supply and demand either regionally or at the world level. The second part of the study uses the supply and demand projections for grains, with some revisions, as the input for a trade flow model. Additional input to this trade model included fertilizer use, plant capacity for fertilizer production, and transportation costs for grain and fertilizer. These inputs were then used in a linear programming framework to generate trade projections for grains. Nongrain foods were not discussed in the second part of the study.

The University of California study (1074) was issued in the summer of 1974, a period of considerable public concern about the adequacy of future world food supplies. It was based to a large extent on preliminary FAO work and focused on world nutritional problems and their relation to research. The study emphasized the factors likely to influence future production and consumption levels. There is detailed discussion of crop and livestock crop production determinants, including climate, natural resources, energy, environmental quality, nutritional requirements,

---

3/ In the GOL study, grain includes rice. In some studies, the word "cereals" is used when rice is included.

4/ The GOL model was also used to project to the year 2000. These results were presented at a seminar held in Rome (165) and they also appear in (164).

and food technology. However, the quantitative impact, either nationally or internationally, of these and other factors was not treated in depth. The quantitative projections shown in the California Study are largely extrapolations of the FAO projections study published in 1971. Supply and demand balances are computed for the world, for seven continental regions, and for 17 food groups. In addition to the traditional tonnage supply-utilization estimates, the study's projections are converted into caloric and protein equivalents. The role of prices was not defined. One interesting conclusion of the study is that where shortages exist, they are likely to be due to caloric rather than protein shortfalls.

The Food and Agriculture Organization (FAO) study (1072) was prepared in 1973 and 1974 and was designed to provide a framework for discussion of world food problems at the World Food Conference of November 1974. FAO's study was also prepared at a time of serious concern over the overall adequacy of food supplies. Demand projections based on population and income were made for all foods, and for 19 specific food groups; the FAO study also translated 1985 projections into caloric and protein equivalents. Particular emphasis was given to the developing market economies. The projections appearing in the Rome Conference's assessment papers drew heavily on this 1973-74 FAO study as well as on FAO's earlier projections to 1980 published in 1971 (605).

The International Food Policy Research Institute (IFPRI) published a report in February 1976 (1043) which estimated the probable cereals import gap in 1985 in the developing countries, with emphasis on the policy issues involved. The methodology of the study was to project production using historical (1960-74) trend growth rates. Demand was projected for three alternatives—high income growth, low income growth, and as a function of population growth only, assuming a constant 1969-71 per capita consumption. The study does not define either the world conditions associated with alternative grain balances or the effects of various prices and price ratios on the overall level of imports. The IFPRI study contains a brief discussion of the importance of root crops in food supplies and how they might substitute for grain and/or increase the requirements for cereals.

The Organization for Economic Cooperation and Development (OECD) published a study in late 1976 (805). The study analyzes factors affecting production and consumption, and compiles existing projections material. The study, like that of the University of California, is mainly a qualitative rather than a quantitative study; the projections published in the study were drawn largely from the work of other organizations, both governmental and nongovernmental. Projections were made for grains, feeds, meats, and dairy products for selected country groups and regions.

These studies all differ somewhat as to methodology and in the assumptions made. The major differences between these studies and the GOL study are as follows:

(1) The GOL study is the only study that presents projected values directly from a mathematical model. This requires specification of mathematical assumptions as well as the usual policy assumptions.

(2) The GOL model projects both quantities and prices simultaneously. Most other projections studies assume constant prices, the continuation of price trends, or ignore prices entirely.

(3) The GOL model projects grain production, consumption, and stocks in balance at the world level; it is assumed that production policies would be changed, stock management policies adopted, or consumption dampened by high prices in order to keep world grain supply and demand in relative balance.

(4) While the GOL model does not ignore continuation of trends, it depends more on underlying factors affecting demand and supply than do the other studies being compared. Specifically, consumption is projected on the basis of population, income growth, and other demand factors, while projected production levels are affected by the cost and productivity of the input bundle used. Both production and consumption are brought into balance at the world level through prices affecting both production and consumption and in turn being affected by production and consumption.

While the studies vary in methods and assumptions, all use data with reconcilable differences; differences in adjusted projected values can consequently be evaluated in terms of differences in methodology and assumptions or conclusions regarding likely developments in the world food situation.

Comparison of Results

Two conclusions appear to be common to all of the studies referred to above, particularly where the grain sector is concerned:

(1) There exists sufficient capacity at the global level to meet the food needs of an expanding, more affluent world population well beyond 1985, and

(2) Regional food production and consumption distribution problems are likely to persist and in some cases possibly to worsen by 1985.

The Food and Agriculture Organization study, the University of California study, the Iowa State study, and the GOL study all point to world physical capacity sufficient to produce grain in amounts several times greater than likely demand in 1985 or beyond to 2000. While differing somewhat on detail, all four studies point to reserves of idle but potentially arable area that are 100 to 150 percent of the area currently cultivated. All four studies point to large, unused potential in the use and availability of water and other physical inputs, and to the production implications of existing but yet unadopted technology. There is also common agreement, however, that political or organizational and/or institutional constraints are likely to keep food production well below the potential implied in physical capacity.

Most of these projection studies indicate that it is also economically feasible to achieve marked improvements in both the quantity and quality of the world's diet. The production growth rates underlying table 28 for the high growth alternatives indicate that a doubling of world food consumption is quite possible by 1985 and that, if growth rates are extended, a doubling of per capita consumption is possible by 2000.

With regard to the geographic distribution of likely food production increases, all of the studies point to growing deficits in the developing and several of the developed countries, and increased surpluses in the traditional exporting countries.

The projections of increased food deficits of the developed importers receive substantially less attention than do those of the low income countries. West European and Japanese grain import demand is projected to increase substantially by 1985—possibly to more than a third of their annual consumption. The 50 million to 70 million tons of grain forecast to move to these countries would account for as much as 35 to 45 percent of world trade. The projections studies cited above,

81

however, also conclude that income and exchange reserves in these developed importing countries would undoubtedly be high enough in 1985 to finance these larger imports. Both the OECD study and the GOL model also conclude that, given continued strong demand for livestock products, the bulk of this imported grain would be used for feed. Strong import demand in these countries could actually tighten the world market, raise the price paid, and possibly lower the quantities imported by the lower income countries.

As also indicated in table 28, the developing countries' 1985 net grain import requirements are projected to be as high as 113 million tons in the Iowa State University Study and as low as 34 million tons under the GOL model's alternative that assumes accelerated growth in productivity and 37 under the most optimistic scenario of the California Study. More important than the differences in the size of the import requirement, however, are the differences in assumptions underlying the projections. The 113-million-ton gap projected in the Iowa State study was made by calculating imports as the difference between trend production on the supply side, and high population and income growth rates on the demand side. When constrained by price and foreign exchange factors, however, the gap drops to 66 million tons. The FAO and IFPRI studies show gaps from below 20 million tons to about 85 million tons using much the same trend methodology. Both studies assume constant prices, however, and thus do not take into account the rationing effect of likely price increases, both on dampening demand and encouraging production. The California study projects a somewhat lower gap—37-54 million tons—while the OECD study quotes a potential import range of 0 to 100 million tons, depending on income and population variants. For purposes of comparisons, the various GOL alternatives quoted in table 28 show a range of 34 to 99 million tons, depending on the mix of income, resource, and productivity growth rates assumed.

While a breakdown of developing country imports by region is not available in all of the studies, there is general agreement as to the likely concentration of import demand in the more affluent as compared to the poorer of the developing countries. The net grain imports of the higher income countries of the developing world—i.e., the North African/Middle Eastern countries, the more affluent East Asian countries, and several of the Latin American countries, including Venezuela and Brazil—are projected to grow from less than 19 million tons in the 1970 base period to 40-45 million tons in 1985. The imports of the lowest income countries—the South Asian and Central African countries—are projected to grow from 8 million tons in the 1970 base and an average of 11 million tons in 1973-75 to 11-15 million tons in 1985.

Despite their general agreement as to the range of likely import requirements in developing countries and its approximate geographic concentration, the studies differ in tone. The FAO and the IFPRI studies see the widening import gap, and the increased developing country dependence on a few major food exporters as a measure of declining welfare. The GOL study, as well as the OECD study to a lesser extent, sees the likely import gap of 50 to 100 million tons as at least partially a measure of improvement in the developing countries' capacity to supplement indigenous production with foreign production. In this second context, the slower growth in import demand of the lowest income countries of South Asia and Central Africa—given their low projected production growth rates—is more appropriately a measure of declining welfare. In any case, even at the maximum import levels projected under the Iowa and OECD studies, the developing countries as a unit would be only marginally less self-sufficient in 1985 than in 1970. The highest income developing countries of East Asia, North Africa, and the Middle East and areas of Latin American would register declining self-sufficiency, while the lowest income countries of South Asia and Central Africa would experience improved self-sufficiency.

USDA

FAER-146
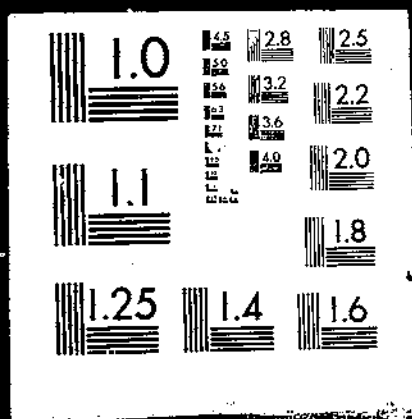
Table 28--Grain projections to 1985, selected comparisons from recent studies

Study	Item	Alternative	Year	World			Developing countries			India			United States		
				Production	Consumption	Net exports	Production	Consumption	Net exports	Production	Consumption	Net exports	Production	Consumption	Net exports
								Million metric tons							
GOL	:Cereals	Base	1969-71	1,064	1,036	1/ 193	279	300	-21	87	41	-3	209	169	40
	:Wheat	"	"	273	267	1/ 87	61	82	-19	21	23	-2	40	22	18
	:Rice	"	"	195	190	1/ 14	114	117	-3	42	43	--	3	1	2
	:Cereals	I	1985	1,570	1,569	1/ 143	432	481	-49	136	141	-5	291	214	76
	:Wheat	I	"				104	145	-41	40	41	-1	58	25	33
	:Rice	I	"				171	174	-3	61	62	-1	5	2	3
	:Cereals	II	"	1,642	1,642	1/ 193	445	516	-71	137	154	-17	349	233	116
	:Cereals	III	"	1,508	1,505	1/ 117	424	465	-41	135	137	-2	228	191	37
	:Cereals	IV	"	1,652	1,649	1/ 167	486	520	-34	154	160	-6	328	237	91
Iowa State	:Cereals 2/	Base	1985	3/ 1,189	3/ 1,145	3/ 44	4/ 369	4/ 482	4/ -113	137	152	-15	332	179	153
	:Cereals 5/	"	"	3/ 1,088	3/ 980	3/ 108	6/ 337	6/ 402	6/ -66	110	113	-3	330	170	84
	:Wheat&rye 5/	"	"	3/ 355	321	3/ 33	66	6/ 105	6/ -39	23	23	-1	83	21	48
	:Rice 5/	"	"	3/ 163	3/ 163	---	6/ 142	6/ 147	6/ -5	57	57	--	3	1	2
FAO	:Cereals	Base	1969-71	1,239	1,207	---	370	386	-16	---	---	---	---	---	---
	:Wheat	"	"	329	331	---	67	87	-20	---	---	---	---	---	---
	:Rice	"	"	302	310	---	168	171	-3	---	---	---	---	---	---
	:Cereals	"	1985	---	1,725	---	853	929	-85	---	---	---	---	---	---
	:Wheat	"	"	570	447	---	121	140	-19	---	---	---	---	---	---
	:Rice	"	"	---	447	---	236	275	-39	---	---	---	---	---	---
California	:Cereals	Base	1970	1,208	1,208	---	617	671	-54	---	---	---	---	---	---
	:Wheat	"	"	318	318	---	97	128	-31	---	---	---	---	---	---
	:Rice	"	"	308	308	---	300	302	-2	---	---	---	---	---	---
	:Cereals	"	1985	1,777	1,777	---	918	955	-37	---	---	---	---	---	---
	:Wheat	"	"	455	447	8	163	174	-11	---	---	---	---	---	---
	:Rice	"	"	444	453	9	433	445	-12	---	---	---	---	---	---
IFPRI	:Cereals	Base	1969-71	---	---	---	---	---	-17	---	---	---	---	---	---
		High	1985	---	---	---	452	534	-83	---	---	---	---	---	---
		Low	1985	---	---	---	452	517	-66	---	---	---	---	---	---
OECD	:Cereals	High	1985	---	---	---	---	---	-100	---	---	---	---	---	---
		Low	1985	---	---	---	---	---	---	---	---	---	---	---	---

-- means less than 0.5 million tons
--- means projections not shown.
1/ Estimated gross exports--shown to indicate trade volume.
2/ Medium population, historical income growth rates, low land bound. Represents potential rather than expected or most likely.
3/ Sum of the 96 countries left out are PRC and many minor countries.
4/ Defined as low-income countries, generally a broader definition than developing market economies.
5/ Projections that resulted from the trade study.
6/ Developing countries.

83

The "Analytical Framework" section of this report refers to the formal mathematical model used to project key economic variables in the grain, oilseed, and livestock sectors of the world's agricultural economy for some future period. The model's mathematical relationships are specified so as to capture the interplay of production, consumption, trade, and prices of grains, oilseeds, and livestock products. The equations appear in a separate volume reporting on the results of this research effort. The economic relationships underlying these equations are presented here.

The "Assumptions" section (see pp. 5 of the present report) discusses the usual assumptions concerning external variables, such as income and population, used to generate the economic variables being projected by a formal mathematical model. Specifying the formal nature of a mathematical model is very similar to specifying the income assumptions. For example, using linear relationships--as has been done-- to represent the interplay of endogenous variables contained in the model does not give the same results as using nonlinear relationships.

The coefficients in the equations quantify the forces assumed to exist between the different variables in the grain-oilseed-livestock sector. However, the theoretical specification for a given variable is obscured by the units of measurement into which the full model is scaled. Therefore, to aid in interpreting the significance of the terms contained in the equations, tables in this section show the demand and supply elasticities, growth rates, input-output rates, and the proportionality factors (expressed in rates and percentages independent of the units of measurement) used in the model.

These tables take the following sequence: (1) Demand elasticities for meat, (2) demand elasticities for dairy products, (3) supply elasticities for meat, (4) supply elasticities for dairy products, (5) factors affecting use of grain as livestock feed, (6) factors affecting use of oilseed meal as livestock feed, (7) demand for grain in nonfeed use, and (8) area and yield elasticities for grain and oilseeds.

The model could not be a product of a direct statistical fit because of its size. The coefficients represented by the elasticities shown in the tables either were synthesized from statistical analyses or were the judgment of experts. Some of the more important work leading to these judgments will be discussed, as will the rationale for developing coefficients for those areas in which direct analyses were not available.

Consumption Levels, Income Response, and Economic Development

Substantial differences exist in consumption patterns among nations. During the 1969-71 base period, meat consumption varied from over 100 kilos in the United States and Australia to less than 10 kilos in some developing countries. Among the developed countries, per capita grain use was 825 kilos in the United States, 422 kilos in the EC-6, 408 in Other Western Europe, and 267 in Japan. In the developing world, per capita usage averaged only 178 kilos.

Knowledge of why these differences exist and future expectations of the differences are important in feed-livestock projections. This study hypothesizes that these differences will gradually diminish, with the low per capita use countries approaching levels of the high per capita use countries, but not necessarily reaching the same high levels or exhibiting identical consumption patterns.

In the present study, the strength of the income response coefficients, while depending on statistical results where feasible, is conditioned by the stage of economic development of a given country or region and by the likelihood of change in food consumption patterns.

Only a few studies have attempted to comprehensively study income response in a coordinated way. FAO has taken leadership in conducting cross section studies, using food surveys from different parts of the world (607) (610). FAO has used these results to build a set of estimated income elasticities for most countries of the world as a basis for its commodity projections work (603) (605). A few other studies involving mathematical models for trade in agricultural commodities also have been based on synthesized, integrated sets of income elasticities (1000) (1010) (1011) (1012) (1015) (1032) (1065) (1068). The income elasticities in the GOL model are also a synthesis of available information.

