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POPULATION AND FOOD

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Abstract

The impact of population size and its rate of growth on levels of living in general and on the demand and/or supply of a basic necessity such as food has long attracted the attention of economists and economic demographers. This paper reviews some recent models of the world food economy in the context of a rapidly growing population in the developing countries. The models range from population carrying capacity exercises devoid of any economics to dynamic general equilibrium models. It would appear from the projections of various models that the demand for food likely to arise from anticipated income and population growth during the next two to three decades or even longer can be met. Yet for an analysis of the long term interaction between population growth and economic development these models are inadequate, for the reason that the behavioural response of households, producers, investors and inventors to anticipated imbalances between supply and demand in terms of changes in fertility behaviour, in the rate and character of technical change, in the rates of saving investment in physical and human capital, etc. are not adequately modeled. At any rate, contrary to the widespread impression, it is not rapid population growth but inappropriate public policies towards agriculture that seem to account for the failure of many developing countries to assure an adequate level of food consumption for their citizens.

Population And Food

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1. Introduction

The impact of population size and its rate of growth on levels of living in general and on the demand for and supply of a basic necessity such as food has long attracted the attention of economists and economic demographers. Almost all recent analyses of the food-population nexus necessarily focus on developing countries. Most of the contemporary developed countries have crossed the stage of demographic transition and are currently experiencing only a slow growth, if any, in the size of their populations. Given their high real income levels, their demand for food in general (and for food grains in particular) is unlikely to grow rapidly, and as such, their role in the world food economy is more sigfnificant on food supplies and exports, although the impact of the imports of a few developed countries such as the USSR on international trade in food and feedgrains could be important. For example, while the cereal imports of industrialized market economies was virually unchanged at about 65.5 and 66.1 million tons respectively in 1974 and 1982, the imports of USSR rose from 7.8 to 40.1 million tons and the imports of less developed countries rose from 64.2 to 95.6 million tons (World Bank (1984), Table 6, p.228). Still, it is fair to say that among the factors that influence the import demand for grains by the USSR population growth is unlikely to be significant.

One could distinguish several channels of influence in each direction in the relationship between population and food. (i) Population growth (and hence the size of the population in the future) obviously affects the demand for food. With growth of income and its distribution among socio-economic groups kept unchanged, an exogenous increase in the rate of growth of population of any group will imply a slower growth of its income per head and hence a slower growth of its food demand per head. However, as long as the elasticity of demand for food per head with respect to income per head does not exceed unity, the rate of growth of total demand for food of each group will increase with an increase in the rate of growth of its population. (ii) To the extent demand elasticities differ across socio-economic groups, changes in income distribution will have an impact on demand even if aggregate income growth is kept constant. And the process of population growth itself could alter income distribution. (iii) Population growth could affect food supplies in several ways; by changing potential labor force in quantity as well as quality, by changing the availabilities (per worker) of other inputs such as land (through changes in the size distribution of farms and the extent of land fragmentation), by influencing the technology of cultivation a la Boserup (1965, 1981) and Simon (1981), by influencing the environment (thereby affecting output per unit of land) through changes in the process of soil erosion and degradation etc. In the opposite direction there is of course the potential Malthusian relationship between availability of food, fertility and mortality. It has been pointed out (World Bank, 1982) that a majority of the world's poor are either landless agricultural laborers or cultivators with small land holdings. It is also suggested that poor have higher fertility rates compared to the population as a whole and fertility is influenced by household income earning opportunities (particularly for women). To the extent the process of growth of agricultural output affects land tenure, farm size distribution, and income earning opportunities, fertility rates and population growth rates may be affected as well.

In modeling the food population nexus, at one extreme is an approach which exogenously projects the likely size of population at some future date (or alternatively its time path from some initial date) with this size influencing food supply (as well as real income) only through its relationship to the size of the work force and total food demand by the identity that aggregate demand equals population size times per capita demand, with per capita demand being a function of per capita income. Such projections made independently for several countries or regions are aggregated to yield the likely excess supply or demand for food for country groups such as low income countries, all less developed countries etc. This approach very often will either assume away any response of food supply or demand to changes in food prices or alternatively treat the projected supply-demand imbalance at unchanged prices as an indicator of the need for price change and/or policy intervention. At the other extreme is an approach in which the processes of population growth, technological and environmental change, the evolution of outputs, prices, incomes and exchange (between individuals, firms and other entities within and across countries and over time) are all interdependent. The time path of the economy of each country and the global system in such an approach will in general depend on the evolution of variables that are exogenous, including stochastic shocks to the system, as well as the response (rational and equilibrating or otherwise) of agents to the shocks! Such a dynamic, stochastic general equilibrium approach, while attractive in theory, is obviously impractical.

This paper is limited in scope. It does not cover general issues relating to population growth and economic development. These have been covered in depth by McNicoll (1984) and less deeply and more conventionally in World Bank (1984) (see also Simon and Gobin (1980)). Nor does it cover determinants of fertility, labor force participation, rural-urban migration, access to land and other assets etc. mainly because other papers at this conference deal with them. Thorny philosophical, moral and ethical issues relating to population policy are not discussed. In particular articulation of value judgements involved in defining objectives of any population policy which is a necessary prelude to a discussion of 'optimum' population growth policy is not attempted. It reviews some recent models of the world food economy in the context of rapidly growing population in the developing countries. Also a model of the Indian economy will be used to assess the impact of alternative assumptions regarding the growth of Indian population until the year 2000, the impact being measured in alternative ways: growth of GNP, its composition, size distribution of income among rural and urban population, the distribution of population (rural and urban) according to per capita caloric intake. The models reviewed vary: in their approach to modeling production and supply, whether they distinguish countries and regions as well as socio-economic groups within countries in deriving demand, whether they are partial or general in modeling market equilibrium and whether they are static or truly dynamic.

Section 2 discusses studies based on the concept of population carrying capacity, i.e. the maximum population that can be sustained indefinitely into the future. By themselves these are of limited use, being technical rather than economic analyses, based as they often are on either known or currently foreseen technological potentials. Besides they have very little to say whether it is appropriate in some well defined sense for population to grow up to carrying capacity from below (and if so, how rapidly) and how to adjust (and how quickly) if the current population exceeded carrying capacity. This section also includes a brief discussion of recent population projections for major areas of the world. Section 3 provides a brief description of the projections of Food and Agriculture Organization (FAO). Section 4 is devoted to a discussion of the grain-oilseed-livestock (GOL) model underlying the food sup ply-demand projections of the Global 2000 report to the President of the USA. Section 5 reports on the results of some simulations with the India model as well as some general results from the linked system of country models (of which India model is a part) put together at or under the auspices of the International Institute for Applied Systems Analysis (IIASA). Section 6 is devoted to a discussion of other projections such as those of Linnemann et al, 1979),the Resources for the Future (RFF), and International Food Policy Research Institute (IFPRI). Section 7 takes up the feed-back-effects in the food-population nexus neglected altogether or inadequately addressed in the models of the previous sections. This discussion will necessarily be speculative. Section 8 concludes the paper with a discussion of issues for further research.

2. Projections of Population Size and Population Carrying Capacity

In Table 1 data from World Bank (1984) dealing with population change and economic development are reproduced. Under the standard projection the population of the less developed countries will increase from 3413 million in mid 1982 to 4835 million and 8313 million respectively in years 2000 and 2050 representing an average rate of growth of about 2.2% per year up to 2000 and a little over 1% per year for the subsequent 50 years. The projection of the Bureau of the Census in the U.S. (reproduced in the Global 2000 report) are somewhat higher, the medium value being 6351 million for the world in 2000, with the high (low) value being 6798 (5922) million. The less developed regions were projected to have a population ranging from 4648 million (low value), 5028 million (medium value) and 5420 million (high value). The medium variant of the United Nations projection for the world population is 6141 million. Though these projections differ somewhat, any of them, if realized, would mean a substantial growth by historical standards.

It is tempting to compare the projected population, say by the year 2050, (even though a hypothetical stationary population level would be somewhat higher) with the potential for feeding this population. The study on population carrying capacities under taken jointly by FAO, United Nations Fund For Population Activities (UNFPA) and IIASA (Higgins et al, 1983; Shah et al, 1984) provides a basis for such a comparison, though it excludes some major countries e.g. China. The objectives of the study were"...to ascertain on the basis of land resource inventories, the potential population supporting capacities in the developing world with various levels of inputs. And, second, to compare these estimates with data on present and projected populations..." (Higgins et al, 1983, p.5.). Some of the earlier attempts reviewed in Shah et al, (1984) involved the estimation of potential arable land and potential yield per hectare in different regions of the world to arrive at an estimate of potential output in grain equivalent units. Dividing the output estimate by an assumed consumption level per head, one obtains an estimate of population potential. Such estimates varied depending on variations in each of the three inputs: estimates of arable land, yield per hectare and per capita consumption needs. The range was enormous: from a low estimate of 902 Million by Pearson and Harper in 1945 to 147 billion by Clark in 1967 (Shah et al,1984, p.5)!

