Appendixes

APPENDIX A
Population Projections

Introduction

Population projections play a key role in any assessment of future world conditions, since the size of the population determines the number of consumers of goods and services and the number of people available to produce those goods and services. The rate and distribution of population growth will also determine the short-term strains that are put on the world's socioeconomic system, just as the ultimate size of population will determine the long-term strains that are put on the planet's physical and biological systems. Three of the global models–World 3, World Integrated Model (WIM), and Latin American World Model (LAWM) —try to describe the general long-term behavior of all components of the global system, including population. In these models, the determinants of population change—fertility and life expectancy—are linked to other sectors through feedback loops that simulate the effect of changing physical and socioeconomic conditions on the rate of population growth. The other models try to provide a detailed, short-term prediction of world conditions; in these models the future size of the population is projected in a more straightforward way, unrelated to the projection of other conditions.

These differences in purpose and technique, combined with differences in time horizon and the uncertainties surrounding the present size and future behavior of the world's population, lead to variations in the projections themselves and in their relative reliability. The projections are also influenced by policy assumptions and by the models' degree and pattern of geographical regionalization. All of these factors affect the usefulness of the models and projects for the policymaker.

Purposes, Structures, and Projections

World 3

This highly aggregated global model was designed to display the long-term interactions among major world systems—population, nonrenewable resources, capital, agriculture, and pollution—in order to investigate the consequences of five major trends at the global level: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and environmental deterioration. In order to examine the long-term effects of these trends, the model *was* designed to simulate interactions over a 200-year period, from 1900 to 2100. The system dynamics modeling technique is particularly useful for simulating two important kinds of system behavior—feedback and delays–and is thus a powerful tool for understanding complex system behavior. This makes it a suitable approach for exploring the general shape of long-term global system behavior, but it is generally less useful than other techniques for producing accurate short-term forecasts of individual variables.

The population sector of World 3 is highly aggregated: it has only one geographic region and only four different age groupings: O to 14, 15 to 44, 45 to 64, and over 64. Global population is determined solely by the effects of changes in birth rates and death rates, but the determination of these rates depends heavily on interaction with the rest of the model. The death rate is calculated from average world life expectancy, which in turn is determined by four influences that the authors, based on historical evidence and expert judgment, postulate in the following relationships:

- Life expectancy 'increases with increasing food availability, reaching a maximum when food per capita is about four times the present world average.
- Life expectancy increases with increasing health services per capita, although with about a 20-year delay.
- Life expectancy initially increases with crowding because of increased industrialization and urban services, but beyond a certain level crowding has a negative influence on life expectancy due to the effect of local pollution and stress-related diseases.
- Life expectancy decreases as the amount of persistent pollution increases.

These relationships are intended to capture the general direction and magnitude of the four influences on life expectancy. Although exact equations must be entered into the model, these equations are not meant to be rigorous quantifications of the actual relationships.

The birth rate is calculated from the fertility rate, which in turn is influenced by two factors: desired fertility, and fertility-control effectiveness. Fertility-control effectiveness is expressed *as a* function of level of development, as measured by industrial output per capita, and reaches 100 percent at a level of development three times higher than the current average world level. Desired family size is assumed to be affected by two further influences-the social norm and the individual response

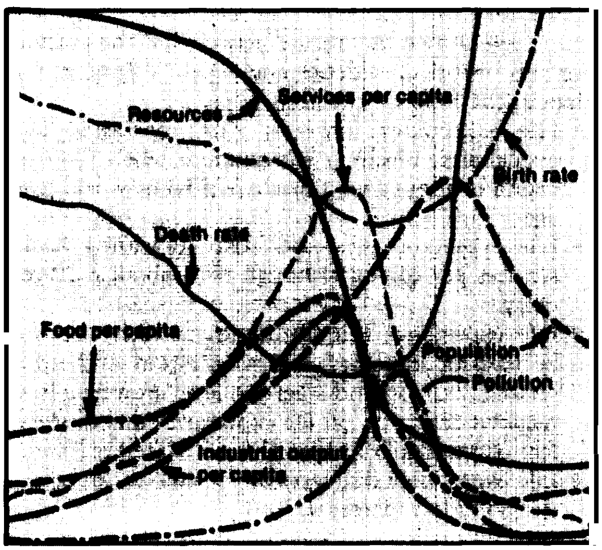
[1]The following material is based on an OTA working paper prepared by J. Stover of the Futures Group, Glastonbury, Corm. For further Information on this subject, see OTA's assessment, *World Population and Fertility-Planning* Technologies The Next 20 Years, OTA-HR-157, February 1982.

to the social norm—in such a way that desired family size ranges from a high of 5 children when income is low to a low of 1.5 children when income is high. As with life expectancy, however, the specification of these relationships is based on expert judgments aided by the small amount of available historical evidence.

The entire World 3 model was calibrated by simulating the period from 1900 to 1970, during which period the model correctly represents the broad dynamics of world population.