In general, at low levels of income, food consumption is expected to increase substantially with increases in income, but as income continues to rise the food consumption response weakens. At high levels of income, the added income expended for some food groups may taper off and even become negative. At low levels of income, diets are generally based on a few staple crops. Added income generally translates almost directly to consuming more of the same staples than to diversifying consumption with other products. But as income continues to rise, the income elasticity of grain for food begins to decline as diets become diversified from a cereals base to a wider grain-carbohydrate base and ultimately to a cereals-carbohydrate-livestock product base. A shift may also occur within the grains group, generally in the direction of wheat and rice at the expense of coarse grains. At appreciably higher levels of income, income elasticities for food grains fall off and eventually become negative as staples are replaced by a wide range of higher-price consumer preference products. This shifting pattern of consumption over time can also be viewed as part of a sequence of economic development from a single pastoral economy to a highly integrated, trade-oriented, commercial agricultural economy. An ERS study by Regier (158) demonstrated that income is a good indicator of the overall pattern of food consumption at different stages of economic development.

With respect to demand for grain for food, each stage of development can be observed throughout the world. Most of the developing countries--particularly South Asia, Central Africa, and the poorer parts of East Asia--fall into the category of relatively high, positive income elasticities. Results of studies on India (418), Pakistan (401), the Philippines (425), Bangladesh (401), and other countries (131) (407) (431), while varying somewhat as to statistical bases, indicate that the developing countries have positive income elasticities of demand ranging from .3 to .9 for wheat and rice, and from .2 to .5 for less preferred coarse grains. The income elasticities used in the GOL model for these developing countries fall within these ranges. Many countries in Latin America and the Middle East fall into a second category, characterized by moderately high income elasticities of demand of around .1 to around .3 for wheat, with coarse grains near the bottom of this range (402) (406) (410) (411) (413) (420) (426) (429). Many of the lower income developed countries and the developing exporting countries fall into a third category, categorized by very low, positive or possibly negative income elasticities in the range of +.1 to -.1 (127) (130) (137) (148) (412) (419) (421) (424). On the other hand, in a few of the developed countries, including the United States and some countries in Western Europe, the income elasticities for grains for food tend to be negative (149) (400) (404) (405) (414) (415) (422) (423) (427).

A number of factors, independent of income, can accelerate or decelerate changes in a country's elasticities. A country's present or traditional position as a surplus producer exporting grain or as a deficit producer depending on imported grain is the most obvious of the factors speeding up or slowing down income

elasticity changes. Income elasticities of demand have moved further and faster along the hypothetical function described above in the case of the major exporters, particularly the United States, Canada, and Argentina, in earlier years and Thailand in recent years. The introduction of new grains or the introduction of new grain products can also keep elasticities higher than income levels alone would suggest. Such has been the case with wheat and wheat products in much of East Asia and to a lesser extent with coarse grain and coarse grain food products in parts of the United States and Western Europe.

In the GOL model, the income response to demand for grain for feed is considered differently for countries with fully developed livestock economies than it is for countries which are beginning to develop a livestock sector. In the former, income response coefficients appear explicitly in the meat and dairy product demand functions. Thus, in this case, consumption of feed grains and oilcake is a function of livestock output and the income effects are imputed through the feed input-livestock output ratios discussed below.

Two approaches are used for countries in which a livestock sector is not specified. If the livestock sector is not important, only a demand function for total coarse grains is specified. However, for areas where significant livestock growth is expected, a separate function for coarse grains used for feed is specified with higher income elasticities than those in the grain-for-food equation.

The same studies that provided income elasticities for grains were also useful for estimating income elasticities for meat and dairy products. In addition, econometric studies treating income, price, and other effects jointly were used and are identified below in relation to price elasticities. Income elasticities used in this study vary widely among regions, and within a region they vary among the different meat and dairy products. For the United States, there may still be room for further expansion of meat consumption, but the income effect is expected to taper off with continued income growth. Meat consumption is also at comparably high levels in Australia, a major exporter of beef and mutton, even though income levels are much lower than in the United States. Argentina, a major exporter of beef and mutton, also has high beef consumption levels, even though income levels are much lower than in the United States. For Argentina, the income coefficient is assumed to be .3. The income elasticities used for the EC-3, the EC-6, and Other Western Europe are higher than those used for the United States because of the lower consumption and income levels. Because meat consumption in Japan is still quite low in relation to the income level, the income elasticity exceeds unity. The study assumes that Japan will eventually attain the consumption levels of the United States and that national policy may be an important determinant as to their consumption levels.

Demand-Price Elasticities for Meat

The price-demand elasticities used in the GOL model rely heavily on the econometric studies cited below for the United States, Canada, the United Kingdom, France, Germany, Australia, and Argentina. The analyses in these studies, in general, are based on time series (historical) data, though cross section analysis is used for some countries (notably France, Japan, and the United Kingdom). Summaries of the elasticities obtained from these studies are summarized in Regier (157) and Mielke (147).

The Brandow study (1015) and a demand study by George and King (1032) present tables of direct and cross price elasticities for the mid-1950's and the mid-1960's,

respectively. These interrelated price and income elasticities are subject to certain imposed consistency conditions of homogeneity and symmetry (see Frisch for this study). The direct and cross price elasticities shown in table 29 for the United States reflect these elasticities.

The demand-price elasticities synthesized for the EC-6 are based heavily on demand analysis in studies for Germany by Langen (1051), Stamer and Wolffram (1066), and Plate (1059); for France by CREDOC (404) and INSEE (1028); for both these countries by Kost (142); and for total meat demand for the EC-6 as a whole by Regier (155).

For several years, the United Kingdom has conducted annual household food surveys (1089) and has published demand elasticity measures as a result of this work. Time series analysis has also been done based on the surveys. Ferris, Josling, and others at Michigan State (301) also calculated demand elasticities for the United Kingdom, with somewhat different values for roughly the same time periods. Jones (422) developed a 39x39 matrix of demand elasticities for the United Kingdom. The elasticities used in the GOL model are closer to those reported in the U.K. study.

For Japan, three studies are important. Japan's Ministry of Agriculture has conducted demand analyses based on household budget surveys and has published demand results from both cross sectional and time series analyses (1045). The other two studies are by Filippello. The first study (1026) is an econometric analysis of the feed-livestock sector, while the second (127) uses the statistical results of the first study to determine a consistent matrix of elasticities.

Several country studies, cited elsewhere in this volume, have been useful in determining the demand elasticities for the other countries that have a modeled livestock sector. The more detailed work for the countries discussed above helps to fill the gaps in empirical work, particularly the cross substitution effects among the different meats. Thus, the analysis of demand elasticities for other Western Europe has been modeled after those determined for the EC-6. Canada has been patterned to some extent after the United States.

Australia-New Zealand, Argentina, Brazil, and Mexico-Central America are the other regions in the GOL model containing explicit livestock sectors. Demand-price (direct and cross) elasticities tend to be higher in the countries with the most developed livestock and marketing systems because of the availability of supply and choices open to the consumer.

Demand-Price Elasticities for Dairy Products

The dairy sector has been modeled only for the United States, Canada, the EC-3, the EC-6, Other Western Europe, Japan, and Australia-New Zealand (table 30). Many of the econometric studies cited above also contained price elasticity information for the dairy sector, as they dealt with the whole livestock sector. The Brandow (1015) and George and King (1032) studies estimated a demand matrix for a group of commodities. In addition to the studies cited for Germany, a study by Hesse (1038) was directly concerned with demand elasticities for milk and milk products.

Measuring consumers' price response to fluid milk and milk products has a very long history, mostly because the milk industry was one of the first to be regulated. Recent work by Halberg and Fallert (1034), Prat (1060), Wilson and Thompson (1087), and Boehm and Bobb (1013) confirms earlier studies that the demand for milk is

Table 29--Demand elasticities for meat

Item	Elasticity with respect to price of					Income elasticity
	Beef		Pork	Poultry	Mutton	
	Finished	Other				
United States:						
Beef, finished	-.7	.2	.1			.4
Beef, other	.4	-.8	.1	.1		.3
Pork	.4		-.8	.1		.1
Poultry	.3		.2	-1.0		.8
Mutton						
Canada:						
Beef		-.6	.3	.15		.7
Pork		.4	-.7	.15		.15
Poultry		.3	.2	-.8		.9
Mutton						
EC-6:						
Beef		-.7	.3	.1		.6
Pork		.5	-.8	.12		.5
Poultry		.38	.5	-1.07		1.0
Mutton		.15	.15		-.25	0
EC-3:						
Beef		-.6	.2	.08	-.2	.7
Pork		.18	-.8	.2	.17	.45
Poultry		.3	.3	-.6		1.0
Mutton		.1	.1	.1	-.1	0
Other Western Europe:						
Beef		-.6	.2	.1		.7
Pork		.2	-.7	.2		.6
Poultry		.1	.2	-.8		.9
Mutton		.15	.15		-.25	0
Japan:						
Beef		-1.2	.26	.35		1.2
Pork		.20	-.90	.11		.9
Poultry		.50	.17	-1.10		.6
Mutton		-.4	.2	.3	-.4	.5
Oceania:						
Beef		-.5			.2	0
Pork		.2	-.4			.1
Poultry						
Mutton		.4			-.8	0
Mexico & Central America:						
Beef		-.4	.1			.7
Pork		.1	-.3			.6
Poultry						
Mutton						
Argentina:						
Beef		-.4				.3
Pork		.2	-.4			0
Poultry						
Mutton		.2			-.4	0
Brazil:						
Beef		-.6	.3			.4
Pork		.2	-.6			.4
Poultry						
Mutton						

Table 30--Demand elasticities for dairy products

| Item | Elasticity with respect to price of | | | Income elasticity |
	Milk	Butter	Cheese	
United States:				
Milk, fluid	-.2			-.1
Butter		-.7		
Cheese			-.5	.5
Canada:				
Milk, fluid	-.2			-.1
Butter		-.7		-.3
Cheese			-.5	.6
EC-6:				
Milk, fluid	-.25			.2
Butter		-.7		.2
Cheese			-.6	.5
EC-3:				
Milk, fluid	-.15			.2
Butter		-.5		.2
Cheese			-.6	.3
Other Western Europe:				
Milk, fluid	-.2			.3
Butter		-.5		.3
Cheese			-.6	.6
Japan:				
Milk, fluid	-.7			.95
Butter		-.7		1.0
Cheese			-1.69	1.25
Oceania:				
Milk, fluid	-.2			.1
Butter		-.4		-.1
Cheese			-.3	.5

inelastic. There appears to be a general agreement that the demand-price elasticity is in the neighborhood of -.2 for fluid milk. The values used in the GOL model for all areas except Japan approximate the historical values (table 30). A considerably higher elasticity is used for Japan because of the still low per capita consumption. The demand-price elasticity for cheese ranges between -.5 and -.6 and much higher in Japan for the same reasons cited above. The price elasticity for butter varies from -.4 to -.7. Higher elasticites for butter were used for regions where margarine is substitutable because of availability, as in the United States.

Supply-Price Elasticities for Livestock, Meat, and Dairy Products

A complete study of the supply side of the livestock sector would include the study of factors affecting livestock numbers, slaughter numbers, slaughter weight or yield, and production. It would include a study of cycles, mostly for beef cattle and to a lesser extent for hogs. However, the present study projects only equilibrium values at some future time period and abstracts from cycles and explicit projections of the herd. As presently modeled, supply relations in the GOL livestock sector are based on direct and cross price elasticities for livestock commodities or products, and on a set of supply shift variables which reflect long-term growth factors.

Considerable work on supply response has been done on products competing for some fixed bundle of resources. Most of these studies have been confined to activity analysis. Supply response coefficients derived from such programming models, while very informative, seldom can be used directly in a projections model such as GOL, which essentially is a behavioral model. Results from regression type analyses are more compatible for developing direct and cross supply response coefficients.

While many regression studies appear to report statistically significant results for direct supply-price elasticities, most studies have difficulty in determining the cross price effects. For this reason, the sets of direct and cross supply-price elasticities used for many of the model's regions are based on judgment. Some of these coefficients are tentative and will be improved over time.

Results obtained from regression analyses by Johnson (139) and Regier (155) for the meat sector, and by Halberg and Fallert (1034) for the dairy sector were helpful for assessing the supply response for the United States and the European Community. ERS also conducted feed-livestock studies for Canada (148), Argentina (1037), Australia (130), and New Zealand (105) in the early 1970's that concentrated on the supply side (tables 31-32).

Recent results indicate that the supply response of milk production to milk price still remains relatively low--the supply-price elasticity is in the neighborhood of .2 (see Halberg and Falbert (1034). The GOL model used an elasticity of .15. As expected, the studies of the meat sector also showed that the price-supply response for beef was the lowest, for pork more responsive, and for poultry the most responsive. Major adjustments in beef cattle operations take several years from the time of initial decision compared with major adjustments that can take place within a single year for a poultry operation. The price-supply response appears to be between .3 and .4 for beef, around .6 to .7 for pork, and somewhat higher for poultry.

Feed Demand Equations

The crop and livestock sectors of the GOL model are linked via two sets of feed demand equations--one for grain and one for oilseed meal. Each equation has three components: (1) input-output coefficients defined in physical terms which relate quantities of grain or meal used as feed to quantities of livestock products produced, (2) direct and cross price elasticities which affect feeding rates with changing prices, and (3) long-term growth factors reflecting changes in basic feeding patterns.

90

Table 31 — Supply elasticities for meat

Item	Elasticity with respect to price of						
	Beef	Pork	Poultry	Mutton	Milk	Corn	Oilcake
United States:							
Beef	.3					-.2	-.05
Pork		.5				-.4	-.1
Poultry			.9			-.6	-.2
Mutton							
Canada:							
Beef	.4	-.1				-.2	-.05
Pork	-.2	.6	-.2			-.4	-.1
Poultry	-.1	-.2	.7			-.4	-.2
Mutton							
EC-6:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.3	.7	-.3			-.4	-.2
Poultry	-.2	-.2	.7			-.4	-.3
Mutton	-.15			.3	.15	-.15	
EC-3:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.15	.7	-.15			-.4	-.2
Poultry	-.2	-.2	.7			-.4	-.3
Mutton	-.15			.3	.15	-.15	
Other Western Europe:							
Beef	.4	-.15			.15	-.2	-.1
Pork	-.2	.5	-.2			-.3	-.15
Poultry	-.2	-.2	.6			-.3	-.25
Mutton	-.15			.3	.15	-.15	
Japan:							
Beef	.5	-.1	-.1	.2		-.3	
Pork		.7	-.2		-.15	-.4	-.2
Poultry		-.2	.7			-.4	-.3
Mutton							
Oceania:							
Beef	.4			-.1			
Pork	-.1	.3				-.2	
Poultry							
Mutton				.2			
Mexico & Central America							
Beef	.4	-.1					
Pork	-.1	.3				-.4	
Poultry							
Mutton							
Argentina:							
Beef	.5						
Pork	-.1	.3				-.2	
Poultry							
Mutton				.2			
Brazil:							
Beef	.5						
Pork	-.1	.4				-.3	-.15
Poultry							
Mutton							

Table 32--Supply elasticities for dairy products

Item	Elasticity with respect to price					Elasticity of joint output with beef
	Milk	Butter	Cheese	Corn	Oilcake	
United States:						
Milk, total	.4			-.3	-.2	
Cheese		-.6	.6			
Canada:						
Milk, total	.30			-.40	-.20	
Cheese		-.6	.6			
EC-6:						
Milk, total	.35			-.5	-.3	.5
Cheese			.4			
EC-3:						
Milk, total	.35			-.2	-.1	
Cheese			.4			
Other Western Europe:						
Milk, total	.3			-.35	-.1	
Cheese			.5			
Japan:						
Milk, total	.8			-.25	-.3	
Cheese						
Oceania:						
Milk, total	.4			-.2		
Cheese		-1.0	1.0			

The input-output coefficients computed for the 1969-71 base period reflect full utilization and distribution of grains and oilseed meals among livestock products. Studies by Allen (200), the National Academy of Sciences (500-504), OECD (803-804), and Weightman (505-509) on feed use provided bases for the budgeting process. The input-output coefficients are shown in table 33 for grain and in table 34 for oilseed meal.

Results from regression analyses for the United States by Ahalt and Egbert (103), and Womack (1088) and for the EC-6 by Regier (157) form the basis for estimating price coefficients used in the GOL model. Results of the U.S. and EC-6 studies are similar. For example, in both cases, the demand elasticity for feed grain with respect to grain prices is around -0.4 to -0.5 and about 0.1 with respect to meal prices. Because oilcake forms a much smaller proportion of total feed than grains, the price elasticities for meal with respect to prices of grain and oilcake are much higher.

Expected growth in input-output rates not explicitly accounted for by the first two components discussed above are introduced as an explicit growth factor. For those regions in which feed demand equations are not directly related to livestock production, an income variable is used to reflect growth in demand for livestock products. The income elasticities resemble those associated with direct demand for meat.