The FAO-UNFPA-IIASA study differs from the earlier studies in its use of a more disaggregated data base and superior methodology. Briefly stated, it uses an overlay of a climate map providing spatial information on temperature and moisture conditions on to a soil map providing spatial data on soil texture, slope and phase. This resulted in dividing the study area into grids each covering an area of 100 square kilometers area. In all 14 major climates during growing period were distinguished with normal (i.e. containing a humid period) length of the growing period (LGP) divided into 13 intervals and inter mediate (with no humid period) LGP being divided into 6 intervals. Fifteen most widely grown food crops, namely, wheat, rice, maize, barley, sorghum, pearl millet, white potato, sweet potato, cassava, phaselous bean, soyabean, groundnut, sugar cane, bananas/plantain and oil palm were considered. Three alternative levels of farm technology (low, intermediate and high) varying from no change in existing cropping patterns, no use of fertilizers and pesticides and no mechanization to optimum use of plant genetic potential, along with needed fertilizers and pesticides and full mechanization are postulated.

The soil characterstic, climate, growing season length, technology and cropping pattern together with the requirement that production be sustainable (i.e.that appropriate fallowing requirements and soil conservation measures are allowed for) determine the production potential in each of the soil-climate grids. These are then aggregated to yield production potential at the level of a country. After deduction of seed, feed and wastage one then obtains the crop-wise potential output available for human consumption. Livestock production potential was also assessed both under the assumption that only grassland will be used to support herds and under the assumption crop residues and by products wil be used as well. (Shah et al 1984, p.32). Given the average energy (measured in kilo calories per day) and protein (in grams per day) requirements based on the 1973 recommendations of an expert committee of FAO and World Health organization (WHO) and the age and sex distribution of the population of a country and the production available for human consumption in terms of energy and protein, the maximum population that can be supported can be determined. The results are shown in Table 2. In this table "critical" countries are the ones that cannot meet the basic food needs of their population even if all their arable land were devoted to growing food crops and "limited" countries are the ones that cannot meet these needs if part of their arable land has to be diverted to produce other food and non-food cash crops. Finally "surplus" countries are the ones that meet their food as well other non-food crop requirements.

It should be noted that the population carrying capacity reported in Table 2 for "limited" countries is the population that can be sustained if all arable land was devoted to crop production and this exceeds their projected population in year 2000. However, if a third of all land is assumed to be devoted to other crops and the carrying capacity correspondingly reduced by a third, the projected population (by year 2000) of these countries will exceed the reduced carrying capacity. This is why they are listed under the category "limited". Since in many countries of the developing world population will still be growing in year 2000, Shah et al (1984) compare population carrying capacity with the hypothetical size of stationary population. In this comparison, even with a high level of technology eleven countries cannot support the size of their stationary population, the most populous among them being Bangladesh which is expected to reach a stationary population of 430 million in year 2035. Eight countries can support their stationary population only at a high level of technology, but of the most populous among them, namely Nigeria, the balance between carrying capacity (701 million) and stationary population (623 million) is too close for comfort.

Yet another study of this nature is attributed (with no source cited) to Bernard Gilland (World Bank, 1984, p.91). By multiplying an assumed maximum yield of 5 tons of grain equivalent per hectare and an assumed (indefinitely sustainable) availability of 1.5 billion hectares of land, a maximum global output of 7.5 billion tons of grain equivalent is obtained. Gilland's assumption that "a completely satisfactory" diet including some meat will involve an average daily total intake (direct and indirect through livestock products) of

9000 kilo calories per capita of "plant energy" leads him to conclude that the earth can support 7.5 billion people. A projected stationary population of roughly 11.5 billion people can be supported at a consumption about 6000 kilo calories per capita.

What inference can one draw from such studies? It would appear that there is technological capability and land resources to sustain a population of as high as 33 billion (or nearly 9 times the projected population of 3.6 billion in year 2000) in the five regions of the world included in the FAO-IIASA study. But this by itself is no cause for complacency since there is virtually no economic analysis underlying these projections even though their data base and assumptions regarding technology are considerably more sophisticated and far more spatially disaggregated than any of the earlier studies of the same genre. Since farming is done by millions of individual peasants, unless it is in their private economic interest, given the prices for inputs and outputs they face and the constraints to which they are subject, they will not produce a particular set and levels of crop outputs merely because it is agro-climatically and technologically feasible to produce it. In particular the investments in land, capital equipment, livestock, technical skills and knowledge needed to attain the potential output will not be forthcoming unless the returns are adequate. By asking whether each country or region within a country has the potential to sustain its projected year 2000 or its stationary population, one completely ignores the economic cost of such autarkic development even if it were feasible to do so. Thus fundamental ideas of comparative advantage and gains from trade between regions within a country and between countries are conspicuous by their absence in such analyses. At best these studies are useful in pinpointing countries where with a technology which raises the output per unit of land to the fullest extent, even current level of population cannot be sustained relying solely on home production. This may be taken as indicating the need for out-migration of a part of its population or for investment in production for exports to pay for food imports or some combination of both.

3. FAO's Agriculture Toward 2000

The Food and Agriculture Organization (FAO) published its projections for the year 2000 in its publication Agriculture: Toward 2000 (FAO, 1981). This study individually covered 90 developing countries, accounting for 98% developing country population outside of China and summarily covered 34 developed countries. Its purpose was to project and analyze the implications for agriculture of three major scenarios: A trend scenario representing a continuation of the trends since the early 1960's, a modest improvement over these trends (Scenario B) and a more ambitious (Scenario A) and still deemed feasible rate of growth. The agronomic and technical bases for the projections are perhaps stronger than their economic basis. The presence of the latter is however an improvement over its virtual absence in studies of population carrying capacity. On the other hand, while the study emphasizes that access to productive assets, particularly land and other critical inputs including credit, has to be widely shared for successful agricultural development, by not addressing the existing distortions, it implicitly assumes that they will continue. The medium variant of the UN population projections is common to all scenarios. The demand for agricultural products is mostly driven by exogenously specified income and population trends of each scenario, except that caloric intake per capita is not allowed to fall in countries with declining trends and not allowed to exceed certain upper bounds in countries with rising trends. Production estimates were based on projections of land and water resources, investment and optimistic (though deemed reasonable) increases in yield per hectare of land.

The results are given in Table 3. The study concludes that doubling of agricultural production in 20 years in the ambitious Scenario A (and an 80%

increase in the less ambitious Scenario B) depends on a tremendous transformation of agriculture in all developing countries that is no less than:-" almost an agricultural revolution, involving widespread modernization in technology and techniques, and based primarily on a massive increase in imputs into agriculture (well over doubling annual investment and no less than tripling current inputs alone in Scenario A). The overall development strategy thus relies heavily on rapid increases in current inputs, backed by a steady expansion of relatively high cost investment with longer gestation periods, and pursued with an increased awareness of the need to conserve the environment and avoid undesirable social consequences " (FAO (1981), p. 57). Yet even if this ambitious and challenging task is accomplished, the study concludes that 260 million (390 million in Scenario B) people in 86 of the 90 study countries constituting 7% of their population, will be seriously undernourished in year 2000. In three of the countries more than 15% of the population will be seriously undernourished. However these estimates of undernourished population have to be used with caution since the scientific basis of fixed energy requirements on which they rely is under debate.

The FAO study briefly addresses the question whether a less rapid (or more rapid) population growth compared to the growth rates assumed would materially modify the results (FAO (1983, p. 42). Depending on where the slowing down (or speeding up) occurred, the results would be changed substantially - speeding up of population growth in already poor countries with weak agricultural and economic growth prospects could be disastrous. On the other hand, a slowing down of population growth may reduce the cereal import requirements of cereal importing countries and the number of seriously undernourished in the population.