In the standard run of the World 3 model, world population increases to about 6 billion by 2000 and reaches a maximum level of about 7 billion by 2025, but then declines rapidly to only 4 billion by 2100 (see fig. A-l). This decline occurs because resource depletion causes an increasing fraction of capital to be used in extracting raw materials, thereby reducing the amount available for other investments, especially agricultural production. As investment in agriculture lags, food per capita begins to decline, causing a higher death rate, a decline in life expectancy, and ultimately a decline in population. This model run is meant to represent the most likely mode of system behavior if there is no change in past trends and policies, and the authors argue that it demonstrates the need for action to ensure that such a result does not occur.

Figure A-1.—World 3 Standard Run



The "standard" world model run assumes no major change in the physical, economic, or social relationships that have historically governed the development of the world system. All variables plotted here follow historical values from 1900 to 1970. Food, industrial output, and population grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialization. Population growth is finally halted by a rise in the death rate due to decreased food and medical services.

SOURCE: *Limits to Growth.*

In a series of sensitivity and policy tests, the authors show that neither increased resources nor improved technologies have any significant effect on this basic behavior mode: population invariably peaks before 2050 and declines thereafter, although the maximum population varies from 7 billion to 9 billion and the population in 2100 varies from 3 billion to 5 billion. The reasons for the collapse do change, however: for example, when the resource limits to growth are removed, increases in pollution become the factor that eventually causes the death rate to increase.

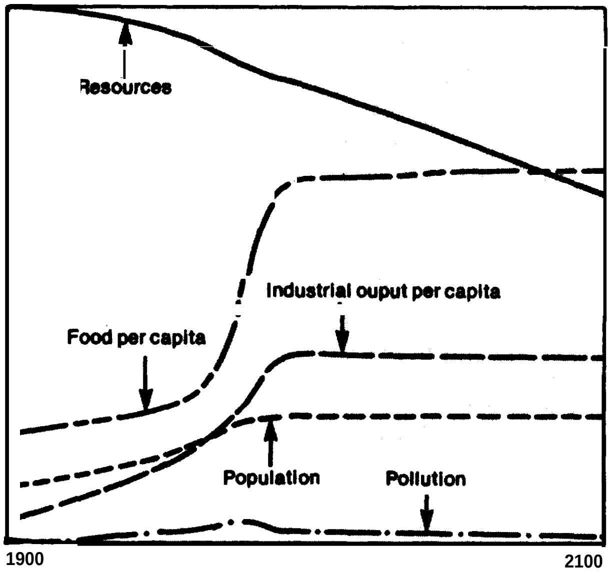
Only two scenarios were able to avoid the basic pattern of overshoot and collapse. In the first, based on the highly unrealistic condition of removing all the physical limits to growth, population continued to grow and reaches about 14 billion by 2100. The second is the "global equilibrium" scenario, based on an integrated set of policies designed to bring about a gradual transition to a stable, nongrowth world (fig. A-2). These policy changes, all of which are implemented beginning in 1975, include the availability of "perfectly effective" birth control and a worldwide reduction of desired family size to 2 children. Under these conditions, the population grows to only 5 billion by 2000 and stabilizes at around 6 billion by 2050. If the needed policy changes are delayed until 2000, however, the equilibrium state is not sustainable (fig. A-3).

The usefulness of this model to policy makers lies mainly in pointing out the potential dangers ahead, the costs of delaying action, and the need for considering the whole system when thinking about one aspect of the problem. However, since the model does not contain adequate policy levers (i.e., policymakers cannot directly control the variables in the model), its usefulness for policy testing and evaluation is limited.

World Integrated Model (WIM)

This global model, the first of several to be built in response to what many saw as the inadequacies of World 3, differs from the latter in one major aspect—disaggregation. WIM represents a world composed of many different subsystems that interact with one another hierarchically on five different planes or strata: individual, group, demographic-economic, technological, and environmental. It also divides the world into 10 or more geographic regions; each region is a complete model in itself, but interacts with the other regions through international trade. The model is not an explicit system

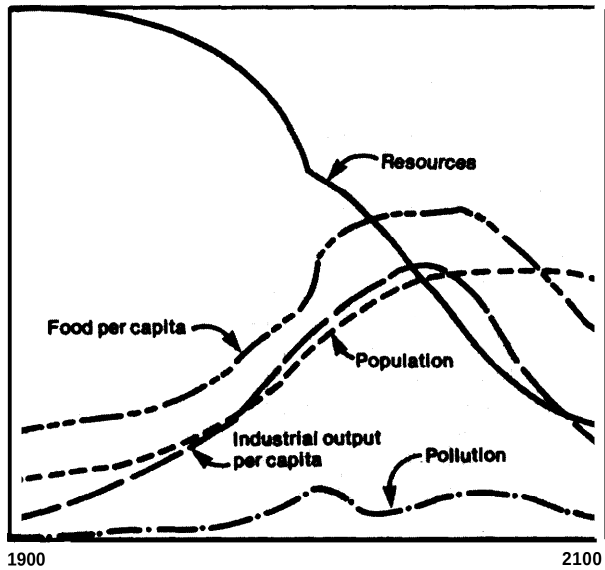
Figure A-2.—World 3 Equilibrium Run



Technological policies and growth-regulating policies produce an equilibrium state sustainable far into the future. Technological policies include resource recycling, pollution control devices, increased lifetime of all forms of capital, and methods to restore eroded and infertile soil. Value changes include increased emphasis on food and services rather than on industrial production. Births are set equal to deaths and industrial capital investment equal to capital depreciation. Equilibrium value of industrial output per capita is three times the 1970 world average.

