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SERIE RESEARCHMEMORANDA

WORLD FOOD PROSPECTS TILL 2000

Hans Linnemann

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AMSTERDAM**

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Hans Linnemann

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World Food Prospects Till 2000

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I. SOME RECENT LONG-TERM STUDIES

In recent years, a number of studies on the long-term prospects of the world's food and agriculture situation have been made.¹ In spite of differences in methodology, data base, and country coverage, it is interesting to compare some of these studies in terms of their main results - results which may perhaps be described as 'conditional forecasts'. Three such studies will be briefly reviewed here, viz. the FAO (1981) study Agriculture: Toward 2000, The Global 2000 Report to the President prepared by the Council on Environmental Quality and the Department of State of the US (1980), and the analysis of Linnemann, De Hoogh, Keyzer and Van Heemst (1979) in MOIRA: Model of International Relations in Agriculture. Of Global 2000, only the food and agriculture model is discussed. The three analyses have in common that they are agricultural sector studies only, even though MOIRA formally has one non-agricultural sector as well. Also, in all studies growth of population and of GDP (in MOIRA non-agricultural GDP) is given exogenously.

AT 2000 is based on a detailed analysis of production and demand prospects for 28 crop and 6 livestock products. The 90 developing countries studied individually comprise nearly all of the developing world outside China; the 34 developed countries that are included are examined more summarily. No formal economic model linking all countries and commodities is used. An effort has been made to

incorporate in the country analyses (particularly for the developing countries) all accumulated information and insight built up by FAO over the years - including data on land classes, and current input and investment requirements. The quantitative analyses are built primarily around three scenarios for the 90 developing countries: a trend scenario based on an extrapolation of past trends, an optimistic Scenario A based on the high economic growth objectives of the UN International Development Strategy and substantially improved agricultural performance, and a medium-growth Scenario B based on more modest growth rates in both agriculture and the overall economy.

The Global 2000 study has made use of the Grain-Oilseed-Livestock (GOL-) model developed by staff members of the US Department of Agriculture. The GOL-model is described as a conglomerate of some 28 regional agricultural sector models made up of grain, oilseed, and livestock supply, demand and trade equations that sum to a world total; hence, it emphasises cross-regional and cross-commodity quantity and price linkages. On the basis of historic trends per region in the relation between growth in GOL commodities and growth in total food production, the GOL projections are in a submodel augmented to arrive at total food projections. Other simple submodels relate to arable land and fertilizer use. Three alternative sets of projections are generated: Alternative I is a baseline projection assuming median growth rates of population and per capita incomes together with unchanged policies, weather conditions and energy prices; II is an optimistic upper bound with lower population growth, higher per capita incomes and favourable weather; and III is seen as a lower bound with higher population growth, lower per capita income growth, poor weather conditions and higher (than 1974-76) energy prices.

The third study referred to here is MOIRA, a model of international relations in agriculture that has been developed and used to simulate alternative (international) food policies. It describes the food sector of 106 individual (groups

of) countries, and links these sectors by means of an equilibrium model of international trade. Agricultural production is measured in terms of vegetal protein produced, of which a constant percentage per country is consumable protein or food. The production decision follows from behaviour equations. At the demand side, food consumption is modeled for six agricultural and six non-agricultural income classes. Government policies at the border affect the domestic food price level and the relative income position of agricultural producers. Overall results of four simulation runs are shown here, two runs (111 and 113) assuming high rates of growth of non-agricultural GDP and two runs (211 and 228) assuming low growth outside agriculture. Runs 111 and 211 assume unchanged policies, run 113 is based on the assumption that income inequalities outside agriculture are gradually reduced to one half of their initial magnitude over a 35-year period, and run 228 simulates the effects of a specific package of international food policies, i.e. world food market price stabilization (at a relatively high level) and large-scale food aid to food-deficit income groups.

II. GLOBAL PROSPECTS

In the present context it is impossible to go into the specifics of the methodology of the three studies and to discuss their stronger and weaker points. The purpose of a comparison of the results obtained in the different studies is primarily to see whether or not the three approaches lead to significantly different future development perspectives for the food and agriculture sector. Table 1 presents a summary picture, mostly in terms of future annual growth rates of important variables, of the quantitative results obtained in the various scenarios for the period till 2000, for all developing countries (LDCs) together and all developed countries (DCs) together.