Table 33—Factors affecting use of grain as livestock feed

Explanatory factors	United States	Canada	EC-6	EC-3	Other Western Europe	Japan
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished	5.74					
Beef, other	2.02	4.60	1.30	2.27	2.46	2.33
Pork	6.43	6.50	3.60	4.22	4.60	5.09
Poultry	2.76	2.90	2.70	2.70	2.80	2.40
Lamb and mutton	(1.86)		.25	.25		
Milk	.33	.33	.125	.21	.28	.20
Eggs	2.91	3.10	3.10	3.10		2.40
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished	.22					
Beef, other	.03	.25				
Pork	.25	.25	.50	.50	.40	.50
Corn	-.40	-.40	-.50	-.50	-.50	-.60
Oilseed cake	.10	.10	.10	.10	.10	.10
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita						

Explanatory factors	Australia, New Zealand	South Africa	Eastern Europe	Soviet Union	China	Mexico Central America
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other	.30		2.80	3.00		.30
Pork	3.40		4.60	5.00	2.0	3.00
Poultry	3.00		3.00	3.50	1.0	
Lamb and mutton						
Milk	.12		.30	.30		
Eggs	3.00		(3.10)	3.50		
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						.20
Beef, other						-.20
Pork	.30		.25			
Corn	-.30	-.30	-.25			
Oilseed cake						
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita		.25				.10

Continued--

93

Table 33--Factors affecting use of grain as livestock feed --Continued

Explanatory factors	Argentina	Brazil	Venezuela	Other South America	N. Africa-Middle East high	N. Africa-Middle East low
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished	.50	1.50				
Beef, other						
Pork	3.60	3.60				
Poultry						
Lamb and mutton						
Milk						
Eggs						
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork	.30	.30				
Corn	-.30	-.40	-.30	-.40	-.30	-.15
Oilseed cake		.10				
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita	.20	.20	.20	.20	.30	.10

	East Africa	Central Africa	India	Other South Asia	Thailand	Other Southeast Asia
	Kg. grain use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk			(.05)			
Eggs						
	Percentage change in grain use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn	-.30		-.40	-.20	-.1	-.3
Oilseed cake						
	Percentage change in grain use per unit percent income change					
Income elasticity:						
Income per capita	.20	.15	.40	.20	.1	.2
	Grain use as a proportion of commodity supply					
Market shares:						
Commodity supply feed grain			.15			

Continued--

94

Table 33--Factors affecting use of grain as livestock feed--Continued

Explanatory factors	Indonesia	East Asia high	East Asia low	Rest of world
		Kg. grain use per kg. product		
Input-output rates:				
Beef, finished				
Beef, other				
Pork				
Poultry				
Lamb and mutton				
Milk				
Eggs				
		Percentage change in grain use per unit percent price change		
Price elasticities:				
Beef, finished				
Beef, other				
Pork				
Corn	-.30	-.50	-.30	
Oilseed cake				
		Percentage change in grain use per unit percent income change		
Income elasticity:				
Income per capita	.30	.40	.20	
Market shares:				
Commodity supply feed grain				

Table 34--Factors affecting use of oilseed meal as livestock feed

Explanatory factors	United States	Canada	EC-6	EC-3	Other Western Europe	Japan
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished	.25					
Beef, other	.44	.10	.16	.12	.15	.50
Pork	.45	.35	.67	.55	.65	1.40
Poultry	.87	.60	1.18	1.05	1.16	1.20
Lamb and mutton	1.72					
Milk	.033	.03	.033	.025	.028	.08
Eggs	.47	.35	.71	.60		.70
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished	-.10					
Beef, other	.23					
Pork	.27	.90	1.20	1.80	1.00	1.20
Corn	1.00	2.50	.90	1.00	1.20	1.50
Oilseed cake	-.53	-.98	-.25	-.37	-.20	-.30
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita						

	Australia New Zealand	South Africa	Eastern Europe	Soviet Union	China	Mexico Central America
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork			.40	.40	.40	
Poultry			.50	.50	.50	
Lamb and mutton						
Milk			.01	.01		
Eggs			.13	.40		
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn						.20
Oilseed cake	-.30					-.20
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita.						
	Oilmeal use as a proportion of commodity demand					
Market shares:						
Commodity demand feed grain.	.19					.32

Continued--

Table 34--Factors affecting use of oilseed meal as livestock feed--Continued

Explanatory factors	Argentina	Brazil	Venezuela	Other South America	N. Africa-Middle East High	N. Africa-Middle East Low
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk						
Eggs						
	Percentage change in oilmeal use per unit percent price change					
Price elasticites:						
Beef, finished						
Beef, other						
Pork						
Corn						
Oilseed cake	-.50	-.40			-.30	
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita						
	oilmeal use as a proportion of commodity supply					
Market shares:						
Commodity demand feed grain	.047	.064			.21	.30

Explanatory factors	East Africa	Central Africa	India	Other South Asia	Thailand	Other Southeast Asia
	Kg. oilmeal use per kg. product					
Input-output rates:						
Beef, finished						
Beef, other						
Pork						
Poultry						
Lamb and mutton						
Milk			(.10)			
Eggs						
	Percentage change in oilmeal use per unit percent price change					
Price elasticities:						
Beef, finished						
Beef, other						
Pork						
Corn						
Oilseed cake			-.20			
	Percentage change in oilmeal use per unit percent income change					
Income elasticity:						
Income per capita			.10			

Continued--

97

Table 34--Factors affecting use of oilseed meal as livestock feed--Continued

Explanatory factors	Indonesia	East Asia High	East Asia Low	Rest of World
	Kg. oilmeal use per kg. product			
Input-output rates:				
Beef, finished				
Beef, other				
Pork				
Poultry				
Lamb and mutton				
Milk				
Eggs				
	Percentage change in oilmeal use per unit percent price change			
Price elasticities:				
Beef, finished				
Beef, other				
Pork				
Corn				
Oilseed cake	-.20	-.30		
	Percentage change in oilmeal use per unit percent income change			
Income elasticity:				
Income per capita	.30	.30		

98

Demand-Price Elasticities for Grain for Food

Two general tendencies can be identified concerning the demand-price elasticities for grain consumed directly for food. The first is that demand price elasticities tend to be higher in low income countries having primarily cereal diets than in high income countries with more diversified diets. The second tendency is that the demand price elasticity for grain consumed as food is lower than the demand elasticity for grain as feed, both within single countries and across country groupings. These inferences can be drawn from summaries of demand elasticities presented in Rojko, Urban, and Naive (167), Hutchinson (136), Keefer (140), and in a cross section world study by Regier (154) (table 35).

The demand response to price changes in the developing countries is appreciably stronger than in the developed countries. This results at least in part because the budget effect of comparable price changes is greater when incomes are low and a large proportion of the budget is spent on food. Furthermore, in some developing countries, grain accounts for as much as 60-70 percent of total food expenditures. Consequently, the highest price elasticities, or the strongest responses to price changes, would be found in the lower income, less developed, importing countries consuming the bulk of their grain directly as food rather than indirectly as livestock products. South Asia and parts of East Asia fall into this category. In contrast, the more food demand-price inelastic regions—that is, the least food demand-price responsive of the regions treated in the GOL model—include the highest income, grain-feeding, developed exporting countries such as the United States, Canada, and Oceania.

Supply Elasticities for Grains and Oilseeds

The GOL model's grain production functions are basically generated through three sets of equations. The first set is an equation for each region that generates the total area used in grains and oilseeds. The second set of equations generates area used specifically in the production of wheat, coarse grains, rice, and oilseeds. The third set of equations introduces a yield variable to generate production for wheat, coarse grains, rice, and oilseeds. The area equations for the individual crops are constrained by the total area projected from the first set of equations. Area assigned to the individual crops depends on relative prices of these crops and basic long-term shifts that are projected to occur among the crops. The production equation basically reflects both area and yield effects in the projection period. 5/ This is accomplished by incorporating the projected area as a variable in the production equation for combination with yield variables. The production equations also contain variables to reflect changes in production due to yield. These yield factors include relative prices, some trend values reflecting yield growth changes due to changes in technology, and a shift variable to reflect different levels of input activity. For the developed world, input activity is represented by a cost index variable. For the developing world, a physical input use bundle is used as a variable to indicate input intensity. Specifically, different levels of production may be generated by varying this input bundle of resources (table 36).

5/ Ideally, area and yield equations should be generated separately and the estimates from them multiplied to obtain total production. Because our model does not allow for nonlinear relationships, it was essential to achieve equivalent results through use of additive functions.

Table 35--Factors affecting nonfeed use of grains and oilseeds 1/

| Item | Elasticity with respect to price of | | | Income elasticity | Annual demand trend 2/ | |
	Wheat	Rice	Coarse grains		Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
United States:						
Wheat	-.2			.2		
Rice		-.2				
Coarse grains			-.2			
Oilseeds						
Canada:						
Wheat	-.05		.03	-.25		
Rice		-.3		.15		
Coarse grains	.05		-.10	-.3		
Oilseeds						
EC-6:						
Wheat	-.2			-.1		
Rice		-.3		.2		
coarse grains			-.2	.1		
Oilseeds						
EC-3:						
Wheat	-.1			-.03		
Rice		-.3		.2		
Coarse grains			-.15	.05		
Oilseeds						
Other Western Europe:						
Wheat	-.25		.1	-.05		
Rice	.2	-.3		.2		
Coarse grains	.15		-.35	.10		
Oilseeds						
Japan:					50	.99
Wheat	-.45	.2		.2		
Rice	.10	-.15		-.20		
Coarse grains			-.25	.2		
Oilseeds 3/			-.1	.8		
Australia & New Zealand:						
Wheat	-.15			-.25		
Rice		-.1		.1		
Coarse grains			-.15	-.2		
Oilseeds						
South Africa:						
Wheat	-.15		.10	.1		
Rice	.15	(-.3)		.1		
Coarse grains	.03		-.08	-.05		
Oilseeds						
Mexico & Central America:						
Wheat	-.35	.10	.15	.35		
Rice	.2	-.4	.05	.35		
Coarse grains	.05		-.2	.1		
Oilseeds						
Argentina:						
Wheat	-.1		.05	-.1		
Rice	.05	-.2		.15		
Coarse grains	.05		-.1	-.25		
Oilseeds						

See footnotes at end of table.

Continued--

Table 35 --Factors affecting nonfeed use of grains and oilseeds 1/ --Continued

Item	Elasticity with respect to price of			Income elasticity	Annual demand trend 2/	
	Wheat	Rice	Coarse grains		Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
Brazil:						
Wheat	-.25	.10	.10	.25		
Rice	.2	-.2	.02	.15		
Coarse grains	.05	.05	-.15	.1		
Oilseeds						
Venezuela:						
Wheat	-.3	.1	.1	.35		
Rice	.2	-.1		.15		
Coarse grains	.15		-.25	.15		
Oilseeds						
Other South America:						
Wheat	-.25	.1	.15	.3		
Rice	.2	-.2		.35		
Coarse grains	.2		-.35	.15		
Oilseeds						
North Africa/Middle East--High:						
Wheat	-.25	.03	.02	.25		
Rice	.18	-.3	.04	.3		
Coarse grains	.2	.1	-.2	.15		
Oilseeds						
North Africa/Middle East--Low:						
Wheat	-.35	.15	.10	.05		
Rice	.15	-.25	.10	.2		
Coarse grains	.15	.1	-.25	.1		
Oilseeds						
East Africa:						
Wheat	-.3	.05	.15	.35	20	3.54
Rice	.1	-.25	.15	.3		
Coarse grains	.02	.01	-.05	.:		
Oilseeds						
Central Africa:						
Wheat						
Rice		-.2		.1		
Coarse grains						
Oilseeds						
India:						
Wheat	-.4	.15	.1	.7		
Rice	.1	-.4	.01	.7		
Coarse grains	.1	.10	-.35	.2	-210	-.86
Oilseeds						
Other South Asia:						
Wheat	-.4	.25	.01	.4		
Rice	.2	-.30	.03	.4		
Coarse grains	.15	.2	-.20	.2		
Oilseeds						
Thailand:						
Wheat	-.05	.2		.2		
Rice		-.05	.01	.1		
Coarse grains		.2	-.1	.2		
Oilseeds						

Continued--

\See footnotes at end of table.

Table 35--Factors affecting nonfeed use of grains and oilseeds 1/--Continued

| Item | Elasticity with respect to price of | | | Income elasticity | Annual demand trend 2/ | |
	Wheat	Rice	Coarse grains		Quantity	Percent of 1969-71 base
					1,000 metric tons	Percent
Other Southeast Asia:						
Wheat	-.1	.15		.2		
Rice	.01	-.05		.1		
Coarse grains				.15		
Oilseeds						
Indonesia:						
Wheat	-.6	1.0	.4	.55	5	.94
Rice	.04	-.25	.03	.45		
Coarse grains	.03	.3	-.3	.3	50	2.09
Oilseeds						
East Asia--High:						
Wheat	-.3	.2	.04	.10		
Rice	.15	-.3	.05	.05		
Coarse grains	.1	.2	-.3	.05		
Oilseeds						
East Asia--Low:						
Wheat	(-.35)	(.15)	.2	.35		
Rice	(.05)	(-.22)	.05	.2		
Coarse grains	(.05)	(.15)	-.25	.2		
Oilseeds						

1/ Including food use of soybeans in the case of Japan. The use of parentheses in the table indicates trade prices; the absence of parentheses indicates demand prices.

2/ Trend in demand independent of any price effect.

3/ The coefficient shown in the coarse grain column is an elasticity with respect to the price of soybeans.

Table 36--Factors affecting the supply of grains and oilseeds 1/

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
United States:								
Wheat	(2.5)		(-1.84)	(-.69)	(.05)			
Rice		(.8)				(.10)		
Coarse grains	(-.83)		(2.3)	(-1.00)			(.10)	
Oilseeds	(-.78)		(-3.60)	(3.25)				(.02)
Canada:								
Wheat	.5		-.40	-.15	.15			
Rice							.15	
Coarse grains	-.55		.55	-.15				
Oilseeds	-.16		-.24	1.0				.20
EC-6:								
Wheat	.7		-.70		.25			
Rice		.20				.20		
Coarse grains	-.61		.61				.30	
Oilseeds								
EC-3:								
Wheat	.65		-.55		.2			
Rice							.2	
Coarse grains	-.161		.147					
Oilseeds								.02
Other Western Europe:								
Wheat	.25		-.25		.25			
Rice		.15				.15		
Coarse grains	-.185		.185	.10			.30	
Oilseeds				.10				.10
Japan:								
Wheat					.30			
Rice		.012		-.02		.15		
Coarse grains							.25	
Oilseeds		-.2		.28				.15
Australia & New Zealand:								
Wheat	.4		-.35		.15			
Rice		.10				.1		
Coarse grains	-.75		.66				.15	
Oilseeds				.30				.15
South Africa:								
Wheat	.30				.25			
Rice								
Coarse grains			(.30)	(-.3)			(.30)	
Oilseeds								(.10)
Mexico & Central America:								
Wheat	.45		-.25	-.07	.20			
Rice		.15				.10		
Coarse grains	-.02		.04	-.02			.07	
Oilseeds	-.28		-.46	.50				.05
Argentina:								
Wheat	.4		-.31		.10			
Rice		.25				.30		
Coarse grains	-.21		.3	-.15			.15	
Oilseeds	-.15		-.30	.45				.10

See footnote at end of table.