SOURCE: Limits to *Growth.*

Figure A-3.—World 3 Run With Stabilizing Policies Introduced in the Year 2000



If all the policies instituted in 1975 in the previous figure are delayed until the year 2000, the equilibrium state is no longer sustainable. Population and industrial capital reach levels high enough to create food and resource shortages before the year 2100.

SOURCE: Limits to Growth.

dynamics model, but it does incorporate some of the feedback relationships and delays that are contained in World 3, as well as many new ones.

The population sector of each region divides the population into 85 l-year age cohorts. Fertility is determined by the level of socioeconomic development in each region, including both the reduction in desired family size and the increased effectiveness of contraceptive use. Increasing levels of education also lead to declining fertility.

Mortality is also linked to the rest of the model. Life expectancy increases with increasing level of development and (in some versions of the model) it is also affected by food availability: the model calculates the amount of calories and protein available in each region, and when these amounts fall below sufficient levels, additional deaths due to starvation result. All of these relationships are judgmentally determined–as in World 3, they are meant to capture the general shape of the real-world relationships, without attempting to quantify them rigorously.

The standard run of the model shows the result of continuing historical patterns of development. In this run, however, the relationships between education, development, and fertility are replaced by the "optimistic though reasonable" assumption that successful population policies will cause fertility rates in all regions to drop to the replacement level (i.e., births equal deaths) within 35 years. The authors did this in order to "avoid biases that might be introduced by the predominance of population growth factors. "[2] This standard run shows world population increasing from 4 billion in 1975 to about 6.4 billion by 2000 and stabilizing at about 6.8 billion by 2015.

In other runs the authors have examined the effects on world population of delays in starting a worldwide policy to achieve replacement fertility rates. Assuming that it takes 35 years from the start of such an effort until replacement level fertility is reached, they found that world population would stabilize at about 7 billion if the effort is started in 1975, 10 billion if it is started in 1985, and 12 billion if it is started in 1995.

Because of the differences in regional detail, the conclusions of the WIM study are different from those of

[2] M. D. Mesarovic and E. Pestel, *Mankind at the Turning Point* (New York: Dutton, 1974), p. 57.

World 3. The authors conclude that worldwide collapse is not likely to result even if past trends continue, but that catastrophes could well occur at the regional level well before 2050. These regional collapses, occurring at different times and for different reasons, will nevertheless profoundly affect the entire global system. The solution to this problem lies not in stopping all growth but rather in achieving what the authors call "organic growth' '-i.e., different kinds of growth in different regions, such as continued industrial growth in the LDCs but service-oriented growth in the developed countries. Without early action to ensure a transition to this kind of balanced, differentiated growth, the authors say that regional and finally global disaster is inevitable.

The model was designed to be employed by policymakers. Extensive work has gone into making the model interactive so that policy makers can experiment with it and, thereby, increase their understanding of the future effects of current policy decisions. Since the original model is not disaggregated to the country level, policymakers cannot see the effect of specific policies that they might implement in their own countries. However, subregional and country models based on the same concepts have been developed by former members of the modeling team in response to the needs of specific clients.

Latin American World Model (LAWM)

This model was also constructed in response to limitations seen in the World 3 model, and in particular to its disturbing implications for the developing world, If economic growth must stop soon in order to avert world collapse, what hope do the poor countries have of ever alleviating their poverty? The Latin American authors of this study concluded that the proper question to ask is: "What changes in the structure of the present socioeconomic system would be required in order to bring about a better life for all?"

Since the model attempts to answer a different question, its modeling technique is also different. LAWM is based on optimization techniques, and the model is structured in such a way as to determine the allocation of labor and capital that will ultimately maximize life expectancy—its measure of the satisfaction of basic human needs. The model divides the world into four regions—the developed countries, Latin America, Africa, and Asia—each of which functions more or less independently. The model does contain some physical constraints, but its structure reflects a general underlying assumption that physical limits to growth will not be as important as social and political limits. As a result, its projections do not reflect how the world will be, but rather how it could be if the indicated allocation policies were followed.

The population sector of LAWM, which is designed to identify the social and economic factors that influence population growth and life expectancy, is both more detailed and more complicated than those of World 3 and WIM. The complex web of variables and influences (shown in fig. A-4) can, however, be reduced to a single, fairly straightforward hypothesis: "The only truly adequate way of controlling population growth is by improving basic living conditions."[3] Thus, the allocation of capital and labor to any of the basic needs sectors—food, education, housing, and other consumer goods and services—will result in lower birth rates and/or higher life expectancy. These influences are in fact compounded, since lower birth rates lead to higher life expectancy, which in turn leads to a further decrease in birth rates.