Perhaps the most important point on which the three studies agree is the fact that achieving a long-run rate of growth of agricultural production in LDCs of

at least 3 percent per year is judged to be feasible; note, however, that this relatively good performance of the agricultural sector is associated with high rates of overall economic growth. In the DCs, agricultural output increases at a slower pace; in MOIRA runs 111 and 113 this rate of increase is higher than the historical rate of the recent past due to high levels of demand and prices. For obvious reasons, food demand per capita shows much lower growth rates; in AT 2000 food demand per capita increases at a higher rate in LDCs than in DCs, while for Global 2000 the opposite is true because of higher population growth assumptions for LDCs (see the Notes by Table 1) combined with lower overall growth assumptions.

From the point of view of reducing the prevalence of hunger and malnutrition (undernutrition) in the world, it is the increase in food consumption per capita in LDCs only that matters. Due to changes in the composition of the food basket when incomes increase, higher per capita food consumption levels result only in part in higher calorie consumption; hence, average levels of calorie intake improve even more slowly than average food consumption (assuming unchanged distributional inequalities). All studies tried to estimate the changes in the number of undernourished people, according to the various scenarios. None of them foresees a complete eradication of hunger and malnutrition by the year 2000. On the contrary, the number of people whose food intake remains below the assumed norms is likely to remain high, with a considerable reduction in numbers only in AT 2000 Scenario A, a small reduction in AT 2000 Scenario B and Global 2000 Alternative II, and a constant number in MOIRA run 113. Estimates of this kind are hard to make and do not go undisputed²; for this reason no figures are given here, but it is clear that the studies paint a bleak future for the hungry in the world.

The implications of the possible development paths of agriculture for world trade in food are shown in the last two columns of Table 1. Most alternatives show a further strengthening of the export position of (a number of) developed countries, or at least (in the case of Global 2000) the continuation of export

Table 1 Average annual percentage growth rates, for the period till 2000, of the exogenous variables population and GDP, and of gross agricultural production, food demand per capita, and calorie consumption per capita; self-sufficiency ratios in the year 2000

	popu- lation	GDP	gross agricult. production	food consumption per cap.	calorie consumption per cap.	SSR all cereals	
	(1)	(2)	(3)	(4)	(5)	DCs (6)	LDCs (7)
AT 2000:						78-79 = 107	78-79 = 91
Trend scenario							
DCs	0.7		1.5 - 1.3	0.5	0.2	117	
LDCs	2.4		2.8	0.5	0.3		83
Scenario A							
DCs	0.7	3.8	1.1	0.5	0.2	109	
LDCs	2.4	7.0	3.7	1.3	0.8		93
Scenario B							
DCs	0.7	3.2	1.2	0.5	0.2	114	
LDCs	2.4	5.7	3.1	0.8	0.5		87
						73-75 = 116	73-75 = 93
Global 2000:							
Alternative I							
DCs	0.5	3.4	1.5	0.8		114	
LDCs	2.4	4.6	3.0	0.3	0.3		93
Alternative II							
DCs	0.3	4.1	1.5	1.1		106	
LDCs	2.0	5.1	3.3	0.5	0.3		96
Alternative III							
DCs	0.7	2.8	1.2	0.3		116	
LDCs	2.7	4.0	3.1	0.0	0.0		92
						SSR all agric.	
						74-76 = 92	74-76 = 102
MOIRA:							
Run 111							
DCs	0.8	(4.1)	3.0	1.5		110	
LDCs	2.4	(6.1)	3.5	1.5	(0.8)		93
Run 113							
DCs	0.8	(4.2)	3.3	1.7		112	
LDCs	2.4	(6.1)	3.6	1.7	(1.0)		90
Run 211							
DCs	0.8	(2.1)	1.8	0.7		100	
LDCs	2.4	(3.2)	2.4	0.0	(0.0)		99
Run 228							
DCs	0.8	(2.1)	1.6	0.6		98	
LDCs	2.4	(3.4)	3.2	0.6	(0.3)		105

Notes by Table 1:

All figures have been taken directly from the three studies mentioned in the main text, or have been computed from data contained in these studies. However, figures in parentheses are estimates only. To improve legibility, all growth rates have been rounded off to show one decimal place only. Main characteristics of the various scenarios, alternatives and runs are given in the text.