Continued--

103

Table 36--Factors affecting the supply of grains and oilseeds 1/ --Continued

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
Brazil:								
Wheat	.7		-.70		.05			
Rice		.2	-.10			.10		
Coarse grains	-.12		.3	-.20			.08	
Oilseeds			-1.10	1.6				.05
Venezuela:								
Wheat								
Rice		.50	-.756			.15		
Coarse grains		-.10	.15				.15	
Oilseeds								
Other South America:								
Wheat	.2		-.05		.10			
Rice		.15	.07			.15		
Coarse grains	-.10		.05	-.03			.05	
Oilseeds			-.08	.20				.10
North Africa/Middle East-- High:								
Wheat	.1	-.03	-.03		.05			
Rice	-.20	.50				.15		
Coarse grains	-.25		.09				.05	
Oilseeds								
North Africa/Middle East--Low:								
Wheat	.15		-.06		.10			
Rice	-.02	(.30)				(.20)		
Coarse grains	-.20		.07				.05	
Oilseeds								
East Africa:								
Wheat	.10				.05			
Rice		.20				.15		
Coarse grains			.15				.10	
Oilseeds								
Central Africa								
Wheat								
Rice						.20		
Coarse grains								
Oilseeds								
India:								
Wheat	.30	-.20	-.11		.08			
Rice	-.05	.25	-.10			.07		
Coarse grains	-.05	-.10	.17	-.062			.04	
Oilseeds	-.055	-.09	-.12	.20				.15
Other South Asia:								
Wheat	.1	-.05	-.02		.05			
Rice	-.015	.025				.03		
Coarse grains	-.25		.07				.02	
Oilseeds								
Thailand:								
Wheat								
Rice		.05				.10		
Coarse grains			.1				.10	
Oilseeds								

See footnote at end of table.   Continued--

Table 36—Factors affecting the supply of grains and oilseeds 1/ --Continued

Item	Area elasticity with respect to price of				Yield elasticity with respect to price of			
	Wheat	Rice	Coarse grains	Oilseeds	Wheat	Rice	Coarse grains	Oilseeds
Other Southeast Asia:								
Wheat					.10			
Rice		.10				(.20)		
Coarse grains								
Oilseeds								
Indonesia:								
Wheat					.10			
Rice		.2	-.03			.05		
Coarse grains			.14	-.10				.02
Oilseeds			-.15	.30				
East Asia—High								
Wheat	.25	-.20			.20			
Rice	-.02	.19	-.10	-.01		.15		
Coarse grains		-.25	.3	-.10			.20	
Oilseeds		-.26	-.19	.25				.02
East Asia—Low								
Wheat					.08			
Rice		.06	-.06			.05		
Coarse grains		-.10	.1					(.03)
Oilseeds								

1/ The use of parentheses in the table indicates trade prices; the absence of parentheses indicates supply prices.

105

The elasticities used in the equations are shown in table 36 and were derived from published and unpublished USDA studies or from studies outside the USDA. Only three studies are cited here because each contains summaries of supply response studies. These studies are by Rojko, Urban, and Naive (167), FAO (607), and Behrman (1008).

While the assumption that production in the developed countries is price responsive is generally unchallenged, some question might be raised as to the applicability of price analysis in the study of developing countries. The GOL model assumes that farmers in the developing countries respond much the same as do farmers in the developed countries—positively to price increases and negatively to price decreases. However, studies indicate a weaker response in the developing countries when the total agricultural sector is analysed rather than the smaller, commercialized market subsector. This dampened responsiveness is largely due to physical and institutional constraints on production as well as to constraints on the distribution of surplus production in isolated, near-subsistence regions.

The supply elasticities used in the GOL model for both the developed and developing countries reflect the full effect of a price change on production adjustment over a number of successive years. In short they might be considered long-term elasticities.

Area Elasticities

Land use patterns are affected by changes in multiple-cropping cultivation or previously uncultivated area, or through displacement of other crops. A number of other physical factors affect a region's area-price responsiveness. Climate and soil constraints as well as limited supplies of arable land or multiple-cropping potential tend to dampen area responsiveness. Nonphysical factors such as rural institutions, agricultural infrastructure, and the degree to which an agricultural sector has been commercialized also affect a producer's responsiveness. While the above factors probably apply more to the developing countries, the overriding factor in the developed countries may be agricultural programs, particularly in periods of heavy supply.

Extreme caution should be used in interpreting area elasticities presented in table 36. These elasticities represent both the usual or traditional individual producer response to economic stimuli and the aggregate response to government programs. In addition, the area elasticities shown include the cumulative effects of both the total area and individual crop equations.

Under alternative I, very high area-price elasticities are used for the major grain exporters to reflect government programs that result in lower acreages when supply appears to be growing faster than demand. On the other hand, under alternative II, the area-price elasticities for these exporters are considerably reduced as pressure is applied against the base of readily available land and expansion of area requires considerably higher costs. These area coefficients reflect government programs when land is not fully utilized but approach traditional producer's price response as prices go above support levels.

The somewhat higher than expected area elasticities for the EC-6 and EC-3 of .6 to .7 reflect the ease of substitution of one grain crop for another as relative prices change. However, the total area response of .1 is quite low, indicating that there is little room for expansion of total area in the EC-6 or EC-3.

Lower elasticities were used for the other resource-tight developed importing countries (for instance, Japan) and for the developing countries with large

106

subsistence sectors or large reserves of arable land but fixed, traditional land usage patterns (such as Central and East Africa).

The lowest direct area elasticities—+.05 to +.10—were used for land-short, largely subsistence farming regions, such as India and Other South Asia. Indirect or cross elasticities were found to be more closely related to the degree of commercialization and the number of competing crops. The more subsistence-oriented farmers were found to be less able or willing to move out of a particular staple grain crop, to break with traditional patterns of cultivation, or to change crop rotation.

Yield-Price Elasticities

Expanding production in the decades ahead is likely to depend on growth in yields rather than growth in area. Yield responses to price changes within a single decade are likely to be largely related to increased use of fertilizer. Increases in yield within a single decade from increases in other yield-augmenting inputs such as an increase in irrigation facilities will be limited. Changes in yield in response to price changes over the longer term of several decades depends on the degree that yield-augmenting inputs can be changed. Costly, long-term investments in agricultural infrastructure necessary if high productivity inputs are to be used effectively are not easily speeded up or slowed down in response to price changes. Also, improvements in technology—perhaps the single most important source of growth in yields—often take place irrespective of price changes: the effect of these technological improvements on reducing costs may actually raise net farm returns even as product prices are falling.

The yield-price elasticities used in the GOL model reflect increased use of fertilizer, with limited changes in the total bundle of other inputs. Thus, yield elasticities appear to be positively correlated with existing levels of yields and past yield growth rates. The highest elasticities were found in those regions with grain yields in excess of 2.5 tons per hectare and with trend growth in yield in excess of 2.0 percent per year. Elasticities appear to be directly related to a region's agricultural infrastructure and its level of agricultural technology as reflected in machinery use (e.g., mechanized plowing, planting, harvesting, and processing), use of chemical inputs (e.g., chemical fertilization and application of pesticides), and use of improved seeds (e.g., hybrid, high-yielding, dwarf, or short stock varieties). Also crucial in regions with higher elasticities were improved managerial practices and availability of inputs. Few if any of the more price responsive regions had sizable subsistence sectors.

Consequently, the highest elasticities—+.1 to +.25—were used in the technologically advanced, heavily commercialized regions using large amounts of high productivity inputs and making heavy capital investments in agricultural infrastructure. Among these regions were most of the developed countries, including both the exporters and the importers. The developed importers (i.e., the EC-9, Other Western Europe, Japan) were found to have higher yield elasticities than the exporters (e.g., the United States, Canada, Oceania) because of tighter constraints on the importers supply of arable or potentially arable land.

The lowest elasticities—+.01 to +.10—were found in the largely subsistence, low technology regions of the developing countries. Elasticities were low in the developing countries well endowed with arable land; elasticities were also low, however, in the subsistence, low technology areas of South Asia faced with severe arable area constraints. In a limited number of land-short, partially developed countries, including the high income East Asian countries, elasticities were found to be appreciably higher than in the rest of the developing countries and, in a few cases, comparable to levels reported in land-extensive developed exporting countries.

107

CONTRIBUTIONS TO ANALYSIS OF WORLD FOOD PROBLEMS

This chapter summarizes the principal sources—both published and unpublished—that went into development of the GOL model and its use for delineating world food and agriculture in 1985. Background is also presented for the reader interested in technical development of the model. Researchers interested in aspects of the world food economy will also find this a guide to some basic sources.

Organizations

A number of organizations—public and private, domestic and foreign, national and international—are interested in world food problems and agricultural commodity projections. Two with ongoing research and analysis of long-term aspects of food and agriculture are the Economics, Statistics and Cooperatives Service (ESCS) of the U.S. Department of Agriculture (USDA), and the Food and Agriculture Organization of the United Nations (FAO). These two institutions have also been the primary publishers of formal projections studies; these published studies are discussed in the next section.

Over the years, ERS [6] has conducted agricultural commodity analysis and projections, on both a U.S. and international basis, and has contributed to an expanding literature on aspects of the world food problem.

The Foreign Agricultural Service (FAS) and the Science and Education Administration (SEA), two other USDA agencies, share with ESCS a responsibility for analysis of the world food problem. FAS implements U.S. agricultural policy abroad and collects agricultural data from foreign countries. SEA is concerned with technological aspects of U.S. and world food production. Inevitably, these agencies become involved with the social and economic implications of their work.

FAO is concerned with comprehensive data development, analysis, and policy formulation for world agriculture, and with ongoing appraisal of the world food problem. Much of the best analytical work of FAO, useful to development of the GOL model, is that of the Committee on Commodity Problems, an advisory body composed of national member governments charged with reviewing FAO's commodity analysis.

In addition to the USDA and FAO, numerous organizations share serious concern for world food and agriculture. Other U.S. cabinet departments are heavily involved in aspects of world food and agricultural conditions. Monetary and financial considerations involve the U.S. Department of the Treasury. Trade and commerce involve the U.S. Department of Commerce and the International Trade Commission. Negotiation with foreign governments brings in the U.S. Department of State. The U.S. Agency for International Development provides financial resources and technology assistance to countries with problems of production and marketing of food and agricultural commodities. Its role is policy implementation rather than research and analysis per se. The White House itself calls for policy evaluation from time to time in this general area.

---

[6] As of January 1, 1978, the Economic Research Service (ERS), Statistical Reporting Service (SRS), and Farmer Cooperative Service (FCS) were merged into the Economics, Statistics, and Cooperatives Service (ESCS). Hence, for the purpose of this report the terms ERS and ESCS are interchangeable.

A number of institutions in the Washington, D.C., area have a continuing concern for orientation of U.S. Government policy regarding food and agriculture. In recent years, this interest has converged on the world food problem. The National Science Foundation is concerned with scientific and technological research priorities and their policy implications. The National Institute of Health is concerned with implications of food scarcity or abundance for health problems related to famine or disease. The Brookings Institution and Resources for the Future have a concern for orientation of U.S. Governmental policy given the materialization of one or another set of circumstances in the future.

In addition to FAO, the United Nations organization includes a number of international agencies and regional organizations concerned with problems related to world food. Many of them bring their analyses to bear through the FAO. Perhaps equally as important are regional commissions--for instance, the Economic Commission for Europe, Economic Commission for Latin America, Economic and Social Commission for Asia and the Pacific, Economic Commission for Africa, and Economic Commission for Western Asia. The U.N. Conference on Trade and Development (UNCTAD) provides a forum for the developing countries to focus their concerns about their problems related to trade, commodities, and economic development.

As a U.N. specialized agency, the recently created World Food Council, was given authority, upon recommendation by the World Food Conference held at Rome in November 1974, to coordinate intergovernmental policy regarding food, and to review problems and policy issues to achieve an integrated approach to a solution.

Efforts of the World Bank, the FAO, and the U.N. Development Program to help solve the world food problem are being coordinated by two consultative groups--the Consultative Group on International Agricultural Research, and the Consultative Group on Food Production and Investment. Other such groups are under consideration.

In the background of these consultative groups and the World Food Council are the major private sector research entities, such as the Ford Foundation, Rockefeller Foundation, and others, together with research institutes sponsored and financed by them. Included here are Hudson Institute, Aspen Institute, World Watch Institute, and the International Food Policy Research Institute (IFPRI). IFPRI was established to analyze the policies of governments as they bear on problems of food supplies, resources, and prices affecting the food situation and future prospects in the developing world. A similar organization is the International Institute of Applied Systems Analysis (IIASA-Austria).

Situated in Europe, the Organization for Economic Cooperation and Development (OECD) is essentially an agency of the developed countries which endeavors to coordinate economic activity in the interest of smooth functioning of the monetary, financial, and commercial mechanism of the world. It also has a role in coordinating developed country policy with regard to agriculture and food, and has produced important analytical work. The OECD is an important source of international data.

The EC Commission and the Statistical Office of the European Communities have also contributed to analysis of the world food problem. Much of the effective energy of the EC, however, has been focused recently on the dynamics of European aspects of the food problem and on the intricate problems of economic harmonization of the nine member countries.

Projection Studies

This section focuses on projection studies of world food and agricultural commodities.

In recent years, ERS has presented such studies as the following: World Food Budget 1970, prepared under the direction of Quentin M. West (121) and published in 1964, and based on Food Balances for the world by region (202-206), which appeared in 1964 and 1965; World Food Situation by Abel and Rojko (100) in 1967; World Demand Prospects for Grain in 1980 by Rojko, Urban, and Naive (167) in 1971; The World Food Situation and Prospects to 1985 in 1974 (124); and Organizing Agriculture in the Year 2000 by Rojko and O'Brien (164-165) in 1976 and 1977. Numerous studies of individual countries and regions have also been published, in a number of commodity and other reports, namely situation and outlook reports and projection studies of the United States 7/.

The GOL Model discussed in this report is a further development of work previously published by ERS in 1971 under the title World Demand Prospects for Grain in 1980 (167). That report contains a description of the mathematical model used to project world demand, supply, and trade in grain, with emphasis on trade impacts on developing countries. The 1971 model underlies another study entitled World Demand Prospects for Wheat in 1980 and also published in 1970 (136). Also in the same series, but using a different model, is World Supply and Demand Prospects for Oilseeds and Oilseed Products in 1980, published in 1971 (150). The 1971 mathematical grain model also drew partly on another ERS study, Growth in World Demand for Feed Grains published in 1970 (158). Based on the above works, the model was expanded and reworked to produce the world GOL model. The feed grain study explored some aspects of the interface between the grain and livestock sectors. These studies are important in that they develop projections for the world in such a way that commodity prices can vary so as to produce a calculated equilibrium for each commodity with world exports equal to world imports. The purpose has been to develop a set of cross-linked commodity models which are sensitive to price changes, and which in a sense are estimators of prices, to project a limited number of highly important and interrelated commodity complexes. The World Food Situation and Prospects to 1985 (124) and Organizing Agriculture in the Year 2000 (164-165) are applications of the GOL model. In 1973, FAS coordinated a policy analysis within the USDA entitled Agricultural Trade and the Proposed Round of Multilateral Negotiations (172), which was prepared at the request of Peter Flanigan, then Assistant to the President for International Economic Affairs.

Prominent among policy evaluations called for by the White House is The World Food Problem (1080-1081), a 1967 Report of the President's Science Advisory Committee. Also published in the same year is Food and Fiber for the Future (1079), a Report of the National Advisory Commission on Food and Fiber. Also falling into this category are the 1977 National Academy of Sciences' World Food and Nutrition Study (1078), looking into future research priorities on food problems, and the 1975 Agricultural Research Policy Advisory Committee report, Research to Meet U.S. and World Food Needs (102).

With each separate commodity a major national concern for some member country, part of the FAO commodity projection program is to project a detailed balance of each country's supply and domestic utilization of each agricultural or food commodity and to sum these balances to the world level. Over the years, FAO has made several important contributions to the literature of long-term analysis and projection: Agricultural Commodities: Projections for 1975 and 1985 (603), a two-volume study in 1967; Agricultural Commodity Projections 1970-1980 (605), also in two volumes in 1971. The mass of data contained in these volumes makes them

---

7/ Citations are limited in this section to comprehensive studies that analyzed the major countries and regions of the model in a world context. The ERS projections program, both historical and current, is discussed by Porter (152) and Quance (153) respectively. Projections to 1985 for the United States are given by Smith (168).

110

indispensable for serious quantified analysis of world food problems. The OECD study Agricultural Projections for 1975 and 1985 (801-802) summarizes detailed projections for the developed countries, which were prepared for FAO and contributed to FAO's own projections in the 1971 study. FAO prepared for the November 1974 U.N. World Food Conference in Rome an Assessment of the World Food Situation, Present and Future (1072-1073). Another major FAO projections study is Provisional Indicative World Plan for Agricultural Development (604), published in 1969.

The 1976 OECD Study of Trends in World Supply and Demand of Major Agricultural Commodities (807) shows continuing interest of member governments in the field of projections.

The literature on the world food problem being generated by the major universities of the United States is too large to treat adequately here. It can only be suggested by citing the work done at Iowa State University by Earl Heady and associates in World Food Production, Demand and Trade (1012); at University of California in A Hungry World: The Challenge to Agriculture (1074) in 1974; and by D. Gale Johnson of the University of Chicago, in World Food Problems and Prospects, dated 1975 (1046); and by mentioning work being done at such schools as Illinois, Minnesota, Wisconsin, Kansas State, Michigan State, North Carolina State, Stanford, and the Massachusetts Institute of Technology.

A European association of agricultural projection economists, ASEPELT, is producing a growing literature, exemplified by Europe's Future Food and Agriculture (1002). Numerous foreign universities around the world have become active in the analysis of food and agricultural problems.