Education and agriculture seem to have been given particular weight in LAWM, but all of the relations were estimated through descriptive analysis, using scattered data and rather esoteric mathematical techniques, and they should not be confused with causal relationships, although the formulation of the model implicitly assumes them to be causal.[4] The correlations between estimated and actual birth rate and life expectancy for the test period (1960-70) are very high (+0.90 and +0.95, respectively), but this technique gives no indication of whether or not the postulated functions are correct. If demographic change in the real world follows different rules, this optimization procedure will not generate reliable projections.

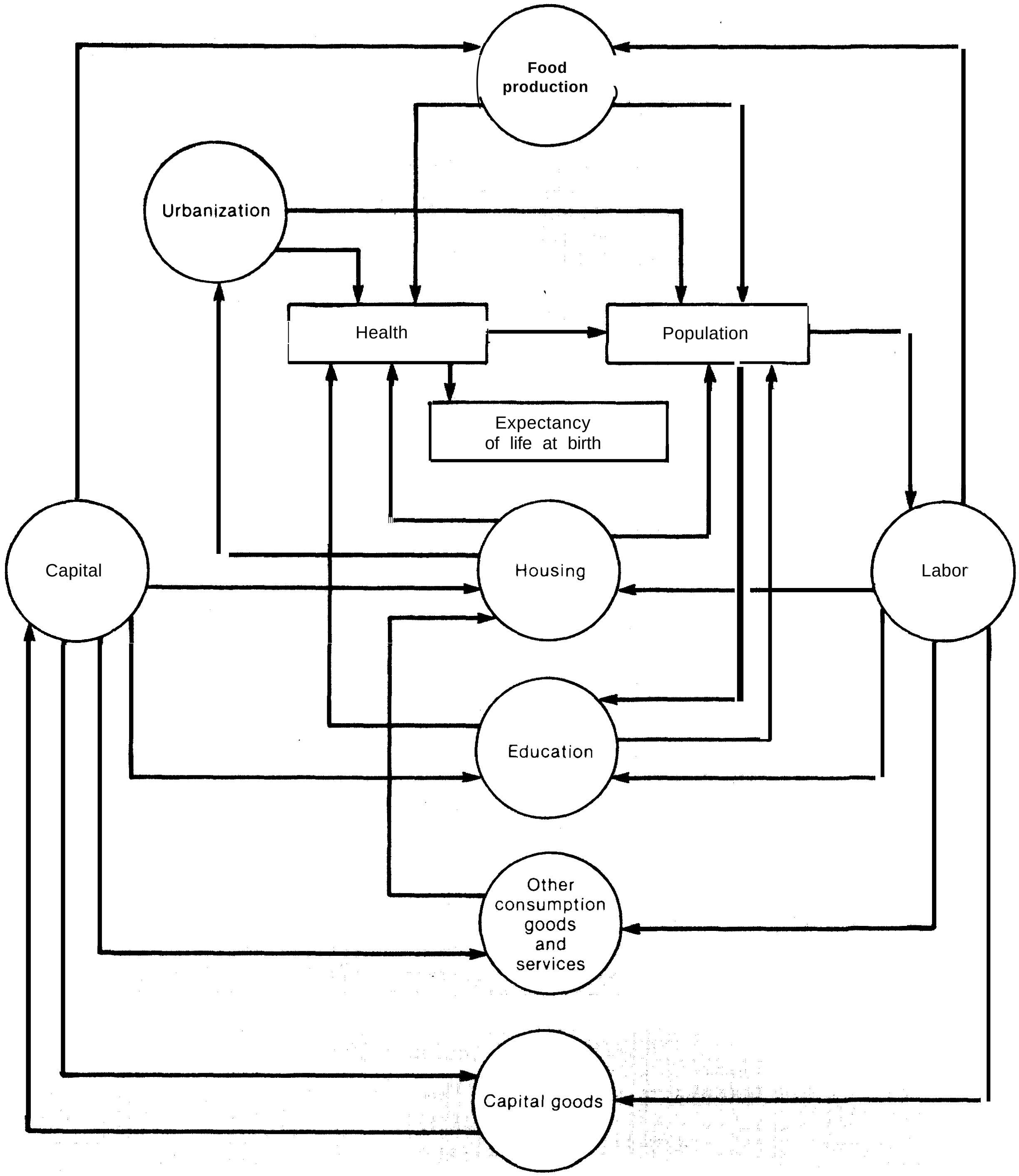
The results of the LAWM standard run are mildly optimistic for all regions except Asia, where the only basic need that is satisfied is education. By 2010 all available land in Asia is being cultivated, which means that the growth of food production is unable to keep up with population growth; although progress continues in housing and income, food availability per capita falls to dangerous levels, and the delay in achieving basic needs causes a delay in reducing population growth. The population projections show a total world population of 6.4 billion by 2000, 1,2 billion in the developed world and 5.2 billion in the developing world. By 2040 the world population reaches 11 billion and is still growing at 1.1 percent per year, due largely to the 1.4 percent growth rate in Asia.