Country coverage of the two groups DCs (developed countries) and LDCs (developing countries) is not exactly the same in the three studies, the most important difference being that in AT 2000 DCs comprise - in addition to 26 developed market economies - eight developed centrally-planned economies including the USSR. In the other two studies, DCs (as reported here) comprise developed market economies only. In all three cases, LDCs as given here exclude China.

AT 2000: time period 1980-2000. Trend scenario: based on past trends over the period 1961-65 to 1980, with slight modifications; col. (2): no explicit economic growth assumptions are made for this scenario, the historical figures being approximately 4.2 for DCs and 5.5 for LDCs; col. (3): the trend figure of 1.5 for DCs implies growing world surpluses (cereals), while the lower figure of 1.3 is based on DCs production accommodation to the net trade balances of the rest of the world.

Global 2000: time period 1970-2000. Col. (1): explicitly mentioned as assumed rates for the period 1975-2000. Reported results, as e.g. for total grain and grain per capita, imply different population growth rates, however; implied average population growth rates for 1974-2000 are, for the three alternatives, for DCs 0.7, 0.6 and 1.0, respectively, and for LDCs 2.6, 2.4 and 3.0, respectively. Col. (3): total food production.

MOIRA: time period 1975 (already a simulation year)-2000. Col. (2): exogenous is non-agricultural GDP growth, with 4.2 (DCs) and 7.2 (LDCs) for high-growth runs and half these values for low-growth runs. Col. (5): not given explicitly in the study but estimated from its Table 8.12. Cols. (6) and (7): SSRs refer to all agriculture.

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surpluses of these countries. In Third-World countries, the share of domestic food demand that has to be covered by imports tends to increase except in the most favourable cases (AT 2000 Scenario A, Global 2000 Alternative II). The volume of world trade in food is likely to increase at a higher rate than world production. Note that the self-sufficiency ratios (SSRs) refer in the case of MOIRA to all agricultural production; their level cannot be compared directly to that of the other two studies in which SSRs for all cereals are given.

III. REGIONAL DIFFERENCES

The figures of Table 1 give a crude indication of what might happen in future years, and focus on the North-South comparison only. Within the South, however, future developments may differ considerably between countries and regions. Table 2 gives an impression of the regional differences as they show up in the three studies under review, according to selected alternatives. From AT 2000, the medium-growth Scenario B is chosen; from Global 2000 the medium Alternative I (with constant energy prices) is selected, and from MOIRA the 'unchanged policy' runs 111 and 211 with high and low non-agricultural growth rates, respectively. The geographical coverage of the regions differs somewhat between the studies, as indicated also in the notes by the table.

The relationships between the variables shown in the columns of Table 2 are obvious but at the same time not straightforward. The figures in the first six columns are averages over countries and/or products, thus obscuring in part underlying variations. Food consumption per capita in col. (4) strongly depends on per capita income as determined by cols. (2) and (1). However, food consumption growth is also influenced by relative price changes (particularly in Global 2000 and MOIRA) and by the structure of income distribution (MOIRA). The development of total demand for food, cols. (4) and (1), is the main driving force behind the growth of agricultural production, col. (3), but the latter also depends on a country's production conditions and on export demand and import

Table 2 Average annual percentage growth rates, for the period till 2000, of the exogenous variables population and GDP, and of gross agricultural production and food demand per capita; self-sufficiency ratios and net cereal trade in 2000; for major LDC regions

	popu- lation	GDP	gross agricult. production	food consumption per cap.	SSR all cereals		net cereal trade 2000 in mln tons
	(1)	(2)	(3)	(4)	1975-79	2000	(7)
AT 2000:							
Scenario B:							
Latin America	2.6	6.0	3.3	0.8	98	94	- 10
Near East	2.6	5.4	3.0	0.5	82	72	- 30
Africa	3.0	5.4	3.4	0.6	83	70	- 36
Asia and Far East	2.1	5.8	3.0	0.9	95	93	- 29
Global 2000:					SSR all cereals		
Alternative I:					1973-75	2000	
Latin America	2.6	4.8	3.5	0.8	101	108	+ 14
N.Afr./M. East	2.8	6.3	3.1	0.2	78	72	- 35
Other Africa	2.7	5.2	2.3	- 0.7	93	97	- 2
South Asia	2.1	3.0	2.7	0.3	95	93	- 19
Southeast Asia	2.2	4.6	3.7	0.5	120	129	+ 14
East Asia	2.0	5.1	3.1	0.8	79	73	- 26
MOIRA		non- agric. GDP			SSR all agric.		
Run 111:					1974-76	2000	
Latin America	2.5	7.2	3.9	1.9	113	100	
Middle East	2.9	9.6	4.6	2.3	85	65	
Trop. Africa	2.5	6.3	3.8	1.9	104	93	
Southern Asia	2.3	4.4	2.7	0.6	101	97	
Run 211:							
Latin America	2.5	3.6	3.7	0.5	114	140	
Middle East	2.9	4.8	3.6	0.7	81	85	
Trop. Africa	2.5	3.1	2.2	0.0	106	96	
Southern Asia	2.3	2.2	0.4	- 0.9	101	75	