While not directly involved in making projections, several studies concerned with longrun policy implications do make use of other 1976 projections or make their own. In this category fall the 1976 IFPRI study on Meeting Food Needs in the Developing World (1043); Fred Sanderson's study on world agriculture with emphasis on reassessment of trends and policies and Crosson and Frederick's The World Food Situation: Resources and Environmental Issues (1020).

Informal groups such as the Club of Rome have also entered the field of quantifying and projecting putative implications of population, food, ecological, and environmental considerations. This group has published such works as: The Limits to Growth (1055); Towards Global Equilibrium (1054); Dynamics of Growth in a Finite World (1053); and Mankind at the Turning Point (1056).

Finally, there are highly motivated individuals, such as Lester Brown. His contributions to the growing literature on world food problems include: Seeds of Change (1016); and By Bread Alone (1017).

Methodology

The world GOL model builds upon an expanding literature on the mathematical aspects of estimating structural economic relationships, addressing the problems of international agricultural economics, and using computer procedures and automatic data processing in large models to gain insight into the solution of these problems. The methodological emphasis in the GOL model was on parameter estimation and handling solutions of equation systems. Previous sections discussed parameter estimation. This section concentrates on solutions of large systems.

Leon Walras in 19th century Switzerland (1085) made significant contributions to the analysis of large equation systems in the context of pure economic theory.

However, it was the development of the computer during World War II that made practical the development of solutions of such systems, the inversion of large coefficient matrices, and the development of matrices of demand elasticities where formerly single coefficients were made to serve.

Leonid Hurwicz, Kenneth Arrow, George Dantzig, Paul A. Samuelson, and others have pioneered the mathematics of solution methods for large equation systems to be handled by computers. Working principally at the U.S. Departments of Defense and Commerce, at the Rand Corporation, and at various universities, they and their students have developed linear programming, quadratic programming, activity analysis, nonlinear programming, separable programming, or just simply mathematical programming.

Some of the earliest applications of these methods to agricultural economics occurred in the field of spatial economics. At Iowa State, Earl Heady and associates conducted a number of studies in this area, notably Regional Changes in Grain Production: An Application of Spatial Linear Programming (1022).

At the University of Illinois, George C. Judge and Takashi Takayama constitute another team of methodology developers. A classical series of journal articles by Takayama and Judge which broke new methodological ground include "Equilibrium Among Spatially Separated Markets: A Reformulation" (1070); "International Trade and Mathematical Programming" (1067); and "An Intertemporal Prize Equilibrium Model" (1069). Recently, Takayama extended his efforts to agricultural trade models, publishing in 1976 Projection and Evaluation of Trends and Policies in Agricultural Commodity Supply, Demand, International Trade and Food Reserves (1068).

At the University of Wisconsin, Lee D. Bawden has also made his contribution: "An Evaluation of Alternative Spatial Models" (1006); and "A Spatial Price Equilibrium Model of International Trade" (1007).

At the University of Minnesota, James P. Houck is central to a group of large-model analysts of the world commodity economy. Soybeans and Their Products: Markets, Models, and Policy by Houck, Mary E. Ryan, and Abraham Subotnik (1041) is representative of their work.

The Secretariats of FAO and UNCTAD have also been working on theoretical aspects of large-model computer methods for analysis of problems of world food, agriculture, and trade. Some of this work has been presented under the names of developers of the models: Hans Alm, Jack Duloy, and Odd Gullbrandsen, Agricultural Prices and the World Food Economy (1000), for instance. FAO is continuing work in the direction of price-quantity interacting projection models of agricultural commodities.

Connected with large systems of equations is the problem of evaluation of consistency of equation parameters, particularly since many effects cannot be directly fitted statistically. A method of calculating demand interrelationships for many commodities as functions of all prices and income was published by Ragnar Frisch in 1959 (1030). Waugh also was concerned with these consistencies and assumptions, particularly from the price flexibility viewpoint (177).

This method served as the basis for estimates of demand for agricultural commodities which were published in 1961. Working with U.S. data and applying Frisch's assumptions, George E. Brandow (1015) derived matrices of demand elasticities (both price and income) for 24 categories of food, plus all food and nonfood.

Brandow's estimates have been reinforced by the work of George and King (1032) at the Giannini Foundation and the California Agricultural Experiment Station.

REFERENCES

I. Prepared by the U.S. Department of Agriculture: Analytical Studies (100-199)

II. Prepared by the U.S. Department of Agriculture: Data Sources (200-299)

III. Prepared for the U.S. Department of Agriculture: Studies of Effects of Economic Integration on Agriculture (300-399)

IV. Prepared for the U.S. Department of Agriculture: Studies of Agricultural Supply and Demand (400-499)

V. Prepared for the U.S. Department of Agriculture: Technical Studies of Livestock Feeding (500-599)

VI. Prepared by the Food and Agriculture Organization: Analytical Studies (600-699)

VII. Prepared by the Food and Agriculture Organization: Data Sources (700-799)

VIII. Prepared by the Organization for Economic Cooperation and Development: Analytical Studies (800-899)

IX. Prepared by the Organization for Economic Cooperation and Development: Data Sources (900-999)

X. Studies Prepared by and for Other Sponsors (1000-1099)

XI. Weather Literature Citations (1100-1199)

I   Prepared by the U.S. Department of Agriculture:
         Analytical Studies

(100) Abel, Martin E., and Anthony S. Rojko
          1967. World Food Situation. U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr.
          Econ. Rpt. 35. August.

(101) Abel, Martin E. and Frederick V. Waugh
          1966. Measuring Changes in International Trade. Jour of Farm Econ. Vol.
          48. November.

(102) Agricultural Research Policy Advisory Committee
          1975. Research to Meet U.S. and World Food Needs: Report of a Working
          Conference. 2 Vols. ARPAC. Kansas City, Missouri. July 9-11.

(103) Ahalt, J. Dawson, and Alvin C. Egbert
          1965. Demand for Feed Concentrates: A Statistical Analysis. Agr. Econ.
          Res. Vol. 17. April.

(102) Bailey, W.R., F.A. Kutish, and A.S. Rojko
          1974. Grain Stocks Issues and Alternatives: A Progress Report. U.S. Dept.
          Agr. Econ. Res. Serv. Agr. Econ. Rpt. February.

(105) Barry, Robert
          1974. New Zealand: Growth Potential of the Beef and Dairy Industries.
          Econ. Res. Serv. U.S. Dept. Agr. Foreign Agr. Econ. Rept. 97.
          October.

(106) Barse, Joseph R.
          1969. Japan's Food Demand and 1985 Grain Import Prospects. U.S. Dept. Agr.
          Econ. Res. Serv. Foreign Agr. Econ. Rpt. 53. June.

(107) Berntson, B.L., O.H. Goolsby, and C.O. Nohre
          1969. European Community's Common Agricultural Policy. Econ. Res. Serv.
          U.S. Dept. Agr. Foreign Agr. Econ. Rpt. 55.

(108) Boutwell, Wayne, et al
          1976. Comprehensive Forecasting and Projections Models in the Economic
          Research Service. Agr. Econ. Res. Vol. 28, No. 2. pp. 41-51.

(109) Brown, Lester R.
          1963. Man Land and Food: Looking Ahead at World Food Needs. Econ. Res.
          Serv. U.S. Dept. Agr. Foreign Agr. Econ. Rept. 11. November.

(110) Christensen, Raymond P.
          1968. Taiwan's Agricultural Development: Its Relevance for Developing
          Countries Today. Econ. Res. Serv. U.S. Dept. Agr. Foreign Agr.
          Econ. Rpt. 39. April.

(111) _____
          1970. Economic Progress of Agriculture in Developing Nations, 1950-1968.
          U.S. Department of Agriculture, Foreign Agricultural Economic Report
          No. 59.

(112) Collins, H. Christine
          1975. The Feed-Livestock Economy of Poland: Prospects to 1980, U.S. Dept.
          Agr. Econ. Res. Serv., For. Agr. Econ. Rpt. No. 99, Wash., D.C.

114

(113) Crom, Richard J.
      1970. Dynamic Price-Output Model of the Beef and Pork Sectors. Econ. Res. Serv. U.S. Dept. Agr. Tecn. Bul. 1426. September.

(114) _____
      1972. Economic Projections Using a Behavioral Model. Agricultural Economics Research. Vol. 24, No. 1. pp. 9-15. January.

(115) Dalrymple, Dana C.
      1969. Technological Change in Agriculture: Effects and Implications for the Developing Nations. Foreign Agr. Serv. U.S. Dept. Agr. and U.S. Agency for International Dev. April.

(116) _____
      1971. Imports and Plantings of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations. Foreign Econ. Dev. Serv. U.S. Dept. Agr. and U.S. Agency for International Dev. Foreign Econ. Dev. Rpt. 8. January.

(117) _____
      1971. Survey of Multiple Cropping in Less Developed Nations. Foreign Econ. Dev. Serv. U.S. Dept. Agr. and U.S. Agency for International Dev. Foreign Econ. Dev. Rpt. 12. October.

(118) _____
      1974. Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Countries. U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 95.

(119) _____
      1975. Measuring the Green Revolution: The Impact of Research on Wheat and Rice Production. U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 106.

(120) Duymovic, Andrew, Richard Crom and James Sullivan
      1972. Effects of Alternative Beef Import Policies on the Beef and Pork Sectors. Econ. Res. Serv. U.S. Dept. Agr. Agr. Econ. Rpt. 233. October.

(121) Economic Research Service
      1964. World Food Budget 1970. U.S. Dept. Agr. Foreign Agr. Econ. Rpt. 19. October.

(122) _____
      1965. Changes in Agriculture in 26 Developing Nations 1948 to 1963. U.S. Dept. Agr. Foreign Agr. Econ. Rpt. 27. November.

(123) _____
      1970. Livestock and Feed Survey of Selected Countries: Literature Review and Compendium of Data. U.S. Dept. Agr. Unpublished manuscripts. 9 Vols. prepared as follows:

        Vol. 1. Belgium-Luxembourg   by Donald M. Phillips
        Vol. 2. Netherlands   by Donald M. Phillips
        Vol. 3. France   by W. Scott Steele
        Vol. 4. Germany   by Donald W. Regier
        Vol. 5. Italy   by Hans G. Hirsch
        Vol. 6. Denmark   by Marshall H. Cohen
        Vol. 7. United Kingdom   by Glenn Samson, Lyle Moe, & Arthur Coffing

        Vol. 8. Spain   by James Lopes
        Vol. 9. Japan   by W. Scott Steele

(124)   _____
        1974.   The World Food Situation and Prospects to 1985. U.S. Dept. Agr.
                For. Agr. Econ. Rpt. 98. December.

(125)   _____
        1975.   The Impact of Dairy Imports on the U.S. Dairy Industry. U.S. Dept.
                of Agr. Agr. Econ. Rpt. 278. January.

(126)   _____
        1977.   Food and Agriculture. A Chapter, in Resources For the Future Report
                on Resource and Environmental Consequences of Population Growth, in
                preparation by RFF for National Institute of Health. Washington,
                D.C.

(127)   Filippello, A. Nicholas
        1970.   Japanese Grain-Livestock Economy: An Econometric Projection to 1980
                with Emphasis on Grain Imports. Econ. Res. Serv. U.S. Dept. Agr.
                Unpublished.

(128)   Friend, Reed E.
        1971.   Use of Wheat for Feed in the European Economic Community, With
                Projections to 1975. Econ. Res. Serv. U.S. Dept. Agr. Foreign Agr.
                Econ. Rpt. 74. August.

(129)   Friend, Reed E, and Robert G. Butell
        1969.   Production, Consumption, and Trade of Coarse Grains: Developments
                and Prospects for Selected Foreign Countries and Areas. U.S. Dept.
                Agr. Econ. Res. Serv. ERS-Foreign 272.

(130)   Friend, Reed E., Wayne E. Denney, Mary E. Long, and Thomas A. Twomey
        1972.   Australia: Growth Potential of the Grain and Livestock Sectors.
                U.S. Dept. Agr. Econ. Res. Serv. For. Agr. Econ. Rpt. 80. May.

(131)   Grant, Warren R., Troy Mullins, and William R. Morrison
        1975.   World Rice Study: Disappearance, Production, and Price Relationships
                Used to Develop the Model. U.S. Dept. Agr. Econ. Res. Serv. in
                cooperation with the Agr. Exp. Stas. of Arkansas and Texas. ERS-
                608. October.

(132)   Gustafson, Ronald A. and Roy N. Van Arsdall
        1970.   Cattle Feeding in the United States. U.S. Dept. Agr. Econ. Res.
                Serv. Agr. Econ. Rpt. 186. October.

(133)   Hanrahan, Charles and Joseph W. Willett
        1976.   Technology and the World Food Problem: A U.S. View. Food Policy.
                November.

(134)   Helen, Dale
        1976.   An Economic Analysis of the U.S. Poultry Sector. Amer. Jour. of Agr.
                Econ. Vol. 58, No. 2. pp. 311-316.

(135)   Hendrix, William E., James J. Naive and Warren Adams
        1968.   Accelerating India's Food Grain Production 1967-69 to 1970-71. U.S.
                Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 40. March.

(136) Hutchison, John E., James J. Naive and Sheldon K. Tsu
       1970. World Demand Prospects for Wheat in 1980: With Emphasis on Trade by
              the Less Developed Countries. U.S. Dept. Agr. Econ. Res. Serv.
              Foreign Agr. Econ. Rpt. 62. July.

(137) Hutchison, John E., Francis S. Urban and John C. Dunmore
       1972. Argentina: Growth Potential of the Grain and Livestock Sectors.
              U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 78. May.

(138) Ibach, D.D., and J.R. Adams
       1968. Crop Yield Response to Fertilizer in the United States. Stat. Bul.
              431. U.S. Dept. Agr. Econ. Res. Serv. and Stat. Rptg. Serv.
              August.

(139) Johnson, James B.
       1974. Estimates of Demand and Supply Equations for the U.S. Livestock and
              Poultry Sectors. U.S. Dept. Agr. Econ. Res. Serv. Unpublished.

(140) Keefer, James F., Robert D. Barry, Clarence E. Pike and Amjad H. Gill
       1970. World Supply and Demand Prospects for Rice in 1980: With Emphasis
              on Trade Implications for Less Developed Countries. U.S. Dept. Agr.
              Econ. Res. Serv. Unpublished.

(141) Kirby, Riley H.
       1972. Agricultural Trade of the People's Republic of China, 1935-69. U.S.
              Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 83.

(142) Kost, William E.
       1975. Production and Consumption Models for Grain-Feed-Livestock Products
              for the EEC. U.S. Dept. Agr. Econ. Res. Serv. Unpublished.

(143) Mackie, Arthur B.
       1974. International Dimensions of Agricultural Prices. Southern Journal of
              Agricultural Economics, Vol. VI, No. 1.

(144) Mackie, Arthur B., A. Nicholas Filippello, John E. Hutchison, and
       James F. Keefer
       1968. World Trade in Selected Agricultural Commodities 1951-65. Vol. 2.
              Food and Feed Grains. U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr.
              Econ. Rpt. 45. June.

(145) Matthews, Jimmy L.
       1973. Conditional Market Forecasts and Implications for the U.S. Soybean
              Economy. Fats and Oils Situation. U.S. Dept. Agr. Econ. Res. Serv.
              FOS-268. July. pp. 17-25.

(146) Meilke, K. D.
       1975. An Aggregate U.S. Feed Grain Model. Agr. Econ. Res. Vol. 27, No. 1.
              pp. 9-18.

(147) Mielke, Myles
       1976. Demand Elasticities for Livestock Products in the European Community
              and Japan. U.S. Dept. Agr. Econ. Res. Serv. Unpublished. July.

(148) Missiaen, Edmond, and Arthur L. Coffing
       1972. Canada: Growth Potential of the Grain and Livestock Sectors. U.S.
              Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 77. June.

(149) Mo, William Y.
         1968. An Econometric Analysis of the Dynamics of the United States Wheat
                Sector. U.S. Dept. Agr. Econ. Res. Serv. Tech. Bul. 1395. April.

(150) Moe, Lyle E., and Malek M. Mohtadi
         1971. World Supply and Demand Prospects for Oilseeds and Oilseed Products
                in 1980: With Emphasis on Trade by the Less Developed Countries.
                U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 71. March.

(151) Moriak, Theo R., Roger P. Strickland, and Warren R. Grant
         1975. World Rice Study: A Software Package for Analyzing International
                Trade. U.S. Dept. Agr. Econ. Res. Serv. in cooperation with the
                Agr. Exp. Stas. of Arkansas and Texas. ERS-609. October.