The usefulness of this model for policymakers lacks mainly in its ability to display the effects of adopting a particular broad strategy—that of allocating labor and capital in a manner that corresponds statistically to

[3] A. O. Herrera, et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Center, 1976), p. 8.

[4] See J. Robinson, "The Latin American World Model," in *The Global 2000 Report to the President* (Washington, D. C.: U.S. Council on Environmental Quality and Department of State, 1980), vol. 2, pp. 638 and 641; and D. H. Meadows, J. Richardson, and G. Bruckmann (eds.), *Groping in the Dark: The First Decade of Global Modeling* (New York: Wiley, forthcoming), p. 97.

Figure A-4.— Basic Structure of LAWM



SOURCE: Gracielle Chichilnisky, "Latin American World Model: Theoretical Structure and Economic Sector," in *Proceedings of the Second IIASA Symposium on Global Modeling*, Gerhart Bruckmann (ed.) (Laxenburg, Austria: International Institute for Applied Systems Analysis, 1976), p. 126.

maximized life expectancy. LAWM does not contain policy levers that might be exercised by an individual planner, but the model has nevertheless contributed to the debate on broad strategy by describing an alternative to the present world order.

The United Nations Input-Output World Model (UNIOWM)

The particular goal of this study was to assess the impact of various economic issues and policies on the International Development Strategy for the Second United Nations Development Decade. Specifically, the model was to address the question of whether the existing policies and development targets were consistent with the availability of world resources. Because it uses an input-output approach, the model can be used either to investigate the rates of economic growth achievable given certain constraints (resources, balance of payments, etc.) or to investigate investment and consumption levels that would be consistent with given rates of economic growth.

Unlike the other global models, however, population growth is entirely exogenous in UNIOWM. Although the size and composition of the population affect the rest of the model, there is no feedback from the rest of the model to population. In fact, the model has no population sector as such: it simply uses the population projections prepared by the United Nations Population Division for the 1973 assessment of world population, (This assessment was updated for all countries in 1978, and the discussion below deals with the more recent figures.) These projections, include four variants-high, medium, low, and constant-the constant case is merely a reference projection assuming no change in a country's fertility rate. The medium variant is designed to represent the most likely future demographic trends, based on past and present demographic trends, expected social and economic progress, ongoing government policies, and prevailing public attitudes toward population issues. The high and low variants are intended to reflect plausible variations on these factors.

The fertiltiy assumptions underlying the projections are based on past and present fertility trends in each country, adjusted judgmentally by experts in the U.N. regional population offices around the world and reviewed in the Population Division at U.N. headquarters in New York. These judgments were guided by three general principals:[5]

- Fertility rates will decline as economic and social development takes place.
- Existing or anticipated government policies and programs, as well as nongovernmental activities aimed at such a goal, will expedite the process of fertility decline.
- Once initiated, fertility decline will begin slowly, gain momentum, and then slow down again. For those countries with fertility levels near or below the replacement level, it is assumed that fertility will begin to converge on replacement level before the end of this century.

Judgmental estimates of life expectancy were also prepared for each country, following the general rule that life expectancy would increase by 2.5 years every 5 years until it reaches 55, after which the rate of increase would be less. (For some countries where development has been slow, this rule was changed to allow slower increases.) The projections also take into account assumptions about internal migration (urbanization) in each country.

In the projections prepared by the U.N. in 1978, the population of the world increases from 4 billion in **1975 to 5.9** billion, 6.2 billion, and 6.5 billion by 2000 for the low, medium, and high variants, respectively. Most of this growth occurs in the developing world: the population of the more developed countries increases by only 13 to 21 percent from 1975 to **2000,** while the increase for the less developed world is 57 percent in the low variant to 77 percent in the high projections.

The most rapid rate of growth is in Africa, where population increases by 114 percent from 1975 to 2000, and in Central America and the Caribbean, where it increases by 115 percent. China's population is projected to increase by 26 to 37 percent; this is only half the average rate for all developing countries, although it means an additional 235 million to 335 million people by 2000. India will add even more people to its population, an additional 360 million to 480 million people.

These population projections are used by UNIOWM to explore the consequences of the goals adopted for the Second Development Decade. This model has great utility in displaying the results that would occur if these goals were achieved, and as such it has been useful to those planning the broad strategy of the development decade. Unfortunately, the goals and prescriptions of the development decade do not always have a significant influence on actions taken by individual countries.

Global 2000

This study, conducted by an interagency task force that drew on the expertise and models of the entire U.S. Government, is one of the most comprehensive models in terms of the number of variables it examines. However, the separate submodels comprising "the Government's global model" are not linked to each other, and as a result there is no feedback or interaction between sectors. As a result, the population figures do not

[5] United Nations, *World Population Trends and Prospects by Country 1950-2000 Summary Report of the 1978 Assessment* (New York: United Nations, 1979), p. 2.

reflect the model's pessimistic projections of GNP or food production.