The study also attempts at a longer term projection up to year 2055. With population in the developing world (including China) increasing by more than

60% over its level in year 2000, agricultural production will have to be nearly three times its 2000 level (or nearly five times its 1980 level). Since only a few countries have reserves of arable land and water, production increase will become geographically more concentrated and the importance of international trade will be more significant. Food importers will have to rely on rapid growth of production and exports of non-agricultural products to finance their food imports. The study recognizes (without attempting to quantify) the environmental implications (particularly in terms of soil quality and erosion, and water pollution, etc.) of the irrigation - chemical fertilizer- energy based technology of the rapid expansion of argricultural output. The view is put forward that there is an intertemporal trade-off between reduction of poverty of present generation and the quality of the environment bequeathed to future generations in developing countries and in this trade-off, given the extreme poverty in some countries, the present generation perhaps should be favored.

4. The Global 2000 Report

The Global 2000 Report (Council on Environmental Quality, 1981) to the President of the USA (hereafter the Report) was prepared following the President's 1977 Environmental Message requiring the Global 2000 Study Group "to develop projection of trends in population, resources, and the environment for the entire World through the year 2000" (The Report, Volume 2, p. 3). Each participating group, responsible for projecting population, Gross National Product, Climate and Technology was asked "to make projections using the projection tools it currently employs in making long term projection" (*ibid*., p. 3). The Report candidly admits that "collectively, the executive agencies of the government are currently incapable of presenting the President with a mutually consistent set of projections on world trend in population, resources, and the environment. While the projections presented (in The Report)... are probably the most internally consistent ever developed with the long-range, global models now used by the agencies, they are still plagued by inadequacies and inconsistencies" (ibid. p. 5). The main reason for inconsistencies is that the mutual feedback effects between population, resources and the environment are not fully allowed for in the projections. As the report puts it "In particular, the population and GNP projections that are made in the first step -- (of a three step process ending in environmental projections) are based largely on extrapolations of past trends and are uninformed by interactive feedback from the resource and environmental projections" (ibid. p. 4). This drawback has to be kept in mind in interpreting the results.

The grain-oilseed-livestock (GOL) submodel which forms the projection model of The Report is an econometric model consisting of 930 equations summarizing or describing the demand, supply and trade relating to grains, oilseed and livestock. The model covered the world in terms of 28 (14) countries or regions regarding grains (meat). The exogenous variables include (regional) population and income growth rates, variables describing agricultural and trade policy as well as weather. Endogenous variables include prices at which trade takes place, supply, demand etc. The supply equations reflect technology, that is input-output relationships, and producer behaviour. The full model consisted of three submodels for projecting arable area, total food production and consumption, and fertilizer use. Fertilizer was a proxy for a number of variables relating to technology and its change, such as the adoption of improved crop varieties, use of pesticides, extension of irrigation etc. The arable area submodel included an equation for each of 27 regions (28th. being the residual region called the rest of the world) with reliable historical data defining total arable area as a function of GOL and non-GOL product prices, a time trend and an estimate of maximum potential arable area. The production and consumption of non-GOL products were projected on the basis of historical relationships between GOL and non-GOL products. Consistency checks were made by comparing the projections of output of non-GOL products against the production capacity available for their production as implied by the arable area available for their cultivation (i.e. total arable area minus the area used up by GOL products) and the trend growth in non-GOL products yields. Consumption projections were checked against historic income and price relationships and changes in taste. Apparently these checks proved satisfactory. The fertilizer use sub-model consisted of region-specific equations relating fertilizer use to total food production based on cross-sectional and time-series input-output relationships.

The purpose of the GOL model was to project world production, consumption, trade and prices of grain, oilseed, and livestock products for 1995 and 2000. While the coverage is more extensive with respect to grains and less in respect of livestock, the model is still impressive in its commodity, regional and price detail. The model belongs to the static equilibrium genre and as such, its projections say for 1995, is independent of its projections for any other year, say 2000. Further, the changes between any two years in variables that are exogenous to the model, such as population, per capita income etc. by definition, not influenced by the projections for the same two years of the endogenous variables of the model.

The crucial assumption underlying the projections are: (1) No major man-made or natural shocks will occur. In particular no climatic change is projected though the scenarios include "optimistic" and "pessimistic" weather assumptions; (2) Yeilds per hectare of land will evolve at rates comparable to their historic evolution since 1950. (3) Protectionist agricultural policies in Western Europe and political determination of US trade with China, Eastern Europe and USSR will continue. Three alternative scenarios are simulated: Alternative I is the reference or baseline scenerio in which growth rates of world population and per capita income assume their median values of 1.8% and 1.5% respectively between 1975 and 2000. No change in weather is assumed as compared with to 1950-1975. Energy prices are assumed either to remain unchanged at their 1974-76 real levels or alternatively to reach more than twice these levels by 2000. Alternative II is the optimistic scenario with lower population growth (1.5%) and higher per capita income growth (2.4%). Weather is assumed to be more favorable than during 1950-1975, thereby increasing yields by one standard error above those under 1950-75 weather. Energy prices are kept unchanged relative to their 1974-76 real level. Alternative III is the pessimistic scenario with population growth high (2.1%), per capita income growth low (0.7%) and unfavorable weather resulting in yields falling by one standard error below those under 1950-75 weather. Real petroleum prices more than double in this Scenario relative to their 1974-76 values by year 2000.

The projections(Tables 4 and 5) show that even in the pessimistic third alternative, consumption of food is higher by about 4% in year 2000 over its 1969-71 level, though grain consumption is lower by about 3% from its 1969-71 level of 311 kilograms per capita. Under the base line Alternative I, per capita food consumption in 2000 is higher compared to 1969-71 by 14.5% and 17.0% respectively depending on whether real energy prices more than double between 1974-76 and 2000 or stay constant. Grain consumption is higher by 10.3% and 13.2% respectively under the same circumstances. Though the per capita caloric consumption in 2000 in less developed countries as a whole remains unchanged at its 1969-71 level of 2165 kilocalories per day under the pessimistic third alternative and increases by 7.6% to 9.5% under the baseline alternative depending on the trend on petroleum prices, there are enormous regional variations. The sub-saharan African countries appear to fare the worst: even in the optimistic third alternative their per capita food consumption in year 2000 is lower by 13.7% compared to its 1969-71 level and by a larger 18.7%-19.1% range under the baseline alternative. Daily caloric intake falls from its 1969-71 level of 2139 to 1920 in the optimistic scenerio. Though average calorie requirements are essentially meaningless, for the record the FAO-WHO requirements for developing Africa is 2325. In South Asia and North Africa only the pessimistic scenario leads to a fall in food consumption per capita by 3.6% and 1.6% respectively in 2000 compared to 1969-71. Thus it would appear that except for Subsaharan Africa, the world has the physical and economic capacity to produce enough food to meet modest increases in demand through 2000.

The Report points out that the ability to sustain this modest increase arises from substantial increases in the resources committed to food production and impressive increases in gains in resource-productivity through wider adoption of improved technology and the use of land augmenting inputs such as fertilizers and pesticides. In fact, even though arable land per capita declines from an average 0.39 hectares in 1971-75 to 0.25 by year 2000 (which happens to equal that projected by FAO for 90 developing countries, see Table 3) in the reference alternative, because the use of fertilizers nearly tripled from 55 kilograms in 1971-75 per hectare to 145 kilograms in year 2000, food production roughly doubles over the same period. Achieving such an intensification in input usage is expensive besides being a formidable task. This is because increasing fertilizer use depends to a significant extent on irrigation, and creating irrigation capacity is likely to be capital intensive. Operating the capacity created and producing the fertilizers needed are both energy-intensive. Further managing irrigation systems efficiently is skill intensive.

Since at the regional (and a fortiori at the level of a country) level supplies and demands do not balance, there is a substantial increase in international trade. The extent of the increase by year 2000 varies from 63% to 110% over the 1973-75 level among alternatives. This implies that food importing countries would have to export other commodities to finance such massive increases in their food imports. Since developing country food importers account for 36% - 43% of world imports in the year 2000, the financing problem is indeed a serious one. Apart from the problem of generating exportable surpluses, the task of converting them into export earnings is likely to prove daunting if the protectionist trends in the developed world intensifies. Besides the assumptions that political determination of U.S. grain trade and agricultural protectionism of Western Europe will continue may be realistic, but it would be naive to pretend that they have no serious consequences.

The Report was primarily addressed to assessing the environmental impact of global population and income trends. In its discussion of very long term effects on climate, the Report confines itself to indicating possible frequencies of extremes such as severe droughts (in those areas of the world prone to such events) if global warming or cooling were to take place. However it did not relate trends in population income, industrialization etc. to the probability of long term cooling or warming. The Report recognizes that the effort to increase food output through expansion of arable area, extension of irrigation, use of chemical fertilizers and pesticides will have an impact on the environment particularly in terms of deforestation, desertification, soil degradation, (increasing salinity and erosion) chemical pollution of surface and ground waters, etc. It concludes however that these problems though serious are manageable.