(152) Porter, Jane M.
         1976. Historical Perspective on Demand and Supply Projections in the USDA.
                Agriculture The Third Century No. 3. U.S. Dept. Agr. Econ. Res.
                Serv. September.

(153) Quance, Leroy
         1976. Introduction to the Economic Projections Program. Agriculture The
                Third Century No. 1. U.S. Dept. Agr. Econ. Res. Serv. May.

(154) Regier, Donald W.
         1967. Growth in Demand for Feed Grains in the EEC. U.S. Dept. Agr. Econ.
                Res. Serv. ERS-Foreign 158. July.

(155) _____
         1971. The EEC Feed-Livestock Economy: An Analytical Model. U.S. Dept. Agr.
                Econ. Res. Serv. Unpublished.

(156) _____
         1973. World Meat Economy in Perspective. Livestock and Meat Situation.
                U.S. Dept. Agr. Econ. Res. Serv. LMS-194. December.

(157) _____
         1976. The Livestock Sector and Derived Feed Demand. U.S. Dept. Agr. Econ.
                Res. Serv. Unpublished. October.

(158) Regier, Donald W., and O. Halbert Goolsby
         1970. Growth in World Demand for Feed Grains: Related to Meat and
                Livestock Products and Human Consumption of Grain. U.S. Dept. Agr.
                Econ. Res. Serv. Foreign Agr. Econ. Rpt. 63. July.

(159) Roenigk, William
         1973. Growth Potential of Corn Production in Western Europe through 1975
                and 1980. U.S. Dept. Agr. Econ. Res. Serv., For. Agr. Econ. Rpt. No.
                88.

(160) Reutlinger, Schlomo
         1966. Analysis of a Dynamic Model With Particular Emphasis on Long-Run
                Projections. Jour. of Farm Econ. Vol. 48. pp. 88-105. February.

(161) Rojko, Anthony S,
         1973. Future Prospects for Agricultural Exports: Presenting Projections
                Developed Jointly by Anthony S. Rojko, Donald W. Regier, John E.
                Hutchison, Thomas A. Twomey and Arthur L. Coffing. Speech presented
                at Midwest Agricultural Outlook Conference. Held at Purdue Univ.
                August 15-16.

118

(162) _____
1975. Economics of Possible Food Reserve Systems and Their Relation to Commercial Markets. U.S. Dept. Agr. Econ. Res. Serv. August 8. Unpublished.

(163) Rojko, Anthony S., and Arthur B. Mackie
1970. World Demand Prospects for Agricultural Exports of Less Developed Countries in 1980. U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 60. June.

(164) Rojko, Anthony S. and Patrick M. O'Brien
1976. Organizing Agriculture in the Year 2000. Food Policy. May. pp. 203-219.

(165) Rojko, Anthony S. and Patrick M. O'Brien
1977. Organizing Agriculture in the Year 2000. Chap. 19 in: Food Enough or Starvation for Millions. Edited by Douglas Ensminger. Compendium of papers from a Seminar on Population and Food and Agricultural Development, organized by the International Association of Agricultural Economists in collaboration with FAO and UNFPA, held in Rome, December 1-5, 1975. New Delhi. India: Tata McGraw Hill Publishing Company Ltd. FAO, 1977. pp 343-361.

(166) Rojko, Anthony S., and Schwartz, Martin W.
1976. Modeling the World Grain-Oilseeds-Livestock Economy to Assess World Food Prospects. Agr. Econ. Res. Vol 28, No.3. pp. 89-98.

(167) Rojko, Anthony S., Francis S. Urban, and James J. Naive
1971. World Demand Prospects for Grain in 1980: With Emphasis on Trade by the Less Developed Countries. U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 75. December.

(168) Smith, Allen G.
1976. Commodity Production and Utilization Projections to 1985. Agriculture The Third Century No. 2. U.S. Dept. Agr. Econ. Res. Serv. July.

(169) Stevens, Robert
1965. Elasticity of Food Consumption Associated with Changes in Income in Developing Countries. U.S. Dept. Agr. Econ. Res. Serv. Foreign Agr. Econ. Rpt. 23.

(170) Thorburn, W. Garth
1975. Peanut Industry in India 1964-75 and Projections for 1980. U.S. Dept. Agr. Foreign Agr. Serv. FAS M-267. September.

(171) Urban, F.S., H.C. Collins, J.R. Horst, and T.A. Vankai
1973. The Feed-Livestock Economy of Eastern Europe: Prospects to 1980, U.S. Dept. Agr. Econ. Res. Serv., For. Agr. Econ. Rpt. No.90.

(172) U.S. Department of Agriculture
1973. Agricultural Trade and the Proposed Round of Multilateral Negotiations. Report Prepared at the Request of Peter Flanigan, Assistant to the President for International Economic Affairs. Prepared under the direction of FAS, by FAS, ERS, and ASCS. Released by the U.S. Senate Committee on Agriculture and Forestry. U.S. Govt. Print. Off. April 30.

119

(173) _____
      1975. Perspectives on Prime Lands: Background Papers for Seminar on
             Retention of Prime Lands. Sponsored by the USDA Committee on Land
             Use. July 16-17, 1975.

(174) Van Arsdall, Roy N., and Melvin D. Skold
      1973. Cattle Raising in the United States. U.S. Dept. Agr. Econ. Res.
             Serv. Agr. Econ. Rpt. 235. January.

(175) Vankai, Thomas
      1975. Feed-Livestock of East Germany: Prospects to 1980. U.S. Dept. Agr.
             Econ. Res. Serv. Foreign Agr. Econ. Rpt. 110. September.

(176) Vermeer, James, et al
      1975. Effects of Trade Liberalization on U.S. Agriculture. Agr. Econ. Res.
             Vol. 27, No. 2. pp. 23-29.

(177) Waugh, Frederick V.
      1964. Demand and Price Analysis: Some Examples from Agriculture. U.S.
             Dept. Agr. Econ. Res. Serv. Tech. Bul. 1316. November.

(178) Willett, Joseph W.
      1969. The Impact of New Grain Varieties in Asia. U.S. Dept. Agr. Econ.
             Res. Serv. ERS-Foreign 275.

              II   Prepared by the U.S. Department of Agriculture:
                              Data Sources

(200) Allen, George C., Earl F. Hodges and Margaret Devers
      1974. Livestock-Feed Relationships, National and State. U.S. Dept. Agr.
             Econ. Res. Serv. Stat. Bul. 530. June.

(201) _____
      1975. Livestock-Feed Relationships National and State. Supplement for 1974
             to Stat. Bul. 530. U.S. Dept. Agr. October.

(202) Economic Research Service
      1964. Food Balances for 24 Countries of the Western Hemisphere 1959-1961.
             U.S. Dept. Agr. ERS-Foreign 86.

(203) _____
      1964. Food Balances for 16 Countries of Western Europe 1959-1961. U.S.
             Dept. Agr. ERS-Foreign 87.

(204) _____
      1964. Food Balances for 12 Countries in the Far East and Oceania 1959-1961.
             U.S. Dept. Agr. ERS-Foreign 88.

(205) _____
      1965. Food Balances for 30 Countries of Africa and West Asia 1959-1961.
             U.S. Dept. Agr. ERS-Foreign 119.

(206) _____
      1965. Food Balances for 8 East European Countries 1959-1961. U.S. Dept.
             Agr. ERS-Foreign 124.

(207) _____
  1972. Feed Statistics: Feed Grains, Processed Feeds, Hay and Other Forages. Supplement for 1971 to Stat. Bul. 410. U.S. Dept. Agr. July.

(208) _____
  1972. Food Grain Statistics: Wheat, Rye, Rice, Flour, By-Products. Supplement for 1971 to Stat. Bul. 423. U.S. Dept. Agr. November.

(209) _____
  1972. The 1972 Agricultural Data Book for the Far East and Oceania. U.S. Dept. Agr. ERS-Foreign 267 Revised. October.

(210) _____
  1973. Agricultural Statistics of Eastern Europe and the Soviet Union 1950-70. U.S. Dept. Agr. ERS-Foreign 349. June.

(211) _____
  1975. Agricultural Trade of the Western Hemisphere: A Statistical Review 1963-73. U.S. Dept. Agr. Stat. Bul. 546. July.

(212) _____
  1975. Structural Changes in West European Agriculture 1950-70. U.S. Dept. Agr. For. Agr. Econ. Rpt. 114. November.

(213) _____
  1976. Livestock and Meat Statistics. Supplement for 1975. U.S. Dept. Agr. Stat. Bul. 522. June.

(214) _____
  1976. Poultry and Egg Statistics. Supplement for 1972-75 to Stat. Bul. 525. U.S. Dept. Agr. September.

(215) _____
  1976. Twenty-Six Years of World Cereal Statistics: Area, Yield, Production, 1950-75, By Country and Region. U.S. Dept. Agr. ERS-FDCD. July.

(216) _____
  1976. U.S. Fats and Oils Statistics 1960-75. U.S. Dept. Agr. Stat. Bul. 560. September.

(217) Foreign Agricultural Service
  1960 onward. World Grain Balance Figures. U.S. Dept. Agr.

(218) _____
  1960 onward. World Meat Balance Figures. U.S. Dept. Agr.

(219) Statistical Reporting Service
  1965. Usual Planting and Harvesting Dates. U.S. Dept. Agr. Agr. Handbook 283.

III   Prepared for the U.S. Department of Agriculture:
Studies of Effects of Economic Integration on Agriculture

(300)   Epp, Donald J.
    1968.   Changes in Regional Grain and Livestock Prices Under European
    Economic Community Policies.   Res. Rpt. 4.   Inst. of International
    Agr. Michigan State Univ. E. Lansing, Mich.

(301)   Ferris, John, et al
    1971.   Impact on U.S. Agricultural Trade of the Accession of the United
    Kingdom, Ireland, Denmark and Norway to the European Economic
    Community.   Res. Rpt. 11.   Inst. of International Agr. Michigan State
    Univ.   East Lansing, Mich.

(302)   Gayoso, Antonio, and W.W. McPherson
    1971.   Effects of Changing Trade Systems in Latin America on U.S.
    Agricultural Exports.   Exp. Sta. Monograph Series 1.   Inst. of Food
    and Agr. Sciences.   Univ. of Florida.   Gainesville, Fla.   February.

(303)   Mangum, Fred A., Jr.
    1968.   Grain-Livestock Economy of Italy: With Projections to 1970 and 1975.
    Res. Rpt. 2.   Inst. of International Agr. Michigan.

(304)   Petit, Michel, and Jean-Baptiste Viallon
    1968.   Grain-Livestock Economy of France: With Projections to 1970 and
    1975.   Res. Rpt. 3.   Inst. of International Agr. Michigan State Univ.
    East Lansing, Mich.

(305)   Rossmiller, George E.
    1968.   Grain-Livestock Economy of West Germany: With Projections to 1970
    and 1975.   Res. Rpt. 1.   Inst. of International Agr. Michigan State
    Univ.   East Lansing, Mich.

(306)   Sorenson, Vernon L., and Dale E. Hathaway
    1968.   Grain-Livestock Economy and Trade Patterns of the European Economic
    Community: With Projections to 1970 and 1975. Res. Rpt. 5. Inst. of
    International Agr. Michigan State Univ.   East Lansing, Mich.

IV   Prepared for the U.S. Department of Agriculture:
Studies of Agricultural Supply and Demand

(400)   Aarhus Universitets Okonomiske Institut
    1969.   Projections of Supply and Demand for Agricultural Products in Denmark
    1970-1980.   By Palle Schelde Andersen, Peter Guldager, Arne
    Schmelling, John Vibe-Pedersen, and Hans Egede Zeuthen.   Aarhus,
    Denmark.

(401)   Abbas, S.A.
    1967.   Supply and Demand of Selected Agricultural Products in Pakistan 1961-
    1975.   Oxford Univ. Press.   Pakistan.

(402) Banco de Mexico, S.A.
1966. Projections of Supply of and Demand for Agricultural Products in Mexico to 1965, 1970, and 1975. By Banco de Mexico, S.A., the Secretaria de Agricultura y Ganaderia, and the Secretaria de Hacienda y Credito Publico, under the direction of Victor L. Urquidi and Emilio Alanis Patino. Jerusalem.

(403) Berg, Eric R.
1967. Nigeria, Senegal, and the Congo (Kinshasa): Projected Level of Demand, Supply, and Exports of Oilseed Products to 1975 with Implications for U.S. Exports to the European Economic Community. University of Alberta, Edmonton.

(404) Centre de Recherches et de Documentation sur la Consommation
1967. Production and Uses of Selected Farm Products in France: Projections to 1970 and 1975. CREDOC. Paris,France.

(405) Clark, Colin, et al
1962. United Kingdom: Projected Level of Demand, Supply, and Imports of Farm Products in 1965 and 1975. Inst. for Res. in Agr. Econ. Oxford Univ. January.

(406) Consejo de Bienestar Rural
1965. Long-Term Forecasts of the Supply and Demand of Agricultural and Livestock Products in Venezuela. Draft dated November 1964 by CBR. Caracas, Venezuela. Printed in Jerusalem. December.

(407) Crosson, Pierre R.
1966. Economic Growth in Malaysia. Center for Development Planning. National Planning Association, Washington, D.C.

(408) Department of Political Economy, University of Edinburgh (Scotland)
1964. Ghana: Projected Level of Demand, Supply and Imports of Agricultural Products in 1965, 1970 and 1975. The University, Edinburgh.

(409) Elz, Dieter
1967. Oilseed Product Needs of the European Economic Community 1970: As Indicated by Livestock-Feed and Vegetable-Oil Requirements. Printed in Jerusalem. May.

(410) Fundacao Getulio Vargas
1968. Brazil: Projections of Supply and Demand for Agricultural Products Through 1975. Brazilian Institute of Econ. Getulio Vargas Foundation. Rio de Janeiro. November.

(411) _____
1970. Brazil: Food Consumption, Family Budget Surveys in the Early 1960's. Brazilian Institute of Econ. Getulio Vargas Foundation. Rio de Janeiro. November.

(412) Gruen, F.H., A.A. Powell, B.W. Brogan, G.C. McLaren, R.H. Snape, T. Washtel, and L.E. Ward
1967. Australia: Long Term Projections of Agricultural Supply and Demand 1965 to 1980. 2 Vols. Dept. of Econ. Monas Univ. Clayton, Victoria, Australia.

(413) Hsu, Wen-Fu
1967. Demand Projections of Agricultural Products Relative to Economic Development in Taiwan. Res. Instit. of Rural Socio-Economics. National Taiwan Univ. Taipei, Taiwan. December.

(414) IFO-Institut fuer Wirtschaftsforschung
1967. Long-Term Development of Demand and Supply for Agricultural Products in the Federal Republic of Germany. By Helmut Schmidt and others. Series Studien zur Agrarwirtschaft. Vol. 1. Munich, F.R. Germany.

(415) _____
1969. Aggregation of Future Demand and Supply for Agricultural Products in the European Economic Community 1970-1975. By H. Schmidt and L. Gruenwald. Munich, F.R. Germany.

(416) _____
1971. Agricultural Marketing Systems in the EEC-Member Countries. 2 Vols. Studien zur Agrarwirtschaft. Munich, F.R. Germany.

(417) _____
1973. Agricultural Marketing Systems in the United Kingdom, Ireland, Denmark, Norway, and Sweden. 2 Vols. Studien zur Agrarwirtschaft. Munich, F.R. Germany.

(418) India, National Council of Applied Economic Research
1970. India: Projections of Demand and Supply of Agricultural Commodities. New Delhi. September.

(419) Institute for Agricultural Economic Research (Tokyo)
1964. Japanese Import Requirements: Projections of Agricultural Supply and Demand for 1965, 1970, and 1975. Univ. of Tokyo. March.

(420) Institute of Social and Economic Research (Kingston)
1966. Jamaica, Trinidad and Tobago, Leeward Islands, Windward Islands, Barbados, and British Guiana: Projected Levels of Demand Supply and Imports of Agricultural Products to 1975. By the Institute, Univ. College of the West Indies. Kingston, Jamaica. Econ. Res. Serv. U.S. Dept. Agr. ERS-Foreign 94.

(421) Instituto Nacional de Tecnologia Agropecuaria
1972. Argentina: Projections of Supply of and Demand for Selected Agricultural Products Through 1980. INTA. Buenos Aires, Argentina. November.

(422) Jones, George
1969. United Kingdom: Projected Level of Demand, Supply and Imports of Agricultural Products, 1970, 1975, and 1980. Institute for Research in Agr. Econ. Oxford Univ.