The population projections that were used in most sectors of Global 2000 were prepared by the U.S. Bureau of the Census in 1977. Like the U.N. projections, they are presented with high, medium, and low variants for all regions and selected countries. Underlying all three variants are the assumptions that: 1) fertility will decline more or less continuously throughout the period; 2) all countries will have adopted some kind of family planning program by 2000; and 3) the effectiveness and coverage of such programs will increase. The different fertility rates used in the high, medium, and low variants are based on the judgment of experts and reflect the range of uncertainty about current fertility, future development patterns, and government family planning policies. Specific individual judgments are not reported, however.

The final Census Bureau projections extend to the year 2000 and are substantially the same as the U.N. projections: global population grows to 5.8 billion in the low variant, 6.2 billion in the medium variant, and 6.5 billion in the high variant. The population of the developed regions grows to between 1.3 billion and 1.4 billion by 2000, while the less developed regions grow to between 4.5 billion and 5.1 billion.

An alternative set of projections, prepared by the Community and Family Study Center (CFSC) at the University of Chicago under the sponsorship of the Agency for International Development (AID), is also presented in the Global **2000 Report** but is not used in other sectors. These projections, too, include high, medium, and low variants, but in this case the projected fertility rates are based on a model of fertility decline that relates the rate of decline to the current level of fertility and the strength of family planning efforts within each country. The variants therefore reflect more explicit assumptions about family planning efforts: the high variant assumes that each country maintains its present level of family planning; the medium variant assumes that nations will implement strong family-planning programs by 2000; and the low variant assumes that strong programs will be in place by 1995 and that the effectiveness of these efforts will increase. These assumptions were developed through regression analysis of data for 1968-75, which showed that the strength of family-planning efforts had as much effect on fertility rates as all the measures of socioeconomic development combined.

Because they assume policy changes that would increase the efficacy of family-planning services, the CFSC projections are generally lower than those of the U.N. and Census Bureau: world population reaches 5.8 billion, 5.9 billion, and 6.0 billion by 2000 in the low, medium, and high variants, with the developed regions growing to between 1.2 billion and 1.3 billion and the less developed regions to between 4.5 billion and 4.7 billion. These projections have also been extended to 2050, at which date they show a global population of between 7.8 billion and 8.1 billion people.

The Census Bureau projections, those prepared by CFSC for AID, and all other "stand-alone" projections are useful to the policy maker mainly because they provide an input describing the population conditions under which policy must operate. Such projections are of little direct use to policy makers, but they often become key elements in the analyses that are prepared during the development of policy options.

Other Population Projections

Projections of world population have also been prepared, without the use of a global model, by the World Bank and Harvard University. The World Bank projections, last revised in 1979, were prepared by estimating, for each country, the year in which fertility will reach replacement level.[6] (As defined by the World Bank, "replacement-level fertility" refers to the level at which the number of births equals the number of deaths at the prevailing level of mortality. For countries with high mortality rates the replacement fertility level is considerably higher than 2 children per couple; as mortality declines, fertility must also continue to decline. Thus, a stationary population might not be achieved for more than 100 years after the achievement of replacement-level fertility.) The World Bank projections assume that fertility decline toward the replacement level had started by 1975 in all regions except Sub-Saharan Africa, where the decline was expected to start between 1980 and 1985. These projections show population increasing to 6.0 billion by 2000, with 1.3 billion in the developed world and 4.7 billion in the developing world; the population of the entire world becomes stationary around the year 2175 at a level of 9.8 billion.

In 1977, the Center for Population Studies at Harvard University prepared a single population projection for all countries and regions of the world to the year 2075.[7] In these projections, fertility is assumed to decline to replacement levels by 1990-95 for the developed countries and by 2000-05 for the developing countries; they show the population of the world increasing to 5,9 billion by 2000 and 8.4 billion by 2075.

[6] K. C. Zachariah and My Thi Vu, *Population Projections, 1975-2000 and Long-Term (Stationary Population)* (Washington, D. C.: World Bank, 1979).
[7] G. Littman and N. Keyfitz, *The Next Hundred Years* (Cambridge, Mass.: Harvard University, 1977).

Strengths and Weaknesses of Population Projection Techniques

Among the studies discussed here there are at least two different goals:

- to describe the long-term behavior of the global system; or
- to provide an accurate, short-term (25 years or less) picture of the world situation.

The long-term global modeling studies (World 3, WIM, LAWM) are clearly concerned with the first goal only. They examine the behavior of the entire global system over the next 50 to 125 years, but they make no attempt to provide accurate forecasts of world population (or any other variable) for 2000. All three studies take great pains to point out that accuracy of individual numbers is not a concern. The studies that limit themselves to projecting population only (World Bank, Harvard) are generally trying to satisfy both goals; they present country-by-country forecasts of population in 2000, but they also present longer views of population growth. The two modeling studies that limit themselves to 2000 (UNIOWM and Global 2000) are clearly interested primarily in the second goal.