Note: in col. (7), minus is imports, and plus is exports

Notes by Table 2:

Country coverage and regional boundaries are not exactly the same in the three studies. China is excluded in all cases; only AT 2000 includes other Asian centrally-planned economies. Latin America has the same boundaries in the three studies.

AT 2000: Near East is bounded by Turkey, Libya, Sudan and Afghanistan. Africa includes the Maghreb countries. Asia and the Far East runs from Pakistan eastwards.

Global 2000: North Africa/Middle East is bounded by Turkey, the Maghreb countries, Sudan and Iran. South Asia is bounded by Afghanistan and Bangladesh. Southeast Asia comprises Burma and the Mekong countries. East Asia runs from Malaysia eastwards.

MOIRA: Middle East is bounded by Turkey, Libya, Sudan and Iran. Tropical Africa excludes the Maghreb countries. Southern Asia runs from Afghanistan eastwards.

See the notes by Table 1 for the time period covered in the three studies. As regards Global 2000: Col. (1): explicitly mentioned as assumed rates for the period 1975-2000. However, except for Latin America regional population growth rates implied in the reported production figures are different; for these regions implicit population growth rates are about 0.4 higher than the figures of col. (1). Col. (3): total food production.

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supply. Differences between the rate of growth of food (agriculture) production and the rate of growth of food (agriculture) consumption are reflected in changes in the level of SSRs, cols. (5) and (6). For the main food commodity in international trade, cereals, the volume of trade as implied by col. (6) is shown in col. (7). In addition to the table, note that for all agriculture together Scenario B of AT 2000 results in virtually the same SSR in 2000, for all LDCs combined, as in the late 1970s, with Latin America as an important net agricultural exporter.

Above, differences in (natural) production conditions were alluded to in passing. As the process of photosynthesis is basic to all agricultural production, natural resource availability (in particular arable land) influences future prospects. The most detailed, both country- and crop-specific, assessment of production potential has been made in the AT 2000 study. For the period 1975-2000, detailed estimates indicate that for all LDCs together the factors contributing to increased output will be arable land growth (26 percent), increased cropping intensity (14 percent) and higher yields (60 percent). In land-rich Latin America, the contribution of enlarging the use of arable land is as high as 55 percent, while in Asia and the Far East 76 percent of the increase has to come from higher yields, implying the use of more and better inputs. In Global 2000 the increase in arable land over the same period is much more limited: less than 10 percent for all LDCs together, just over 12 percent in Latin America, a bit more than that in Other Africa, and no increase at all in North Africa/Middle East and in South Asia. Hence, yield increases play a predominant part in production growth in this study; they are (as far as can be deduced from the model description) partly autonomous, partly price-induced. In MOIRA, a completely different procedure has been adopted as regards the natural resource base. Per country the theoretical upper limit (using all arable land, with maximum yield per land class) of agricultural production has been estimated. This upper limit of the agricultural resource base is then used

as an asymptote determining the shape (slope) of the production function; increasing intensity of land use leads to diminishing marginal productivity of the input mix. The agricultural resource base, defined in this way, offers more favourable prospects for output expansion to Latin America and Africa, according to MOIRA, than to other LDC regions.

Variations between the different regions in the three exogenous factors population growth, GDP growth, and agricultural resource base are reflected in the regional differences in possible future development paths as shown in Table 2. Of the developing regions, Latin America would seem to be in the best position as regards its food and agriculture prospects; yet even for this region the SSR may decline. For South Asia and Tropical Africa in particular the future would seem to be grim. Regarding the SSRs, the overall picture is that they tend to decrease in the projections shown in the table, resulting in large food import needs in most developing regions. North American food exports would thus increase considerably, provided the developing countries have the foreign currency to pay for the imports needed.