5. The System of Models of International Institute for Applied Systems Analysis (IIASA)

Unlike the static partial equilibrium GOL model of the Global 2000 Report, the IIASA System of medels is of the dynamic general equilibrium genre. It consists of a set of country models some of which were put together by research groups within each country with a substantial degree of disaggregation and others built by the research team of the Ford and Agriculture Project (FAP) of IIASA). The country models were designed in such a way that they could be aggregated to a common ten sector model, distingishing nine agriculture and livestock product sectors (Wheat, Rice, Coarse grains, Bovine and ovine meats, dairy products, other animal products, Protein Fuels, other food, non-food Agricultural Products) and a single sector covering all non-aggricultural activities. The aggregated country models (22 in all of which 19 are models for individual countries and 3 are for country groups consisting of the European Community (EC), The Eastern European group including USSR called Council on Mutual Economic Aid (CMEA) and a rest of the world residual group) were linked in a global trading system called the Basic Linked System (see Parikh and Rabar (1981) for details).

Briefly stated, each aggregated model consists of a supply module and demand module. The supply module determines the production decisions in each year on the basis of expected prices which are assumed to be a function of current prices (and past prices in some models) the emerging outputs being available for sale in the next year. The output vector thus generated represent claims to income and agents decide on the disposition of income into consumption, savings and investment. The difference between production and domestic use determines the net foreign trade vector of each country. To the extent a country receives or makes international transfers, income and domestic expenditure will differ by the extent of the transfer. Equivalently the transfer al lows a country to run a net deficit on its external trade equaling the value of the transfer at the prices at which trade takes place. In some country models several groups of agents (rural, urban, income classes etc.) are distinguished, each group being endowed with its own preferences and claims to output. Several government policies are modeled: tariffs which establish a wedge between domestic and international prices, export and import quotas, buffer stock operations, domestic rationing and public food procurement and distribution systems, income transfers between agents etc.

The system is solved as follows: For any year of simulation, the output available for exchange is predetermined by producer decisions of the previous year. With this output vector, given an exogenously specified value of trade deficit, and specified government policies, each country's demand vector and hence its net import vector corresponding to any given international price vector can be determined. If the sum of the net import vectors over all the countries is zero, then the given international price vector is an equilibrium vector. If not, the price vector is changed according to some well specified rule and the process is repeated until international equilibrium is achieved. Once the equilibrium price vector is determined, the associated domestic price vector determines the output vector for the next year either through a simple static price expectations mechanism or through more complicated distriuted lags set up involving past domestic prices as well. The output response to the expected prices is influenced also by the investment in production capacity made in the previous year, the investment demand in equilibrium being part of the aggregate demand vector for that year. Thus the model can be solved for each year of a sequence of years. The data base of the model included FAO's supply utilisation accounts for about 1000 commodities for the period 1961-1976, which were aggregated to suit the sectoral classification of the model. The model was calibrated (i.e. free parameters were chosen) so as to reproduce the observed prices, outputs and trade flows of the period 1970-1976 as closely as possible. Then the model was run in a simulation mode for the period 1977-2000. For each country the model can be run in a stand-alone mode in which the time path of the international prices relevant for its foreign trade is exogenously specified or in a linked mode when it is solved as part of the Basic Linked System (BLS) in which the path of the international price vector is itself endogenously determined so as to clear international commodity market along the lines described above. It should also be mentioned that even though population growth was exogenously specified in all models, in some labour force participation rates and rural-urban migration was endogenised through simple income related behavioral equations.

The results are shown in Table 6. Even though the methodology of IIASA models is different from and many ways superior to that of The Report the results are broadly similar. While The Report projects a global population for year 2000 varying from 5921 millions in Alternative II to 6797 million in Alternative III with a figure of 6351 million for the reference Alternative I, IIASA projects a figure of 6106 millions for its reference run. The GNP growth rates in the IIASA model are endogenous while they are exogenous in The Report with the IIASA growth rates being somewhat higher. The output of all grains in the year 2000 for the IIASA model is 1959 million tonnes as compared to the range of 2120 to 2233 million tonnes in The Report. Total exports of grain in year 2000 is of the order of 152 million tons in the IIASA model while it ranges between 178 to 239 million tons in the report. It is understandable that the volume of trade is higher in The Report than in the IIASA projections. The reason is that The Report model of the static partial equilibrium kind limits the extent of adjustment to changing prices. Since the country groupings in the two models are different, a direct comparison of results may not be appropriate. Still it would appear that if we use caloric intake as an indicator of welfare, the prospects for the developing countries as a whole are somewhat better in the IIASA projections then in those of The Report.

The India model of IIASA system is more elaborate than others in that it distinguishes five income (more precisely, per capita real consumption expenditure) groups among rural and urban populations with the groups numbered according to increasing affluence (i.e. group 1 is the poorest and group 5 is the richest in both rural and urban areas). Each group has its own demand function represented by a Stone-Geary linear expenditure system and the distribution of aggregate consumer expenditure among groups is assumed to be log-normal. In this model population growth is exogenously specified and influences only the demand module. Three alternative growth paths were specified: Alternative 1 corresponds to IIASA's reference projection, Alternative 2 corresponds to the standard projections for year 2000 and Alternative 3 corresponds to the rapid fertility decline and standard mortality decline projection of the world bank (1984). There is a difference of 121 million between the projections of Alternative 1 and 3 by year 2000. The model was run in a standalone mode with the time path of the international price vector faced by India exogenously specified to be the same as that emerging as the equilibrium path in the Linked reference run. For the reason that population influences only per capita income and demand and not the production process, the differences between the alternatives are not large (See Table 7). As is to be expected, Alternative 3 with the slowest population growth leads to a minuscule speeding up in the rate of growth of real GDP. However, the impact on caloric intake and on the distribution of population among expenditure groups is more perceptible. In general for all groups caloric intake increases as population growth decreases and the distribution of income improves with higher proportion of the population move to richer expenditure classes, particularly in the urban areas.

The IIASA system of models include an environment module for studying interactions between agriculture and the environment. However this part of IIASA's modeling effort was to rely heavily on modelling by others outside IIASA. Few results are available to review them here.

6. Other Projections

Ever since the Club of Rome sponsored global systems modeling in the early 1970's several models have been published (see Glenn Fox and Vernon Ruttan (1983) for a brief discussion of some of the models) in which the interaction of the processes of population growth, incme growth and exhaustible resource depletion is explored with a view to identifying and characterizing a global equilibrium state that is indefinitely sustainable if one existed. Early models such as those of Forrester (1971) and Meadows et al (1972) were mechanical simulations of the consequences of their assumptions: their equations of motion had no empirical basis and the processes describing behavior were devoid of economic content. Though subsequent models have remedied some of these defects and in particular introduced economic processes, they have not been notable for the soundness of the empirical econometric basis of the myriad relationships included in them. The projection from such models are of limited use if not altogether meaningless and not reported here.

Among models which have food and agriculture as their primary concern, the model of International Relations in Agriculture (MOIRA) (Linnemann et al 1979) which is a precursor of the IIASA system of models is notable for its attempt to incorporate behavioral economics into the analysis, with sectoral value added maximization by producers given input prices and with resources and production technology as constraints. Consumer behavior was presented by separate demand functions for each of 12 income classes. MOIRA describes food sectors of individual countries and links these sectors by means of an equilibrium model of international trade. All national models have the same base year 1965. The projections of MOIRA are couched in terms of "consumable protein" and as such are not directly comparable with those of other models as base. For ease of comparison, the projections have been converted into indexes with 1980. Two alternative income growth (high and moderate) scenarios are presented (See Table 8). These scenarios assume no change in policies relating to tariffs and quotas, and domestic policies relating to rural/urban income parity targets etc. Two variants relating rate of growth of non-agricultural GDP (a crucial variable which is exogenous) were used. In the Scenario with relatively high growth rates, the average growth rates by year in percentage terms were:

	Developing	Developed	Centrally Planned	World
1975-1985	7.6	4.5	6.5	5.0
1985-1995	7.1	4.2	6.4	4.8
1995-2005	6.8	3.8	5.8	4.5

In the relatively low growth rate Scenario these were halved. Similarly population growth rates were halved compared to the standard run in a low population growth variant.