(423) Landbouw-Economisch Instituut
1967. Supply and Demand, Imports and Exports of Selected Agricultural Products in the Netherlands: Forecast for 1970 and 1975. The Hague, Netherlands.

(424) Little, Arthur D., Inc.
1966. Projected Exports and Imports of Selected Agricultural Commodities of South Africa. Rpt. to Econ. Res. Serv. and Foreign Agr. Serv. U.S. Dept. Agr. December.

(425) Mercantile, Inc.
1963. The Philippines: Long-Term Projections of Supply of and Demand for Selected Agricultural Products. U.S. Dept. Agr. Econ. Res. Serv. ERS-Foreign 34.

(426) Mundlak, Yair
    1964. Long-Term Projections of Supply and Demand for Agricultural Products
        of Israel. Hebrew Univ. Jerusalem. May.

(427) Studiecentrum voor Economische en Sociaal Onderzoek
    1967. Long-Term Development of Supply and Demand for Agricultural Products
        in Belgium. By P.H. Virenque, Willy Desaeyere, Helga Stuyck, Emiel
        Van Broekhoven, and J.M. Van Haeperen. SESO. University of Antwerp.
        Belgium.

(428) Tsu, Sheldon and Ernest Koenig
    1964. Italian Agriculture: Projections of Supply and Demand in 1965, 1970,
        and 1975. U.S. Dept. Agr. Econ. Res. Serv. ERS-Foreign 68.
        January.

(429) Universidad Agraria
    1969. Peru: Long-Term Projections of Demand for and Supply of Selected
        Agricultural Commodities Through 1980. Programa de Investigaciones
        para el Desarrollo. Univ. Agraria. La Molina, Lima, Peru. June.

(430) University of Bombay
    1969. Survey of India's Export Potential of Oilcakes. 5 Vols. By Dept. of
        Econ., Univ. of Bombay, and Operations Research Group, Baroda.
        Prepared for U.S. Agency for International Dev. and India, Ministry
        of Foreign Trade and Supply. Limited Distribution. April.

(431) University of Edinburgh
    1962. Nigeria: Determinants of Projected Level of Demand, Supply, and
        Imports of Farm Products in 1965 and 1975. U.S. Dept. Agr. Econ.
        Res. Serv. ERS-Foreign 32. August.

V   Prepared for the U.S. Department of Agriculture:
Technical Studies of Livestock Feeding

(500) U.S. National Academy of Sciences
    1968. Nutrient Requirements of Sheep. 4th res. ed. Nutrient Requirements
        of Domestic Animals, No.5. Washington.

(501) _____
    1968. Nutrient Requirements of Swine, 6th rev. ed. Nutrient Requirements
        of Domestic Animals, No. 2. Washington.

(502) _____
    1970. Nutrient Requirements of Beef Cattle, 4th rev. ed. Nutrient
        Requirements of Domestic Animals, No. 4. Washington.

(503) _____
    1971. Nutrient Requirements of Dairy Cattle, 4th rev. ed. Nutrient
        Requirements of Domestic Animals, No. 3. Washington.

(504) _____
    1971. Nutrient Requirements of Poultry, 6th rev. ed. Nutrient Requirements
        of Domestic Animals, No. 1. Washington.

(505) Weightman, Paul W.H.
      1967. Concentrated Feedingstuffs for Livestock in the United Kingdom.
      A.E. Res. 225. Agr. Exp. Sta. Cornell Univ. Ithaca, N.Y. June.

(506) _____
      1968. Concentrated Feedingstuffs for Livestock in the Netherlands. A.E.
      Res. 239. Agr. Exp. Sta. Cornell Univ. Ithaca, N.Y. January.

(507) _____
      1969. Concentrated Feedingstuffs for Livestock in Belgium-Luxembourg.
      A.E. Res. 286. Agr. Exp. Sta. Cornell Univ. Ithaca, N.Y. May.

(508) _____
      1969. Concentrated Feedingstuffs for Livestock in Denmark. A.E. Res. 287.
      Agr. Exp. Sta. Cornell Univ. Ithaca, N.Y. May.

(509) _____
      1969. Concentrated Feedingstuffs for Livestock in France. A.E. Res. 288.
      Agr. Exp. Sta. Cornell Univ. Ithaca, N.Y. May.

VI   Prepared by the Food and Agriculture Organization: Analytical Studies

(600) Food and Agriculture Organization
      1966. The Response of Rice to Fertilizer. FAO. Rome.

(601) _____
      1966. Statistics of Crop Responses to Fertilizers. FAO. Rome.

(602) _____
      1966-69. Indicative World Plan for Agricultural Development to 1975 and
          1985. FAO. Rome. Regional Studies as follows: Subregional Study
          No. 1. Near East. Provisional Regional Study No. 2 South America.
          Provisional Regional Study No. 3. Africa South of Sahara.
          Provisional Regional Study No. 4. Asia and Far East.

(603) _____
      1967. Agricultural Commodities: Projections for 1975 and 1985. 2 Vols.
      FAO. Rome.

(604) _____
      1969. Provisional Indicative World Plan for Agricultural Development. 3
      Vols. FAO. Rome.

(605) _____
      1971. Agricultural Commodity Projections 1970-1980. 2 Vols. FAO. Rome.

(606) _____
      1971. Analysis of Supply Responses to Price Changes. Committee on
      Commodity Problems. Projections Research Working Paper No. 7. FAO.
      Rome. November 3.

(607) _____
      1971. Impact of Demand Changes in Income Distribution. Committee on
      Commodity Problems. Projections Research Working Paper No. 2. FAO.
      Rome.

(608) _____
       1971. Implications of the Possible Enlargement of the EEC for Agricultural
              Commodity Projections, 1970-1980. Committee on Commodity Problems.
              Projections Research Working Paper No. 6. FAO. Rome.

(609) _____
       1971. A World Price Equilibrium Model. Committee on Commodity Problems.
              Projections Research Working Paper No. 3. FAO. Rome. October 11.

(610) _____
       1972. Income Elasticities of Demand for Agricultural Products.
              Projections Research Working Paper No. 1. Committee on Commodity
              Problems. FAO. Rome. May.

(611) _____
       1975. Fertilizers, An Annual Review of World Production, Consumption,
              Trade and Prices. FAO. Rome. Annual, selected issues.

(612) _____
       1974. World Food Security: Draft Evaluation of World Cereals Stock
              Situation. FAO. Rome.

       VII   Prepared by the Food and Agriculture Organization: Data Sources

(700) Food and Agriculture Organization
       1950 onward. National Grain Policies. FAO. Rome. Annual.

(701) _____
       1950 onward. Production Yearbook. FAO. Rome. Annual.

(702) _____
       1950 onward. Trade Yearbook. FAO. Rome. Annual.

(703) _____
       1971. Food Balance Sheets. 1964-66 Average. FAO. Rome.

     VIII   Prepared by the Organization for Economic Cooperation and Development:
                             Analytical Studies

(800) Organization for Economic Cooperation and Development
       1966. Cooperative Research in Input-Output Relationships in Use of
              Fertilizers in Crop Production. By Olle Johansson, Larus Jansson,
              Bertil Johnsson, Ulf Renborg, and George Stojkovic. Documentation
              in Agr. and Food 84. OECD. Paris.

(801) _____
       1968. Agricultural Projections for 1975 and 1985: Production and
              Consumption of Major Foodstuffs. OECD. Paris.

(802) _____
       1968. Agricultural Projections for 1975 and 1985. Country Studies. 23
              Vols. OECD. Paris.

127

(803) _____ _____
      1968. Cooperative Research on Input-Output Relationships in Beef
            Production. By S.R. Wragg, T.E. Godsell, and Gwyn Williams.
            Documentation in Agr. and Food 82. OECD. Paris.

(804) _____
      1969. Cooperative Research on Input-Output Relationships in Cow Milk
            Production. By F. de Boer, A. Eriks, G. Hamming, M.L. 't Hart, and
            J. de Veer. Documentation in Agr. and Food 83. OECD. Paris.

(805) _____
      1970. An Appraisal of "Income" Elasticities for Total Food Consumption in
            Developing Countries. By Quirino Paris. OECD. Paris.

(806) _____
      1971. Study on the Factors Influencing the Use of Cereals in Animal
            Feeding. OECD. Paris.

(807) _____
      1976. Study of Trends in World Supply and Demand of Major Agricultural
            Commodities. Report by the Secretary General. OECD. Paris.

(808) Yudelman, Montague
      1971. Technological Change in Agriculture and Employment in Developing
            Countries. Development Center Studies. Employment Series No. 4.
            OECD. Paris.

IX   Prepared by the Organization for Economic Cooperation and Development:
                          Data Sources

(900) Organization for Economic Cooperation and Development
      1973. Food Consumption Statistics 1955-1971. OECD. Paris.

(901) _____
      1975. Meat Balances in OECD Member Countries 1960-1973. OECD. Paris.

(902) _____
      1970. Milk Balances and Production of Milk Products in OECD Countries
            1955-1970. OECD. Paris.

(903) _____
      1970 onward. Main Economic Indicators. OECD. Paris. Monthly.

X   Studies Prepared by and for Other Sponsors

(1000) Alm, Hans, Jack Duloy, and O. Gullbrandsen
       1969. Agricultural Prices and the World Food Economy. Progress Report for
             FAO. Rome. March. Also presented at the FAO Inter-Secretariat
             Expert Consultation on Projections. Rome. December 15-19.

(1001) Armington, Paul S.
    1970. A Many-Country Model of Equilibrating Adjustments in Prices and
    Spending. Published as an appendix to Rudolf Rhomberg: Possible
    Approaches to a Model of World Trade and Payments. Staff Papers.
    International Monetary Fund. Washington, D.C.

(1002) Association Scientifique Europeenne pour la Prevision Economique
a Moyen et a Long Term
    1971. Europe's Future Food and Agriculture. ASEPELT Vol. 3 Ed. by A.M.M.
    McFarquhar. North-Holland Pub. Co. Amsterdam.

(1003) Atlantic Institute
    1970. A Future for European Agriculture. Report by a panel of experts.
    Atlantic Papers 4. Paris. France.

(1004) Aziz, Sartaj
    1975. Hunger, Politics and Markets: The Real Issues in the Food Crisis.
    New York: N.Y. Univ. Press.

(1005) Barker, R.
    1969. Economic Aspects of High-Yielding Varieties of Rice with Special
    Reference to National Price Policies. Monthly Bul. of Agr. Econ.
    and Stat. June.

(1006) Bawden, D. Lee
    1964. An Evaluation of Alternative Spatial Models. Jour. of Farm Econ.
    No. 1. 46. pp. 1372-1379. December.

(1007) _____
    1966. A Spatial Price Equilibrium Model of International Trade. Jour. of
    Farm Econ. Vol. 48. pp. 862-874. November.

(1008) Behrman, Jere R.
    1968. Supply Response in Underdeveloped Agriculture. North-Holland Pub.
    Co. Amsterdam. A Case Study of Four Major Annual Crops in
    Thailand. 1937-1963.

(1009) Berg, Eric R.
    1961. Structure of Soybean Oil Export Market. Univ. of Illinois. Agr.
    Exp. Sta. Bul. 674.

(1010) Bjarnason, H.F.
    1967. An Economic Analysis of 1980 International Trade in Feed Grains.
    Ph.D. dissertation. Univ. of Wisconsin. Madison. May.

(1011) Blakeslee, Leroy
    1967. An Analysis of Projected World Food Production and Demand in 1970,
    1985, and 2000. Ph.D. dissertation. Iowa State Univ. Ames.

(1012) Blakeslee, Leroy, Earl O. Heady, and Charles F. Framingham
    1973. World Food Production, Demand, and Trade. Center for Agriculture
    and Rural Dev. Iowa State Univ. Ames.

(1013) Boehm, William T., and Emerson M. Babb
    1975. Household Consumption of Beverage Milk Products. Purdue Univ. Agr.
    Exp. Sta. Bul. No. 75. West Lafayette, Indiana. March.

129

(1014) _____
         1975.   Household Consumption of Storable Manufactured Dairy Products.
                 Purdue Univ. Agr. Exp. Sta. Bul. No. 85. West Lafayette, Indiana.
                 June.

(1015) Brandow, George E.
         1961.   Interrelations Among Demands for Farm Products and Implications for
                 Control of Market Supply. Penn. State Univ. Bul. 680. Univ. Park,
                 August.

(1016) Brown, Lester R.
         1970.   Seeds of Change. The Green Revolution and Development in the
                 1970's. Praeger Publishers. New York.

(1017) _____
         1975.   By Bread Alone. Praeger Publishers. New York.

(1018) Carter, Harold, James G. Youde and Maurice L. Peterson
         1975.   Future Land Requirements to Produce Food for an Expanding World
                 Population. In Perspectives on Prime Lands: Background Papers for
                 Seminar on Retention of Prime Lands July 16-17, 1975. U.S. Dept.
                 Agr. Committee on Land use.

(1019) Colyer, Dale, and George D. Irwin
         1967.   Beef, Pork, and Feed Grains in the Cornbelt: Supply Response
                 Adjustments. N.C. Reg. Res. Pub. 178. Univ. of Missouri. Agr. Exp.
                 Sta. Res. Bul. 921. August.

(1020) Crosson, Pierre and Kenneth Fredericks
         1977.   The World Food Situation: Resources and Environmental Issues.
                 Resources For the Future. Washington, D.C. Unpublished.

(1021) Duloy, John H., and Norton, Roger D.
         1975.   Prices and Incomes in Linear Programming Models. Amer. Jour. Agr.
                 Econ. Vol. 57, No. 4. 591-600.

(1022) Egbert, Alvin C., and Earl O. Heady
         1964.   Regional Changes in Grain Production: An Application of Spatial
                 Linear Programming. Agr. and Home Econ. Exp. Sta. Iowa State Univ.
                 Res. Bul. 521. Ames.

(1023) Egbert, Alvin C., and Schlomo Reutlinger
         1965.   A Dynamic Model of the Livestock Feed Sector. Jour. of Farm Econ.
                 Vol. 47. pp. 1288-1305. December.

(1024) Falcon, W.P.
         1962.   Farmer Response to Price in Undeveloped Areas. A Case Study of West
                 Pakistan. Ph.D. dissertation. Dept. of Econ. Harvard Univ.

(1025) Farnsworth, Helen C., and Karen J. Friedman
         1967.   French and EEC Grain Policies and their Price Effects 1920-1970.
                 Food Research Institute Studies. Special Issue. Vol. 7, No. 1.
                 Stanford Univ.

(1026) Filippello, A. Nicholas
         1967.   A Dynamic Econometric Investigation of the Japanese Livestock
                 Economy. Univ. of Missouri. Ph.D. dissertation. December.

(1027) Fletcher, L., and Mubyarto
        1966.   Supply and Market Surplus Relationships for Rice in Indonesia.
                Paper read at the Agri. Dev. Council--Univ. of Minn. Conference on
                Supply and Market Relationships in Peasant Agriculture.
                Minneapolis.   February 18-20.

(1028) Fouquet, Annie
        1970.   Projection de la Consommation Alimentaire pour 1975 (Projection of
                Food Consumption for 1975).   Les Collections de l'INSEE.   30, Series
                M. No. 5.   Institut National de la Statistique et les Etudes
                Econometriques.   Paris.   October.

(1029) Friedmann, Karen J., and Helen C. Farnsworth
        1966.   The West German Grain Economy and the Common Market Policies,
                Prices, and Production, 1925-1975.   Food Research Institute.
                Stanford Univ.

(1030) Frisch, Ragnar
        1959.   A Complete Scheme for Computing All Direct and Cross Demand
                Elasticities in a Model With Many Sectors.   Econometrica.   Vol. 27.
                No. 2. pp. 177-196.   April.

(1031) General Agreement on Tariffs and Trade
        1972.   The Major Import Markets for Oilcakes with UNCTAD.   International
                Trade Center.   GATT.   Geneva.

(1032) George, P.S., and G.A. King
        1971.   Consumer Demand for Food Commodities in the United States With
                Projections for 1980.   Giannini Foundation Monograph 26.   California
                Agr. Exp. Sta. March.

(1033) Gollnick, H., and P. Maciej
        1965.   Die Projektion der Nachfrage nach Nahrungsmittlen in der BR
                Deutschland bis 1965, 1970, und 1975 (Demand Projection for Food in
                the F.R. Germany for 1965, 1970, and 1975).   Agrarwirtschaft.   Vol.
                14. No. 2.