All this will not come as a surprise to anyone familiar with present-day views on the world food situation; in point of fact, there is probably a good deal of agreement regarding the future outlook for world agriculture, given today's national and international policies. To be sure, the preceding thumbnail sketch of some of the quantitative results of the three studies does not do justice to their analyses and cannot reflect in any way the amount of expert knowledge incorporated in these and many other findings. This is most obviously so in the case of AT 2000, containing a wealth of additional information of a factual and policy nature. Nevertheless, both AT 2000 and Global 2000 should perhaps be criticised for paying little or no attention to alternative development paths that would follow from more fundamental changes in world food policy. A first attempt in this direction has been made in the MOIRA study, and a few aspects of it may be worth mentioning here.

IV. THE WORLD FOOD SYSTEM

The point of departure of most - if not all - approaches to a structural improvement of the world food situation characterised by widespread undernutrition in Third-World countries is the aim to increase as much as possible food production (and gainful agricultural employment) in these countries themselves. The reasons for focussing on LDC domestic production are well-known and need not to be elaborated upon here: high agricultural growth rates are needed (i) to create employment and income for the rural population (where poverty is greatest, and other jobs scanty), (ii) to increase the domestic supply of food and reduce the food import burden weighing heavily on the balances of payments of many countries, and (iii) to avoid LDC political dependence from food exporting countries that might result from continued heavy reliance on food imports. The aim of maximum food production growth in the LDCs is primarily to be pursued by domestic policies in these countries, but the effectiveness of such policies also depends on the world food market constellation and hence on food and agriculture policies of the industrialised countries.

AT 2000 explicitly recognises this point, and advocates accommodation of developed-country production and world market supply to the agricultural performance of the developing world. This is indeed what would be needed; however, the question is how far this accommodation could and should go, and how it is to be realised. The price mechanism, too, forces for example the major world market suppliers to 'accommodate' to changing market constellations, but this type of accommodation may not be the most desirable one from the point of view of stimulating Third-World production. It has led, over the past decades, to an increasing domination of the world grain market by a few suppliers backed by adequate financial resources and by a highly commercialised and flexible agricultural sector. In a world of fluctuating international food prices, food producing sectors and countries with greater agility stand to gain in the course of time.

Domestic and international food prices and price policies play an important part in the MOIRA analysis. Governments are assumed to pursue a domestic food price policy aiming at a desired relative income level of the agricultural sector; at the same time, world market food prices influence the domestic price level - the stronger the more the SSR deviates from 100 (and the smaller the budgetary means available for subsidising imports or exports, if needed). In developing countries, with a large share of population in agriculture, food supply is less price-sensitive than in the developed countries due to a lower level of use of purchased inputs and a lower degree of commercialisation. Under these conditions, price incentives to (more rapidly) expand food production have to be adequate and stable, as it takes time to adapt to the more advanced technique required for output growth. Stability of world market prices is needed for domestic price stability in open economies, and the level of stable international prices affects the level of the domestic food prices.

On the basis of these considerations, MOIRA has tried to analyse the effect of an international food price policy on LDC production growth and the extent of undernutrition. It is assumed that the developed countries jointly decide to implement an international food policy characterised by three (derived) objectives: price stabilisation, maintenance of a desired price level, and food aid to target groups. To pursue this policy, developed countries are required to have control over their (net) position in exports and imports of food; this, in turn, may require the use of additional, or more appropriate, policy instruments domestically to influence relevant variables, in particular production levels. Obviously, stock policy has a role to play as well. Simulation runs of MOIRA make it plausible that both price stabilisation of the world market food price and the level at which this price is stabilised do have an impact on Third-World food production growth. In an international food (price) policy along these lines, the extent or degree of 'accommodation' by the developed countries may certainly be larger than that implied by the AT 2000 scena-

rios; nevertheless, the relevant simulation runs do not show any 'dramatic' consequences of such policy for developed-country agriculture.

It is not difficult to list a number of shortcomings of the MOIRA analysis. In fact, the report states that the model is not "a readily available instrument for prediction and policy making", and it indicates which parts or aspects of the model are most in need of further improvement. An objection of an altogether different nature would be that the political preconditions for a consistent international food policy along the lines indicated above are totally lacking. The latter argument, however, should not be used to obscure the fact that a better understanding of the functioning of the present world food system - including the functioning and the effects of the price mechanism of the world market - is essential to selecting the proper policy package for fighting world hunger. As regards the improvement of the Third-World food situation, the record of the past decades is not very satisfactory, nor is the present outlook. Thorough analysis of past developments and of alternatives for the future, including those presently judged politically very difficult, remains therefore of utmost importance.