These two different goals require the use of two fundamentally different modeling techniques. The first approach (long-term system behavior) considers population as only one of the many elements involved in the integrated behavior of the system: it affects the other sectors and, in turn, is affected by them. With this approach the most important aspects of the population sector are the effects of the rest of the model on population growth. The second technique (accurate short-term forecasts) considers population alone, without integrating it into the world system, It strives for accuracy by making separate projections of the individual countries, which are useful in themselves and can also be summed to produce a world total.

Long-Term Integrated Projections

The first technique has obvious advantages for projecting long-term system behavior. Population really is affected by the rest of the global model—by food production, pollution, and economic and social development—and it is essential to take these factors into account in projecting population growth over a long time period. The difficulty with this approach, however, is that the relationships between fertility, life expectancy, and other variables are not known precisely, nor is the historical evidence rich enough to allow these relationships to be estimated with any degree of confidence. In order to include the relationships in their model, therefore, the modelers are often forced to rely on rough estimates and informed guesses. The sensitivity of the model's behavior to these judgments can be tested, of course, but the reliance on judgment does make the model speculative.

Within this first general approach the models discussed here have adopted three variations. World 3 aggregates everything to the level of the world, with no geographical divisions. This was certainly appropriate for the preliminary versions of the model, which were meant to be simple, easily explained outlines of the eventual model. The large effort that went into constructing and documenting World 3 might have been better served if some regional disaggregation had been employed, but this would have at least doubled the amount of work involved in developing, testing, and documenting the model.

The development gap between the developed and less developed world is so large, however, that the two regions cannot properly be considered as one. WIM divides the world into 10 or more regions, and it therefore supplies a much more detailed representation of real-world behavior. In most of the initial WIM runs, however, the link between fertility and the rest of the model was broken and an optimistic fertility assumption imposed, although mortality rates did respond to the rest of the model.

LAWM takes the same general approach to the population sector as the other two models, with one major difference: the model is not designed to simulate actual world conditions, but rather to simulate what would take place if resources were allocated optimally in order to maximize life expectancy. Since this is not the way the world actually operates, LAWM's usefulness is in describing the world that would evolve, given a particular new mode of behavior, and not in describing what is likely to happen.

Short-Term Stand-Alone Projections

The second method of projecting population is used by each of the other studies. In this approach the population projections are linked to the rest of the world only insofar as the rest of the world is considered by the experts when they make their judgments about fertility and mortality decline. When the U.N. experts made their estimates, for example, they had in mind some view of the future world which influenced their judgments. Their worldview obviously excluded such disasters as nuclear war and massive famine, or their life expectancy assumptions would not have shown steady increases; but it is impossible to describe just what that worldview was. Indeed, since many different people were involved in this exercise, many different (and possibly conflicting) views of the world were used. It is impossible to say whether these worldviews were internally or mutually consistent, or to what extent any of them reflect the feedback effects between population and development. The most that can be said is that the experts generally assumed that the forces at work in the past would continue to operate, with the future largely growing out of a continuation of past trends.

Is this assumption of a "surprise-free" future reasonable? All of the global studies discussed here (including the long-term studies as well as Global 2000 and the UNIOWM) apparently consider this assumption reasonable in the short term. None of the studies show large-scale effects on population due to famine or resource shortages before 2000, although WIM shows regional starvation in Asia. In the longer term, however, the situation is different. The three long-term modeling studies show a high likelihood of significant changes beyond 2000: World 3 shows a collapse of population after 2030, WIM shows rapidly increasing deaths due to starvation in South Asia before 2025, and LAWM shows food availability in Asia dropping to starvation levels by 2040 in its standard run. Other studies not based on mathematical models, such as Herman Kahn's *The Next 200 Years*,[a] do not foresee such problems, but the assumption of a long-term continuation of past trends is certainly questionable. The likelihood of such a future actually developing can only be addressed through a comprehensive, integrated study of all factors affecting population growth.

[a]H. Kuhn and A. Wiener, *The Year 2000 A Framework for Speculation on the Next Thirty-Three Years* (New York: Morrow, 1967).

Factors Affecting the Reliability and Accuracy of Population Projections

Differences in purpose and time horizon also affect the reliability and accuracy of the resulting population projections. World 3, for example, attempts to describe the general behavior of the global system to the year 2100. The precision sufficient for such a model is quite different from that desired in the U.N. or Census Bureau population projections, which are used to predict the populations of individual countries in 2000.

Table A-1 shows the results of the studies that have made long-term population projections. There are two notable differences. Due to increasing death rates, population actually begins to decline in the World 3 model after 2025 and presumably would do so for Asia in WIM and LAWM if they had continued beyond 2060; the other projections all show steadily growing popula-

Table A-l.—Comparison of Long. Range Population Projections

Projection source	Projection	Results
World 3	**Standard run**	**Population increases to 7 billion by 2025 then decreases to 4 billion by 2100**
	Stationary world	**Population stabilizes at 6 billion by 2050**
World Integrated Model	**Standard run**	**Population stabilizes at just under 7 billion by 2015. Death rates due to starvation are high in Southeast Asia**
Latin American World Model	**Standard run**	**Population reaches 11 billion by 2040 and is still growing at 1.1 percent/yr. Death rates are rising rapidly in Asia**
	Second run—improved conditions in Asia	**Population reaches almost 11 billion by 2060 and is growing at less than 0.5 percent/yr.**
United Nations	**1978 population assessment**	**[a]Population reaches 8 to 12 billion by 2050 and stabilizes at 8 to 14 billion by 2150**
CFSC	**Medium and low projections**	**Population reaches 7.8 to 8.1 billion by 2050 and is virtually stationary**
World Bank	**Standard**	**Population stabilizes at 9.8 billion by the year 2175**
Harvard	**Standard**	**Population reaches 8.4 billion by 2075 and is virtually stationary**

[a]These are unpublished, provisional estimates that are not official.