Keeping population growth unchanged, lowering income growth rates lowers per capita income growth and hence shifts demand downwards. This results in lower food production and consumption, the effects being more significant for the developing countries. In Tropical Africa and South Asia food consumption per head in year 2000 goes down by 4% and 23% respectively relative to their

1980 values in the low income growth variant as contrasted with increases of 48% and 4% in the high income growth variant, though the dramatic change in the case of Tropical Africa appears somewhat peculiar. Keeping income growth at its high value but halving population growth increases per capita income growth and per capita demand. On the other hand, a lower population means lower labour availability for agricultural production. Since higher per capita demand is moderated by the lower absolute level of population, the net effect on total demand given less than unitary income elasticity of demand, is downward. This results in lower total output and lower food prices compared to standard population growth run, but in higher per capita comsumption of food everywhere except Southern Asia where per capita consumption is lower in the low population growth run. The reason for this peculiarity is stated to be that domestic food prices have to be raised substantially (compared to high population growth run) to maintain rural/urban income parity (Linnemann et al (1979), p.298).

The last two sets of projections to be briefly noted here were published by the Resources for the Future, Inc.(Resources, Spring 1984) and International Food Policy Research Institute (IFPRI, 1977). The basic underlying assumptions of the former were that population would grow at an average rate of 1.75% per year during 1980-90 slowing down to 1.65% during 1990-95. Ninety-three percent of this growth would be in the less developed countries. The world population would be 6.16 billion in year 2000. Per capita real GNP would grow at an average rate of 3.5% per year during 1980-2000 with the highest growth rate of 5.6% occurring in East Asia, with the European Economic Community (2.5%) and Sub-Saheran Africa (2.6%-3.2%) and Eastern Europe (3.1%) being at the lower end. Given these assumptions as well as assumed demand elasticities projections were made. They show that world production of cereal grows at a rate of 1.83% per year during 1980-200, with the EEC (1.12%) Sub-Saharan Africa (1.70%), Eastern

Europe (1.16%), Asian Centrally Planned economies (1.63%) and North America (1.35%) growing more slowly than the rest of the world. World trade grows substantially with net imports of cereals rising from 131 million tons in 1978-80 to 242 million tons in 2000. Meat imports triple from 2.6 million tons to 7.4 million tons during the same period. The study concludes that "The World possesses the potential to feed a growing population of 6.1 milion people moderately better than it fed 4.3 billion in 1980" (Resources, Spring 1984, p.19), Per capita consumption of cereals increases from 361 kgs. in 1978-80 to 372 kgs. in 2000, with meat consumption rising from 32 kgs to 37 kgs.

IFPRI (1977) study is devoted to an assessment of food needs of developing countries by the year 1990. The methodology used is very simple, even simplistic: production was projected to 1990 by extending the 1960-75 trend. Consumption targets for 1990 were derived from alternative ways: (1) average per capita food consumption of 1975 is to be provided to the 1990 population (2) given a set of income elasticities based on FAO studies, the demand arising from a low (2a) and a high income growth (2b) Scenarios were set as targets and finally, (3) food needs to meet 110 percent of FAO-WHO daily minimum per capita food energy requirements were set as targets. Income growth assumptions were based on World Bank projections. The medium variant of population projections of the United Nations was used as reference in all scenarios while the low variant (2al and 2bl) was used as well in the two alternative income growth scenarios. In all eighty-four developing market economies were included. The projections are reproduced in Table 9. These appear to fall within the range of the other projections reviewed earlier. In the low variant of population growth the food deficit of low income importing countries is somewhat less than in the medium variant and that of others margionally less. Since population growth affects the two IFPRI projections being compared (2a and 2al, 2b and

2b1) only through demand effects arising from the implied changes in per capita income, the relatively small difference observed between low and medium variants of population growth is not surprising.

7. The Neglected Effects

In all the projections reviewed above population growth was exogenous. Besides the effect, if any, of exogenous population growth on the environment through desertification and soil erosion and the associated consequences on climate in general, and frequency of severe droughts and floods in particular, and on farm size and increasing fragmentation of holdings due to subdivisions of land within families, and the impact of these on agricultural output were either completely ignored or treated outside the framework of projections. Writers such as Lester Brown and his colleagues at the World Watch Institute argue that "as world population expands, the shrinking cropland area per person and the reduction in average soil depth by erosion combine to steadily reduce the per capita availability of topsoil for food production. If between 1980 and 2000 there is a 6 per cent net increase in cultivated land area and a continuation of recent soil erosion rates, the amount of top soil per person will fall from 792 tons to 489 tons by the end of the century, a decline of 38 per cent " (Brown et al (1984), ch. 10, p.189). They conclude that "achieving a more satisfactory balance between the world demand and supply of food requires attention in both sides of the equation. On the demand side, the success of efforts to upgrade diets may depend on an emergency program to slow population growth---On the supply side, the scarcity of new cropland, the continuing loss of top soil, the scarcity of fresh water, and diminishing returns on chemical fertilizer combine to make expanding food production progressively more difficult (ibid. p. 190-191). After pointing out that the factors that make expanding food supplies difficult in a technical sense do not make it impossible but only make it progressively costly relative to real incomes (particularly of the poor), they conclude that "nothing less than a wholesale reexamination and reordering of social and economic priorities - giving agriculture and family planning the emphasis they deserve - will get the world back on an economic and demographic path that will reduce hunger (rather) than increase it" (ibid, p.193).

Apart from the doubtful empirical support for estimates of global soil erosion and degradation, the above formulation of the impact of population growth understates (in fact it ignores) the response of private agents to market signals as well as social action that can prevent a situation as grim as the one portrayed from arising. As Kelley (1984) points out essentially there are only two <u>prima facie</u> plausible arguments that can be advanced in support of the hypothesis that rapid population growth will necessarily lead to disaster. First, rapid population growth by extending cultivation to marginal lands and intensive cultivation in intra-marginal lands will lead to a progressively increasing relative price of food because of diminishing returns to factors other than land. Implicit in this argument are the beliefs that (a) reserves of arable land are nearly exhausted (b) technical change that can mitigate diminishing returns will not occur (c) the benign feed-back effect of rising incomes on the rate of natural increase in population, if there is any, will be too slow acting relative to the malign effect of rising cost of food on the health and nutritional status of the poorer groups in the population. The second argument rests on the belief that natural resources (including the environment) are exhaustible in the sense that real marginal costs of extraction will eventually rise steeply and the exploitation of possibilities of substitution (of relatively abundant natural resources and/or primary factors such as capital and labour for scarce resources) are either limited or prohibitively costly.

Simon (1981) has persuasively argued that empirical support for these assertions is almost non-existent. In his view available data suggest that the real cost of food (as well as many other natural resources) has been falling instead of rising. It would appear that there are still reserves of unutilized arable land in some areas of the world (particularly in south America) and in any case the possibilities of increasing the effective availability of land by increasing cropping intensity (i.e. through multiple cropping) are far from exhausted. The potential for raising output in many parts of the developing world through adoption of known superior technology is yet to be realized in full measure. Besides the theory of and empirical evidence for induced innovation (Ruttan and Hayami (1984), Hayami and Kikuchi (1981)) suggest that the process of technical and institutional change themselves will be responsive to emerging scarcities. In any case, the fact that the relative price of food and many natural resources have not risen and in many cases have fallen suggests that the bear of diminishing returns and the bogey of resource depletion have so far been kept at bay! The externality aspects of environmental degradation and institutions to internalize its costs (either through market intervention in the form of taxes and subsides or assignment of "property rights" are well known. One interesting issue is whether the apparently more serious environmental effects are more related to income levels and their growth than to population growth in and of itself.

Some, even among those who do not forsee a rapid population growth as a problem in the long run, would still recognize that there may be an "adjustment" problem in the short and medium run. Ruling out "adjustment" through Malthusian "natural checks" or through draconian and coercive controls over child bearing decisions of couples such as the Chinese one child per family policy from consideration, the problem can be defined as follows. Even though the long run sustainable (i.e. steady state) level of population may be substantially larger than the current level and the level of living associated with the long run steady state may also be much better, it is possible that (in the absence of non-coercive policy instruments that influence population growth) there may be no feasible path that would take the society from its initial position to the steady state. Indeed the argument (it is just that with no strong econometric support) that rapid population growth reduces savings and investment at least in the short and medium run would suggest that the achievement of a steady state could be delayed, if not precluded altogether. However a more serious problem in many developing countries is that inappropriate public policy interventions have blunted and distorted the incentives of farmers to enlarge food supplies. Even in countries where substantial investment in irrigation works, development of location specific agricultural technology including superior crop varieties, diffusion of such technology through extension and subsidized credit etc. have been part of public policy, still the design of these policies and the management of the facilities created have been so poor and leakages endemic as to reduce their benefits and to distort their distribution among socio-economic groups in the rural population. As contrasted with the empirical support for many of the arguments about the deleterious consequences of rapid population growth, the empirical evidence on the cost of ill conceived public policy interventions in agriculture in developing countries in Africa, Asia and Latin America is strong and well documented.