V. A NEW APPROACH

A challenging but basically promising approach in this direction is the Food and Agriculture Program of the International Institute for Applied Systems Analysis (IIASA) at Laxenburg, Austria. In several respects, this is presumably the largest integrated research effort in the area of the world food problem undertaken to date. The research programme, started in 1976, tries to develop national policy models for food and agriculture for more than 20 countries (or groups of countries) that interact through the world market (Parikh and Rabár, eds., 1981). The food problem is seen as "a problem of inadequate food provision for a large number of people as a result of insufficient income and improper distribution, which is exacerbated by uncertain climatic conditions, and

which is amenable mainly only to national policies that are constrained by the actions of other countries. Thus the food and agriculture system of the world is best viewed as a set of national agriculture systems embedded in national economies affected by national governments' policies and interacting with one another." (Ibid., p. 4). As will be clear from this description of the setting of the analysis, the FAP model system will be eminently suited to deal also with the type of questions that MOIRA tried to address.

The national models being developed as part of the FAP system distinguish a varying number of agricultural commodities that are aggregated according to a common classification for international trade linkage. The country-specific models cover the whole economy, and thus have to contain at least one non-agricultural sector and sectoral interdependencies. The food and agriculture sectors are modeled in considerable detail, reflecting heterogeneity of production conditions and techniques between and within these sectors; also, the models differentiate between socio-economic groups in terms of their behaviour, income levels and the like. In addition to the supply module and the demand module, the third main component is the policy module describing the set of policy instruments that can be used by the government - some of them affecting domestic producers or consumers directly and others operating through the exchange part. Every country model has to meet a number of basic (formal) requirements to allow it to be linked into the system as a whole. The innovative methodology underlying the linkage system has been developed mainly by Keyzer (1981a, 1981b). The entire FAP structure can thus be described as a system of linked computable general equilibrium models for food and agriculture policy analysis.

As the FAP model system of IIASA is still being developed, no results of full system runs are available as yet. The system allows the detailed national models to be replaced by simplified models that are condensed versions of their detailed counterparts, or by simpler models preceding in time the ultimate national models. The latter type of simplified models has been used in the so-called basic linked system for a number of (trial) runs. A summary descrip-

tion of some of the national models is given in Parikh and Rabár, eds. (1981); most of them are being developed by research groups outside - but cooperating with - IIASA. The national models that have been built for some Asian countries by the Centre for World Food Studies, in collaboration with research institutes in the countries concerned, are good examples of the type of 'linkable model' that is aimed at. The models incorporate a large amount of detailed agronomic information and reflect a close cooperation between agronomists and economists in depicting the characteristics of a country's specific agricultural and socio-economic situation. Documentation is available for the Thailand and for the Bangladesh model (Centre for World Food Studies, 1980, 1983).

IIASA's basic linked system is operational now, with detailed models for some countries and simplified models for others. Some tentative results of two BLS runs may be mentioned here.³ An 'unchanged-policy' or base run generates economic growth rates that are not unlike those of Global 2000 Alternative I or the AT 2000 Trend scenario; the results of this run may be compared with those of a 'free-trade' run in which for all agricultural products all quotas are released and all duties or subsidies at the border removed (except for the centrally-planned economies) over a five-year period starting 1981. In both runs, world agricultural production increases over the period 1980-2000 by just over 2 percent per year, with population growth at 1.7 percent. Taking into account the increasing income per capita, it is not surprising that food prices tend to increase relative to non-agricultural prices, with on average relative food prices in 2000 that are 20 to 30 percent higher than in 1980. The world market dairy price - initially low as compared to most national prices - even doubles over this period; elimination of the generally high level of protection of this sector results in strongly increasing demand. Average per capita calorie intake increases very slowly only, and in most LDCs at a rate lower than in the past. Due to the higher food prices, it is the nutritional status

of the agricultural population that will improve rather than that of the urban population. Just as in the other studies discussed earlier, world trade in food expands faster than world production - especially so, for obvious reasons, in the free-trade run.