(1034) Hallberg, M.C. and R.F. Fallert
        1976.   Policy Simulation Model for the United States Dairy Industry.   Penn.
                State Univ. Agr. Exp. Sta. Bul. 805.   Univ. Park, Penn.   January.

(1035) Hardin, Clifford M., ed.
        1969.   Overcoming World Hunger.   American Assembly.   Prentice-Hall.
                Englewood Cliffs, N.J.

(1036) Harris, Alan J.
        1967.   An Econometric Analysis of Rice Prices in the Republic of Vietnam.
                Dept. of Agr. Econ.   North Dakota State Univ.   Agr. Econ. T. Series
                67-1.   December.

(1037) Heady, Earl O., Doeke C. Faber and Steven C. Sonka
        1975.   A World Food Analysis: Grain Supply and Export Capacity of American
                Agriculture Under Various Production and Consumption Alternatives.
                In CARD Report 60.   Ames, Iowa: Center for Agricultural and Rural
                Development, Iowa State Univ.

(1038) Hesse, Manfred
        1967. Die Elastizitaeten der mengenmaessigen Nachfrage nach Milch und
               Milcherzeugnissen in der Bundesrepublik Deutschland (Demand
               Elasticities for Milk and Milk Products in the F.R. Germany).
               Agrarwirtschaft, Special Edition 24. Hannover.

(1039) Houck, James P. and Jitendar S. Mann
        1968. An Analysis of Domestic and Foreign Demand for U.S. Soybeans and
               Soybean Products. Univ. of Minnesota Agr. Exp. Sta. Tech. Bul.
               256.

(1040) Houck, J.P., and M.E. Ryan
        1972. Supply Analysis for Corn in the United States: The Impact of
               Changing Government Programs. Amer. Jour. Agr. Econ. Vol. 54, No. 2
               pp. 184-191.

(1041) Houck, James P., Mary E. Ryan, and Abraham Subotnik
        1972. Soybeans and their Products: Markets, Models, and Policy.
               Minneapolis: Univ. of Minn. Press.

(1042) Houthakker, Hendrick S.
        1975. The Adequacy of Prospective Soybean Supplies. National Soybean
               Processors Association. Washington, D.C. July.

(1043) International Food Policy Research Institute
        1976. Meeting Food Needs in the Developing World: The Location and
               Magnitude of the Task in the Next Decade. IFPRI. Washington, D.C.
               February.

(1044) Japan. Ministry of Agriculture and Forestry
        1975. Long Term Prospects of Production and Demand of Agricultural
               Products in Japan. Tokyo: Ministry. August.

(1045) _____
        1974. Shokuryo Juyo Bunseki (Food Demand Analysis). Ministry Secretariat.
               Tokyo. (also 1971 report).

(1046) Johnson, D. Gale
        1975. World Food Problems and Prospects. Foreign Affairs Studies.
               American Enterprise Institute for Public Policy Research.
               Washington, D.C. June.

(1047) Josling, Tim
        1970. Exchange Rate Flexibility and the Common Agricultural Policy of the
               European Economic Community. Weltwirtschaftliches Archiv. Vol.
               104. No. 1.

(1048) Kennedy, F.M., E.A. Harre, T.P. Hignett, and D.L. McCune
        1968. Estimated World Fertilizer Production Capacity as Related to Future
               Needs 1967 to 1972-78. Tennessee Valley Authority. Muscle Shoals,
               Alabama. June.

(1049) Krishna, R.
        1963. Farm Supply Response in India-Pakistan: A Case Study of the Punjab
               Region. The Econ. Jour. Vol. 73. Sept.

(1050) Labys, Walter C.
        1975. Quantitative Models of Commodity Markets. Ballinger. Cambridge,
               Mass.

(1051) Langen, H.
        1970.   Projektion der Nachfrage nach Futtermitteln: Bestimmungs-gruende
                fuer die Nachfrageentwicklung nach Futtermitteln in der BR
                Deutschland seit 1950 und voraussichtliche Tendenzen der weiteren
                Entwicklung (Projection of the Demand for Feedstuffs: Basis for the
                Demand for Feeds in the FR Germany since 1950 and Prospective
                Trends). Frankfurt A.M. DLG-Verlags GmbH.

(1052) Mangahas, Mahar, Aida E. Recto, and V.W. Turran
        1966.   Market Relationships for Rice and Corn in the Philippines. Jour. of
                Farm Econ. Vol. 48. August.

(1053) Meadows, Dennis L., et al
        1974.   Dynamics of Growth in a Finite World. By Dennis L. Meadows, William
                W. Behrens III, Donella H. Meadows, Roger F. Naill, Jorgen Randers,
                and Erich K.O. Zahn. Cambridge, Mass.: Wright-Allen Press.

(1054) Meadows, D.L., and Meadows, D.H.
        1973.   Toward Global Equilibrium. Cambridge, Mass.: Wright-Allen Press.

(1055) Meadows, Donella H., et al
        1972.   The Limits to Growth: A Report for the Club of Rome's Project on
                the Predicament of Mankind. Universe Books. New York.

(1056) Mesarovic, Mihajlo, and Eduard Pestel
        1974.   Mankind at the Turning Point: The Second Report to the Club of Rome.
                New York: E.P. Dutton and Readers Digest.

(1057) Mellor, John W.
        1968.   The Functions of Agricultural Prices in Economic Development. Dept.
                of Agr. Econ. Cornell Univ., Ithaca, N.Y. Reprinted from the
                Indian Jour. of Agr. Econ. Vol. 23. No. 1. January-March.

(1058) Miller, S.F., and A.N. Halter
        1973.   Systems-Simulation in a Practical Policy-Making Setting: The
                Venezuelan Cattle Industry. Amer. Jour. Agr. Econ. Vol. 55, No. 3.
                pp. 420-432.

(1059) Plate, R., and G. Neidlinger
        1971.   Agrarmarkte und Landwirtschaft im Strukturwandel der Siebziger Jahre
                (Agricultural Markets and Agriculture in the Structural Change of
                the 1970's). Hiltrup bei Munster, Germany.

(1060) Prato, Anthony A.
        1973.   Milk Demand, Supply, and Price Relationships, 1950-1968. Am. Jour.
                of Agr. Econ. Vol. 55. No. 2. May.

(1061) Pontanel, Gounelle de, ed.
        1972.   Proteins from Hydrocarbons: Symposium Aix en Provence 1972.
                London: Academic Press.

(1062) Ryan, M.E., and M.E. Abel
        1973.   Oats and Barley Acreage Response to Government Programs. Agr. Econ.
                Res. Vol. 25, No. 4. pp. 114.

(1063) _____
        1973.   Supply Response of U.S. Sorghum Acreage to Government Programs.
                Agr. Econ. Res. Vol. 25, No. 2. pp. 45-55.

(1064) Schmitz, Andrew
        1968. An Economic Analysis of the World Wheat Economy in 1980. Ph.D.
               dissertation. Univ. of Wisconsin. Madison.

(1065) Schmitz, Andrew, and Lee D. Bawden
        1973. The World Wheat Economy: An Empirical Analysis. California Agr.
               Exp. Sta. Giannini Foundation Monograph 32. March.

(1066) Stamer, Hans, and Rudolf Wolffram
        1965. Die Nachfrage nach Agrarprodukten: Elastizitaeten und
               Entwicklungstendenzen (Demand for Agricultural Products:
               Elasticities and Trends). Agrarpolitik und Marktwesen Vol. 5.
               Hamburg: Verlag Paul Parey.

(1067) Takayama, Takashi
        1967. International Trade and Mathematical Programming. Australian Jour.
               of Agr. Econ. Vol. 11. pp. 36-48. June.

(1068) Takayama, Takashi, Hideo Hashimoto and S. Schmidt
        1976. Projection and Evaluation of Trends and Policies in Agricultural
               Commodity Supply, Demand, International Trade, and Food Reserves. 2
               Vols. College of Agr. Univ. of Illinois. Urbana-Champaign. June.

(1069) Takayama, Takashi, and George C. Judge
        1964. An Intertemporal Price Equilibrium Model. Jour. of Farm Econ. Vol.
               46. pp. 477-484. May.

(1070) _____
        1964. Equilibrium Among Spatially Separated Markets: A Reformulation.
               Econometrica. Vol. 32. pp. 510-524. October.

(1071) Tinbergen, Jan, Coordinator
        1976. Reshaping the International Order: A Report to The Club of Rome.
               New York: E.P. Dutton. Amsterdam: Elsevier.

(1072) United Nations World Food Conference
        1974. Assessment of the World Food Situation Present and Future. Rome.
               November 5-16, 1974. E/CONF 65/3. August.

(1073) _____
        1974. The World Food Problem--Proposals for National and International
               Actions. Rome. November 5-16, 1974. E/CONF 65/4. August.

(1074) University of California
        1974. A Hungry World: The Challenge to Agriculture. University of
               California Press, Berkeley, California.

(1075) U.S. Commission on International Trade and Investment Policy
        1971. United States International Economic Policy in an Interdependent
               World. Report to the President and 2 Vols. of Papers Submitted to
               the Commission. The White House. Washington. July.

(1076) U.S. National Academy of Sciences
        1975. Agricultural Production Efficiency. Washington, D.C. Academy.

(1077) _____
        1975. World Food and Nutrition Study: Interim Report. Washington, D.C.
               Academy.

(1078) _____ _____
        1977.   World Food and Nutrition Study: The Potential Contributions of
                Research. Washington, D.C. Academy.

(1079) U.S. National Advisory Commission on Food and Fiber
        1967.   Food and Fiber for the Future. Report to the President and 8 Vols.
                of Technical Papers. The White House. Washington. July.

(1080) U.S. President's Science Advisory Committee
        1967.   World Food Problem. Report of the Committee. The White House.
                Washington. May.

(1081) _____ _____
        1967.   World Food Problem. Report of the Panel on the World Food Supply.
                3 Vols. The White House. Washington. May.

(1082) U.S. Water Resources Council
        1972.   OBERS Projections: Economic Activity in the United States.
                Prepared by U.S. Dept. Com., Bur. Econ. Analysis, and U.S. Dept.
                Agr., Econ. Res. Serv. for U.S. Water Resources Council. 5 Vols. as
                follows: Vol. 1. Concepts, Methodology, and Summary Data. Vol. 2.
                BEA Economic Areas. Vol. 3. Water Resources Regions, 1-8. Vol. 4.
                Water Resources Regions, 9-20. Vol. 5. States.

(1083) Vandenborre, R.J.
        1967.   An Econometric Analysis of the Markets for Soybean Oil and Soybean
                Meal. Univ. of Illinois. Exp. Sta. Bul. 723. March.

(1084) Van Haeperen, J.M., and G. Boddez
        1967.   Estimation de la Production Agricola, de sa Structure et des Besoins
                en Aliments pour Betail 1970 et 1975 (Estimation of Agricultural
                Production, Its Structure and Requirements in Livestock Feed 1970
                and 1975). Cahiers de l'IEA. 63/R-31. Institute Economique
                Agricole. Ministry of Agriculture. Brussles, Belgium. March.

(1085) Walras, Leon
        1974.   Elements d'Economie Politique Pure: Ou Theorie de la Richesse Social
                (Elements of Pure Political Economy: Or Theory of Social Wealth).
                Lausanne: L. Crobaz et Cie.

(1086) Willett, Joseph W., ed.
        1975.   The World Food Situation: Problems and Prospects to 1985. 2 Vols.
                Dobbs Ferry, N.Y.: Oceania.

(1087) Wilson, Robert, R., and Russel G. Thompson
        1967.   Demand, Supply, and Price Relationships for the Dairy Sector. J.
                Farm Econ. Vol. 49. pp. 360-371. May.

(1088) Womack, Abner
        1976.   The U.S. Demand For Corn, Sorghum, Oats and Barley: An Econometric
                Analysis. Dept. of Agr. and Appl. Econ. Univ. of Minnesota Econ.
                Report 76-5. pp. 1-172.

(1089) United Kingdom. Ministry of Agriculture, Fisheries, and Food
        1950 onward. Household Food Consumption and Expenditure. Annual Report of
                the National Food Survey Committee. London. The Ministry.

XI. Weather Literature Citations

(1100) Baier, Wolfgang
        1975. Weather and World Food Situation. Canada Agriculture. Journal of
        the Canadian Dept. of Agriculture. Ottawa. Canada. Winter.

(1101) Baker, K.F.
        1975. Weather Trends, Climatic Change and the 1975 Season. Soil Series
        94. U.S. Dept. Agr. Washington, D.C. February.

(1102) Bird, Alan R.
        1975. Foodplexes: Are They a Key to Better Living for All? U.S. Dept.
        Agr. Econ. Res. Serv. Working material. October.

(1103) Broecker, J.
        1975. Climatic Change: Are We on the Brink of a Pronounced Global
        Warming? Science. Vol. 189. No. 4201. August.

(1104) Bryson, R.A.
        1974. A Perspective on Climatic Change. Science. Vol. 184. No. 4138.
        December.

(1105) Collis, Ronald
        1975. Weather and World Food. American Meteorological Society Bulletin.
        October.

(1106) Duckham, A. G.
        1972. Climate, Weather, and Human Food Systems: A World View. Weather.
        Vol. 29.

(1107) Gasser, William R.
        1976. World Climatic Change and Agriculture: The Issues. Paper presented
        at Symposium on Living with Climatic Change. Phase II. Reston, Va.
        November.

(1108) Gribbin, John
        1976. Climatic Change and Food Production. Food Policy. Surrey.
        England. August.

(1109) _____
        1976. Forecasts, Famines, and Freezes. Walker & Co. Press. New York.

(1110) International Institutes for Advanced Study and the Aspen Institute
        for Humanistic Studies
        1975. The Policy Implications of Food and Climate-Interactions. Summary
        of an IFIAS Project Workshop at Aspen-Berlin, Colorado. February 5-
        7.

(1111) Jensen, Raymond
        1975. A Summary of Estimated Impacts of Climatic Change on Crop
        Productivity. Fourth Conference on Climate Impact Assessment
        Program. February 4-7. Cambridge, Eng.

(1112) Katz, Michael
        1977. Assessing the Impact of Climatic Change on Food Production.
        Climatic Change. Boulder, Colorado. January.

(1113) Lamb, Hubert
   1973. Climatic Change and Foresight in Agriculture: The Possibilities of
   Long-Term Weather Advice. Outlook on Agriculture. Vol. 7. No. 5.

(1114) McBoyle, Geoffrey
   1973. Climate in Review. Houghton Mifflin Co. Boston.

(1115) McQuigg, J.D.
   1976. Climatic Constraints on Food Grain Production. World Food
   Conference. June 27-July 1. Ames, Iowa.

(1116) _____
   1977. Effective Use of Weather Information in Projection of Global Grain
   Production. Chapter 17 in: Food Enough or Starvation for Millions.
   Edited by Douglas Ensminger. Compendium of papers from a Seminar on
   Population and Food and Agricultural Development organized by the
   International Association of Agricultural Economists in
   Collaboration with FAO and UNFPA, held in Rome, December 1-5, 1975.
   New Delhi, India: Tata McGraw Hill Publ. Co. Ltd. Copyright by FAO
   1977.

(1117) Newman, James
   1974. World Climates and Food Supply Variations. Science. Vol. 186. No.
   4167. December 6.

(1118) Rockefeller Foundation
   1976. Climatic Change, Food Production and Interstate Conflict. Working
   Papers presented at a Conference on Climatic Change and Food
   Production, held June 1975 at Bellogio, Italy.

(1119) Science Council of Canada
   1976. Living with Climatic Change. Proceedings of a Toronto Conference
   Workshop, held November 17-22, 1975. Toronto, Canada.

(1120) Sterling Forest Conference
   1974. World Food Supply in Changing Climate. Proceeding of Sterling
   Forest Conference, held December 2-5, 1974. Sponsored by American
   Society of Agronomy and Aspen Institute for Humanistic Studies.

(1121) Thompson, Louis
   1975. Weather Variability, Climatic Change, and Grain Production.
   Science. Vol. 188. No. 4188. May 9.

(1122) _____
   1975. World Weather Patterns and Food Supply. Journal of Soil and Water
   Conservation. Ankeny, Iowa. January-February.

(1123) U.S. National Defense University
   1977. Future World Climatic Change. Research Directorate Manuscript.
   Publication pending in 1978. The University.

(1124) U.S. National Research Council
   1975. Climatic Change: A Program for Action. Report by Committee for the
   Global Atmosphere Research Program. Washington, D.C. The Council.

(1125) _____
   1976. Climate and Food. Report by Committee on Climate and Weather
   Fluctuations and Agricultural Production. Washington, D.C. The
   Council.

END

DATE
FILMED

7-24-79

NTIS