8. Conclusions

It would appear from the projections of various models reviewed earlier that the demand for food likely to arise from anticipated income and population growth can be met. However this conclusion has to be qualified for several reasons. Even though alternative income and population growth scenarios are analyzed in almost all the models, in none of the models population growth is endogenous and only in the IIASA model income growth is endogenous. Endogenizing population growth is very likely to increase the chances of long run viability of the system. Adjustment to incipient excess demands or supplies of goods and factors through relative price changes, at a point in time and overtime, within countries and in the international market is exploited to the greatest extent in the IIASA system of models but to lesser and varying degrees in other models. The process of technical change is very crudely modeled, if at all. In particular it is independent of population growth so that the possibility that the rate of technical progress is augmented by population growth a la Simon and Steinman (1981) is ruled out. Except the IIASA system and the MOIRA models, all others are static but even in the former the modeling of the process of investment in capacity creation appears to be rudimentary and future returns from investing in alternative activities do not appear to influence the pattern of investment.

Several possible channels of influence of population growth on the production capacity of the economy in general and food and agriculture in particular were mentioned above. Not all of which have been nor can be explicity taken into account in the projections reviewed. One of the more important among these is the process of shift of labour away from agriculture resulting in a declining proportion of labour force employed in agriculture in the course of development. In most of the presently developed countries this proportion is less than 10% and in some of the developing countries it has fallen substantially in the post second world war era. Yet in India it has hardly changed in over a hundred years from about 70%, even though the share of agriculture in gross domestic product has steeply declined. The situation in Bangladesh is no better. The proportion of labor force employed in agriculture in China is only marginally less than that of India's according to the World Bank (1984, Table 21, p.258). If a virtually unchanging proportion of a rapidly growing (because of population growth) labour force is employed in agriculture while at the same time the share of domestic products originating in agriculture falls, in the absence of massive transfers income disparities between agricultural and non-agricultural workers will widen. But the failure to reduce the pressure on agriculture would seem to emerge, not from rapid population growth per se but from the strategy of industrialization that increasesd capital intensity of production outside agriculture thereby limiting the scope of expanding non-agricultural employment. In MOIRA and some of the IIASA country models (India model is not one of them) income parity between these two groups is included as a policy target, though the relationship between the target and the policy instruments which can help achieve it is not transparent.

It was mentioned earlier that the pattern of landholdings (in terms of size distribution of farms), land tenure and other contractual arrangements in agriculture may be influenced by population growth and technical changes. Such institutional changes may in turn affect distribution of real incomes (or income entitlements, as Sen (1981) would put it) and access to food. Incorporating these into the formal methodology of projections is not simple, if not for any other reason, for the reason that even the theory endogenesing institutional change is in its infancy. Yet these changes could be far more significant than those included in the projection models.

A discussion of issues relating to famines and other such disasters has been deliberately kept out of the paper for several reasons. Such episodes are occasional and infrequent, if they are distinguished from "normal" fluctuations in output from its longrun trend. And disaster relief from national and international sources is often available if famine threatens. Normal fluctuations whether they relate to output or to terms of trade have to be addressed by other means and population growth has little to do with them. Further, the fact that enough food is available to feed the entire population of a country is no guarantee that no one will starve. Equally, the fact that not enough food is available to prevent starvation of everyone does not mean that everyone will indeed share in the starvation. How the available food is distributed among the population will depend on the institutional arrangements relating to production and exchange (for instance, in a market economy an individual has to have enough purchasing power through his "income entitlements" to be able to afford a diet above starvation level!) including in particular the nature of transportation, storage and distribution net works. As recent tragic events in Ethiopia show, that in the absence of such a network the food shipped by the rest of the world will not reach the starving in time. These elementary and fairly obvious relationships between institutions and access to food and their implications for understanding episodes of famine are elegantly elaborated in Sen (1981). It would appear from his analysis of famines in pre-partition Bengal in India in 1943, Bangladesh, in the Wollo region of Ethiopia and in Sahel the early seventies as well as the famine deaths exceeding a staggering 16 million in China in the early sixties that their main cause was not shortage of food or rapid population growth but colossal <u>policy</u> failures in areas unrelated to population growth.

Once again with famine raging in Ethiopia currently, some continue to assert that, even though successive droughts are contributory causes, rapid population growth and its alleged consequences (of desertification, abandonment of traditional methods of cultivation in favour of others which were ecologically damaging etc.) are behind the tragedy and desertification may even be responsible for the droughts. However as in earlier episodes, policy failures particularly in distorting incentives, may have more to do with the tragedy than slower acting long term ecological processes. Comparison of recent experience of Tanzania and Zimbabwe in coping with drought indeed suggests that Tanzanian policies contributed significantly to its relative lack of success. The cause of eliminating starvation and hunger in the world will be ill served if instead of analyzing avoidable policy failures in not providing an environment in which incentives to innovate and produce are not blunted (an analysis that can be rooted in a firm empirical base), one chases an alleged deleterious relationship between rapid population growth and the food economy for which empirical support is at best shaky. Even if such support were stronger, the pay-off to correcting policy failures is likely to be greater, quicker and surer than attempts to change an admittedly slow-acting process of interaction between population growth and the food economy. This is an inescapable conclusion that can be drawn from the remarkable rebound from what many then viewed as a crisis (whether correctly or not) in the world food economy in 1974. Since then world food production has increased by 30% outstripping population growth. Mr. M. J. Williams the executive director of World Food Council, established by the World Food Conference which met in 1974 is quoted recently as saying that "After 10 years, it's quite clear that globally the world can produce enough food to feed all its population. And that assumes a yearly increase in that population" (New York Times, December 2, 1984). The only exception to this encouraging picture is Africa. According, to the same report Mr. Williams attributed only a small part of Africa's food problems to drought and a larger part to the failure of many African governments to develop farm programmes that would provide incentives to small farmers.

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Table 1

Population Projections (Millions)

Country Grouping/Year	Standard Projection Mid 1982	Standard Projection 2000	Standard Projection 2050	Rapid Fertility Decline 2000	Rapid Fertility Decline 2050	Rapid Fertility & Mortality Decline 2000	Rapid Fertility & Mortality Decline 2050
I. Low Income Countries	2276	3107	5092	2917	4021	2931	4225
of which China	1008	1196	1450	1196	1450	1185	1462
India	717	994	1513	927	1313	938	1406
Bangladesh	93	157	357	136	212	139	230
Pakistan	87	140	302	120	181	122	197
II. Middle Income Country	1120	1695	3144	1542	2321	1556	2437
of which Indonesia	153	212	330	197	285	198	298
Nigeria	91	169	471	143	243	147	265
Brazil	127	181	279	168	239	169	247
Mexico	73	109	182	101	155	101	160
III. High Income Oil Exporting Countries	17	33	77	30	46	30	49
IV. Industrial Market Economics	723	780					
of which U.S.A.	232	259					
Japan	118	128					
V. Eastern European Non-Market Economies	384	431					
of which USSR	270	306					
VI. Total[1]	4520	6046					

[1]Excludes countries with population less than 1 million.

Source: World Bank (1984).