The consequences of opening-up national agricultural sectors to world market influences vary greatly between different countries. Of course, in the free-trade run specialization increases - not only within agriculture but also between agriculture and non-agriculture. In the latter run, e.g., India would (have to) become one of the world's major industrial exporters to pay for the food imports needed; it would become the world's largest importer of dairy products. Leading exporters of dairy would be the European Community, Canada, New Zealand and Mexico. Trade in (bovine and ovine) meat would also expand strongly, with Brazil, Canada, Argentina and New Zealand as top exporters, and the European Community as by far the most important importer. All this would greatly affect trade flows of protein feed, with the US and (at a distance) Brazil as major exporters. As regards trade in cereals, the differences between the two BLS runs are less pronounced; although for some countries the differences in outcome are substantial, the overall trade pattern is not much affected and in both runs the US exports some 150 million metric tons of cereals in 2000, while Canada, Argentina and Australia together supply another 80 to 90 million tons. Note that the CMEA countries and China are assumed to import about 40 and 50 million tons of cereals, respectively.

Especially at the country level it is interesting to compare the results of the two runs, but the space available does not permit us to go here in further detail. Although from the point of view of the Third-World food problem the policy alternative of 'free trade' in agricultural products is probably not the most promising one to be examined (leaving apart issues of political feasibility), it nevertheless illustrates the potential usefulness of the model system developed at IIASA. Of course, the significance of the first and preliminary results

should not be overestimated; yet, this author is convinced that the new approach outlined above is a step in the proper direction for food policy research. In economics, all too often research is undertaken at a certain 'level' of analysis (international, national, micro) without giving due attention to the interaction with the other 'levels' and their actors. Some recent studies of commodity markets try to avoid this limitation (with interesting consequences), and so is the FAP model system of IIASA. The novel way in which policy instruments and their use are built into the models, and the systematic incorporation of a considerable amount of agronomic knowledge also warrant a certain optimism as to the potential improvement of our understanding of the world food system.

VI. UNCERTAINTIES REMAIN

Nevertheless, many uncertainties remain for the time being. In section IV we stressed the importance of developments in the world food market for agricultural production growth in LDCs, and indicated that fluctuating and relatively low world market prices may have (had) negative effects on the rate of LDC agricultural growth. Assuming, for the moment, that this is true, how much does this factor contribute to an explanation of past developments? Has it been the main or only a marginal factor causing the post-war changes in the pattern of world food trade? Would better national LDC agricultural policies have been possible, given the functioning of the international system, and the role played by developed-country agriculture (US, Canada, EC, etc.), and how much difference would it have made? Answers to this type of questions may show what are the priority areas for future policy.

A model system such as developed at IIASA would seem to be the best tool available for trying to find these answers. But not all forces and factors lend themselves for incorporation in a model - least of all those factors of which the effects (or even their existence) are highly uncertain or simply

unknown as yet. What does it mean for the world food system that trade in cereals is dominated by five or six trading houses? Is the recent upsurge of 'agribusiness' a significant phenomenon, or not? Is there a trend towards 'westernization' of food consumption habits in LDCs, and if so, how important is it? In the realm of agronomic sciences, too, open questions remain and ecological processes are understood only partially. After the doomsday prophesies of the Club of Rome as to the biophysical limits to food production the pendulum has swung in the opposite direction - but is it perhaps swinging too far again, and are we underrating the long-term problems at the supply side of agriculture?

This list of questions can easily be extended, even if we limit ourselves (and it is an important limitation) to the economic aspects of the world food problem. Fortunately, the 1970s have witnessed an increased research interest in the area of food and agriculture; a selective survey of recent developments in international agricultural trade models by Thompson (1981) contains no less than 276 references. Research bodies like the International Food Policy Research Institute (IFPRI) are making valuable contributions to our understanding of the food situation and its prospects. Within the limits of this paper it is impossible to do justice to all ongoing efforts in the field. But even if the paper had done so, its main tenor regarding the world food prospects till 2000 would not have been different: there is every reason for serious concern.

NOTES

- 1 For a survey of a number of such studies, see also De Haen (1979) and Fox and Ruttan (1983).
- 2 For a critical discussion of (the high) estimates of the magnitude of world hunger, see e.g. Poleman (1981).
- 3 I am indebted to Dr K. Parikh of IIASA for making a number of computer print-outs available to me. For any possible inaccuracies or misrepresentation of results of these runs, responsibility rests entirely with me and not with IIASA.

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