Table 2

Population Carrying Capacities (Million)

Region	Low	Intermediate	High
	Level of Farming Technology		
I. Africa			
Number of Critical Countries	29	12	4
Limited Countries	4	7	4
Surplus Countries	18	32	43
Population Carrying Capacity of:			
Critical Countries	209 (466)	62 (110)	9 (11)
Limited Countries	68 (62)	340 (258)	70 (52)
Surplus Countries	977 (252)	4087 (412)	12789 (717)
All Countries	1254 (780)	4489 (780)	12868 (780)
II. Southwest Asia			
Number of: Critical Countries	14	14	11
Limited Countries	1	-	3
Surplus Countries	-	1	1
Population Carrying Capacity of:			
Critical Countries	87 (195)	116 (195)	47 (89)
Limited Countries	93 (69)	-	118 (106)
Surplus Countries	-	121 (69)	159 (69)
All Countries	180 (264)	237 (264)	324 (264)
III. Southeast Asia			
Number of Critical Countries	6	2	1
Limited Countries	4	-	1
Surplus Countries	6	14	14
Population Carrying Capacity of:			
Critical Countries	270 (341)	148 (156)	(3)
Limited Countries	1492 (1190)	-	185 (153)
Surplus Countries	702 (407)	4210 (1782)	6149 (1782)
All Countries	2464 (1938)	4358 (1938)	6334 (1938)

Table 2 (continued)

Region	Level of Farming Technology Low	Intermediate	High
IV. Central America			
Number of Critical Countries	14	7	2
Limited Countries	2	-	1
Surplus Countries	5	14	18
Population Carrying Capacity of:			
Critical Countries	34 (52)	17 (24)	1 (2)
Limited Countries	194 (139)	-	11 (10)
Surplus Countries	64 (24)	540 (191)	1281 (203)
All Countries	292 (215)	557 (215)	1293 (215)
V. South America			
Number of Surplus Countries	13	13	13
Population Carrying Capacity of:			
Surplus Countries	1418 (393)	5288 (393)	12375 (393)
VI. All Regions			
Number of Critical Countries	63	35	18
Limited Countries	11	7	9
Surplus Countries	42	74	89
Population Carrying Capacity of:			
Critical Countries	600 (1054)	343 (485)	57 (105)
Limited Countries	1847 (1460)	340 (258)	384 (321)
Surplus Countries	3161 (1076)	14246 (2847)	32753 (3164)
All Countries	5603 (3590)	14928 (3590)	33194 (3590)

Note: Figures in parentheses denote the projected population by year 2000.

Source: M.M Shah et al (1984); Tables 14-18.

Table 3

Agriculture: Toward 2000: Projection

		1980	1990	2000
I.	Population (millions)			
	1. 90 developing countries (included in the study)	2259	2906	3630
	2. Other developing countries (including China)	993	1121	1244
	3. Developed countries	1163	1248	1325
	4. World	4415	5275	6199
II.	Population Growth Rates* (% per year)			
	90 Developing countries	2.5	2.3	
	Other developing countries	1.2	1.0	
	Developed countries	0.7	0.6	
	World	1.6	1.7	
III.	GDP Growth Rate (% per year)**			
	90 Developing countries			
	Scenario A	6.8	7.2	
	Scenario B	5.6	5.8	
	Developed countries			
	Scenario A	3.7	3.1	
	Scenario B	3.8	3.2	

Table 3 (continued)

Agriculture: Toward 2000: Projection

	1980	1990	2000
IV. Caloric intake per capita			
(kilo cals per day)			
90 Developing countries	2180		
Continuation of trends		2330	2370
Scenario A		2445	2635
Scenario B		2380	2500
Developed countries	3315	3415	3475
V. Production of cereals			
(million tons)			
90 Developing countries	382*		
Continuation of trends		518	636
Scenario A		569	786
Scenario B		538	696
Developed countries	818*		
Continuation of trends			1102
Scenario A			1017
Scenario B			1069
VI. Net trade in cereals (million tons)			
90 Developing countries	-36*		
Continuation of trends		-72	-132
Scenario A		-57	-64
Scenario B		-67	-105
Other developing countries			
(including China)	-16		
Scenario A		-15	-17
Scenario B		-19	-27

Table 3 (continued)

Agriculture: Toward 2000: Projection

	1980	1990	2000
All Developing Countries	-52		
Scenario A		-72	-81
Scenario B		-86	-132
VII. Available Land (hectares per capita)			
90 Developing countries		0.29	0.25

* Average for 1976-79

** The first and second columns refer respectively to average annual growth rates during 1980-90 and 1990-2000

Source FAO (1981), Statistical Annex Tables 3 and 5.

TABLE 4

Food Production, Consumption and Trade and Price in 2000

	Alternative I	Alternative II	Alternative III
I. Industrialized Countries			
Population Growth Rate (% per year)	0.52	0.34	0.71
Per capita Income Growth Rate (% per year)	2.57	3.35	1.77
Grain Production (Million Metric Tons)	739.7-679.1	730.0	683.3
Grain Consumption (Million Metric Tons)	648.1-610.8	689.6	590.2
Grain Trade (Million Metric Tons)	+91.3-+68.3	+42.4	+93.1
Food Production Index (1969-71=100)	157.0-143.7	157.1	143.5
Food Consumption Index (1969-71=100)	155.8-147.7	165.7	143.6
II. Centrally Planned Economies			
Population Growth Rate (% per year)	1.21	0.94	1.43
Per capita Income Growth Rate (% per year)	2.01	3.00	1.03
Grain Production (Million Metric Tons)	722.0	746.0	691.0
Grain Consumption (Million Metric Tons)	758.5	755.4	730.0
Grain Trade (Million Metric Tons)	-36.5	-9.4	-39.4
Food Production Index (1969-71=100)	174.0	179.5	166.1
Food Consumption Index (1969-71=100)	179.9	179.2	173.2
III. Less Developed Countries			
Population Growth Rate (% per year)	2.37	2.04	2.71
Per capita Income Growth Rate (% per year)	2.01	3.00	1.03
Grain Production (Million Metric Tons)	735.0-740.6	757.0	745.3
Grain Consumption (Million Metric Tons)	789.8-772.4	790.4	799.4
Grain Trade (Million Metric Tons)	-54.8-31.8	-33.4	-54.1
Food Production Index (1969-71=100)	244.5-247.7	268.2	246.4
Food Consumption Index (1969-71=100)	247.8-242.8	261.2	249.0
IV. World Market Weighted Real Food Prices			
(Index 1969-71 = 100)	145-195	130	215

Source: The Global 2000 Report to the President, Volume Two, Tables 6-1, 6-2, 6-7 and 6-11, pp.78, 91-92 and 96.

Table 5

Per Capita Grain and Food Consumption and Daily Caloric Intake in 2000

	Alternative I		Alternative II		Alternative III	
	Grain (kgs.)	Food Index (1969-71=100)	Grain (kgs.)	Food Index (1969-71=100)	Grain (kgs.)	Food Index (1969-71=100)
I. Industrialized Countries	735.0-692.4	127.7-121.2	798.3	139.1	619.2	110.0
of which United States	1183.3-1111.5	135.9-128.3	1363.3	917.7	154.8	107.9
Western Europe	581.7-548.8	121.4-115.5	599.0	124.5	518.2	110.1
Japan	484.4-452.3	164.2-154.2	481.2	163.2	401.1	138.3
II. Centrally Planned Countries	473.9	135.8	495.1	138.4	396.5	119.0
of which USSR	949.9	141.4	976.4	145.2	828.4	123.7
Eastern Europe	997.6	152.1	1012.1	154.2	920.8	141.2
China	267.8	119.1	281.8	124.7	220.0	99.9
III. Less Developed Countries	210.2-205.5	111.0-108.6	219.4	116.7	189.5	99.9
of which Latin America	282.8-278.1	127.1-125.1	306.6	136.7	243.8	110.8
N. Africa/Middle East	301.8-292.8	105.9-102.2	318.6	112.9	283.7	98.4
Other African LDC's	112.5-112.0	81.3-80.9	119.1	86.3	108.8	78.5
South Asia	186.7-181.0	109.2-105.8	192.4	112.5	164.9	96.4
Southeast Asia	233.2-228.5	117.1-114.6	237.1	119.2	217.9	110.0
East Asia	219.5-217.3	128.7-127.3	221.3	129.7	195.5	114.2
IV. World	352.0-343.2	117.0-114.5	373.0	126.0	302.0	104.0
V. Daily Caloric Consumption in Less Developed Countries	2370	2330	2390		2165	
of which						
Latin America	2935	2905	3080		2710	
N. Africa/Middle East	2530	2460	2655		2390	
Other African LDC's	1840	1830	1920		1800	
South Asia	2180	2130	2230		1985	
Southeast Asia	2400	2365	2425		2310	
East Asia	2505	2480	2520		2320	

Source: Global 2000 Report to the President, Volume Two, Tables 6-8 and 6-9., pp.93-95.

Table 6

Projections from IIASA Basic Linked System

	Year	OECD	CMEA	Developing Countries: Mid Income	Developing Countries: Low Mid Income	Developing Countries: Low Income	Developing Countries: All	World (Including others)
1. Population (Three-year Average up to indicated year)	1980	648	375	389	695	2076	3160	4338
	1990	701	406	502	891	2513	3906	5186
	2000	754	437	637	1119	3023	4779	6106
2. Rate of Growth of Population (% per year)	1971-1980	0.79	0.90	2.63	2.58	2.12	2.28	1.84
	1980-1990	0.79	0.80	2.59	2.51	1.91	2.13	1.80
	1990-2000	0.73	0.71	2.38	2.28	1.86	2.03	1.63
3. Rate of Growth of Real GDP (% per year)	1971-1980	3.94	5.99	6.24	6.09	5.24	5.77	4.63
	1980-1990	3.57	5.33	5.89	5.70	5.09	5.51	4.31
	1990-2000	3.15	4.87	5.84	5.67	4.80	5.39	4.04
4. Daily Caloric Intake* (kilocalories)	1980	3335	3619	2712	2369	2310	2373	2595
	1990	3454	3628	2913	2509	2448	2522	2706
	2000	3550	3580	3059	2626	2552	2637	2787
5. Production of Wheat*	1980	136	127	26	21	84	131	414
	1990	181	141	31	27	112	170	519
	2000	212	156	36	32	139	207	564
6. Production Rice*	1980	15	1	10	52	158	220	241
	1990	16	2	13	67	195	275	298
	2000	18	2	16	89	224	329	355
7. Production of Coarse* Grains	1980	315	172	60	48	120	228	757
	1990	366	193	75	63	142	280	894
	2000	429	199	91	182	172	345	1040
8. Production of all Grains* indicated year)	1980	466	300	96	121	362	579	1412
	1990	563	336	119	157	449	725	1711
	2000	669	357	143	203	535	881	1959
9. Net Exports: Wheat* indicated year)	1980	55	-20	-10	-14	-12	-36	
	1990	84	-22	-17	-23	-25	-65	
	2000	102	-16	-25	-36	-40	-101	

Table 6 continued:

	Year	OECD	CMEA	Developing Countries: Mid Income	Developing Countries: Low Mid Income	Developing Countries: Low Income	Developing Countries: All	World (Including others)
10. Net Exports: Rice*	1980	2	-1	-1	-2	3	-	
indicated year)	1990	2	-1	-3	-7	8	-2	
	2000	2	-	-5	-5	5	-5	
11. Net Exports: Coarse*								
Grains	1980	40	-13	9	-5	-10	-6	
indicated year)	1990	35	-14	3	-10	-23	-30	
(Million Metric tons)	2000	48	-12	-8	-19	-39	-67	

*3 Year average upto indicated year.

Source: Food and Agriculture Project (FAP), IIASA, private communication, June, 1984. Results a preliminarly and likely to change and not to be quoted without permission of Project Leader, FAP, IIASA.

Table 7
Projections from India Model of IIASA

			Alternative 1	Alternative 2	Alternative 3
1.	Population (Millions)	1980	674	672	670
		1990	843	813	788
		2000	1048	995	927
2.	Rate of Growth of Population (% per year)	1971-2000	2.249	2.057	1.808
		1980-2000	2.232	1.980	1.637
		1990-2000	2.206	1.980	1.637
3.	Rate of Growth of Real GDP (% per year)	1971-2000	4.746	4.752	4.756
		1980-2000	5.349	5.356	5.363
		1990-2000	6.077	6.090	6.100
4.	Production of Wheat (Million Metric tons)	1980	33	33	33
		1990	57	57	57
		2000	85	84	83
5.	Production of Rice (Million Metric tons)	1980	47	47	47
		1990	68	68	68
		2000	92	92	92
6.	Production of Coarse Grains (Million Metric tons)	1980	26	26	26
		1990	32	32	32
		2000	35	34	34
7.	Production of all Grains (Million Metric tons)	1980	106	106	106
		1990	157	157	157
		2000	212	210	209
8.	Daily Calorie Intake				
	A. Rural Group 1	1990	1018(28)*	1024(27)	1030 (26)
		2000	1111(20)	1152(18)	1183 (16)
	2	1990	1958(17)	1959(17)	1961 (17)
		2000	2125(16)	2159(16)	2184 (15)
	3	1990	2584(19)	2588(19)	2591 (19)
		2000	2840(20)	2872(20)	2897 (20)
	4	1990	2659(20)	2674(20)	2693 (20)
		2000	2927(23)	2937(23)	2988 (23)
	5	1990	3789(17)	3837(17)	3898 (18)
		2000	3911(22)	4013(23)	4174 (25)
	B. Urban group 1	1990	1170(2.1)	1172(1.0)	1178 (0.9)
		2000	1173(0.5)	1217(0.4)	1261 (0.3)
	2	1990	1654(5.7)	1657(5.3)	1664 (4.9)
		2000	1689(3.4)	1726(2.9)	1766 (2.3)
	3	1990	2029(17)	2039(16)	2052 (15)
		2000	2040(13)	2073(12)	2115 (11)
	4	1990	2379(35)	2396(35)	2419 (34)
		2000	2352(34)	2397(33)	2456 (32)
	5	1990	3102(41)	3145(43)	3200 (44)
		2000	3010(49)	3091(51)	3209 (55)

Source: Same as for Table 6.

* Figures in paranthesis denotes the population of each class as a proportion of the relevant total population.

Table 8

Projections of MOIRA

	High Growth of NonAgricultural GDP				Low Growth of NonAgricultural GDP	
	1990		2000		1990	2000
I. Food Production (index 1980=100)						
	A	B	A	B		
Developing Countries	1.31	1.26	1.89	1.71	1.22	1.47
of which Latin America	1.46	1.47	2.12	2.11	1.45	2.03
Tropical Africa	1.51	1.48	2.17	2.04	1.14	1.48
Middle East	1.33	1.31	2.29	2.15	1.18	1.81
Southern Asia	1.14	1.00	1.53	1.20	1.05	0.91
Developed Countries	1.42	1.27	1.78	1.51	1.17	1.35
of which North America	1.47	1.24	1.74	1.40	1.13	1.25
European Community	1.35	1.28	1.73	1.50	1.17	1.35
World	1.38	1.28	1.80	1.60	1.21	1.42
II. Consumption per Capita (index 1980=100)						
Developing Countries	1.12	1.15	1.30	1.36	0.97	0.94
of which Latin America	1.21	1.28	1.46	1.63	1.04	1.08
Tropical Africa	1.26	1.26	1.48	1.48	1.04	0.96
Middle East	1.21	1.23	1.54	1.67	0.98	1.07
Southern Asia	1.04	1.00	1.12	1.04	0.92	0.77
Developed Countries	1.18	1.19	1.34	1.37	1.07	1.13
of which North America	1.15	1.14	1.26	1.26	1.06	1.11
European Community	1.17	1.18	1.31	1.34	1.07	1.12
World	1.15	1.16	1.28	1.35	1.02	1.02

III. World Price Index of Food (1965=100)	0.75	0.44	0.98	0.22	0.74	0.71
IV. World Population	5237	4318	6146	4722		
of which Developing countries	3916	3122	4733	3484		
Developed Countries	1321	1196	1413	1238		
V. Undernourished (millions)	520	400	740	460		
As a proportion of Developing Country Population	13	13	16	13		

Note: Column A (B) refers to reference (low) population growth scenarios.

Source: Linnemann et al (1979) and Tables 8.2, Appendix 10A, Runs 111,112,211, pp. 245, 306-368.

Table 9

IFPRI Projections

I. Average Growth Rates (Percent Per Year)		Population 1975-1990	Food Production 1960-75 (cereals)	Food Production 1975-1990 (major staples)
A. Food Deficit Countries		2.6	2.8	2.7
of which	Low Income	2.6	2.6	2.4
	Middle Income	2.9	3.6	3.5
	High Income	2.7	2.4	2.4
B. Grain Exporters		2.9	4.0	4.0
C. All 84 Countries		2.7	3.0	2.9

II. Food Consumption in 1990 (Million tons)		Variant 1	2a	2b	3
A. Food Deficit Countries		567	627	649	654
of which	Low Income	349	385	398	427
	Middle Income	166	180	185	170
	High Income	52	62	67	56
B. Grain Exporter		52	56	57	54
C. All 84 Countries		619	682	706	708

'able 9 continued

III. Gross Food Deficit in 1990*		Variant		
(Million Tons)	2a	2a1	2b	2b1
A. Food Deficit Countries	121	103	143	133
of which Low Income	69	55	83	69
Middle Income	21	19	25	21
High Income	31	29	35	33
B. Grain Exporter	--	---	---	---
C. All 84 Countries	726	54	143	133

*In computing gross deficit, from the imports of each group the exports within each group have not been subtracted.

Source IFPRI (1977), Tables 5, 6, 7 and 8, p44-63.