SOURCE: The Futures Group.

tion until some stationary level is reached. The second major difference is in the size of that stationary world population, which ranges from a low 8 billion (U.N. low, CFSC, Harvard) to a high of 14 billion (U.N. high). (The lower figures of World 3 and WIM are based on exceptional population programs begun in 1975, and are thus not comparable.)

There is much less variation in the population projections for 2000, which are compared in table A-2 and figure A-5. They vary from a low of 5.8 billion (Census Bureau, CFSC) to a high of 6.5 billion (U.N. and Census Bureau). This much smaller variation indicates the much higher degree of certainty inherent in population projection for periods under 25 years: there is relatively little uncertainty about the number of reproductive-age females between now and 2000, although there is much greater uncertainty with respect to the number of children that each woman will have.

The reasons for the differences among these different projections and their relative accuracy and reliability depend on several factors, among which are:

- projection technique;
- data base for initial population figures; and
- estimates of future fertility and life expectancy.

Table A.2.—Comparison of Population Projections for 2000

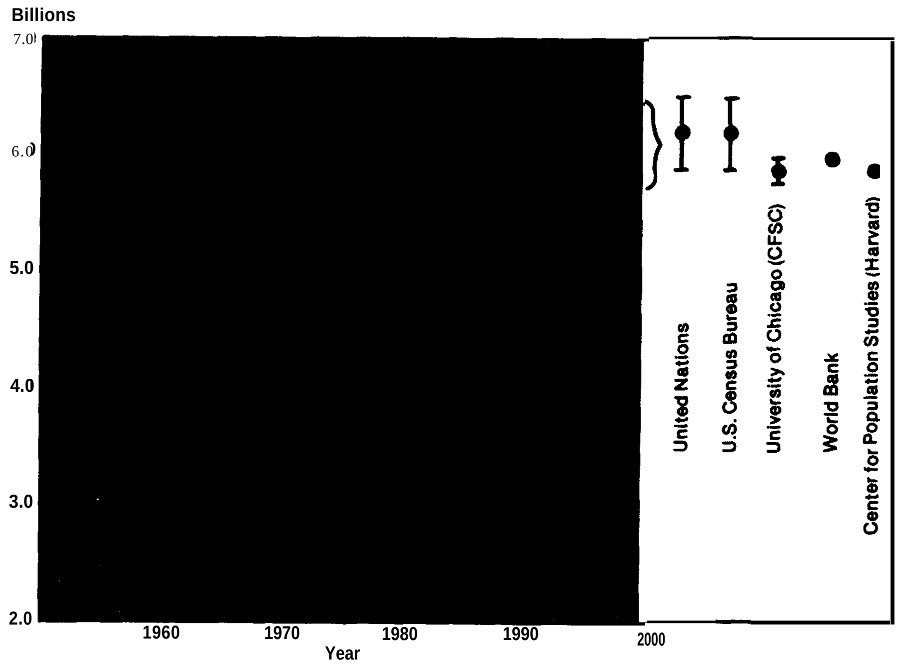
Projection source	Projection	Population in 2000 (billions)
World 3	Standard run	About 6
World Integrated Model	Standard run	6.4
Latin American World Model	Standard run	6.4
United Nations	High	6.5
	Medium	6.2
	Low	5.9
U.S. Bureau of the Census	High	6.5
	Medium	6.2
	Low	5.8
CFSC	High	6.0
	Medium	5.9
	Low	5.8
World Bank	Standard	6.0
Harvard	Standard	5.9

SOURCE: The Futures Group.

Projection Technique

The integrated models include the effects on population from other parts of the global system, and this results in the projection of increasing death rates due to food shortages in at least some parts of the world. The

Figure A-5.-Aiternative Projections of World Population in 2000



SOURCES: *World Population Trends and Prospects by Country, 1950-2000. Summary Report of the 1978 Assessment* (New York: United Nations, 1979). *Illustrative Projection of World Population Projections to the 21st Century* (Washington, D.C.: Bureau of the Census, 1979). Amy Ong Tsui and Donald J. Bogue, *Population Projections for the World, 1975-2000* (Chicago: Community and Family Study Center, University of Chicago, October 1977). K. C. Zachariah and My Thi Vu, *Population Projections, 1975-2000 and Long-Term (Stationary Population)* (Washington, D.C.: Population and Human Resources Division, World Bank, 1979). Gary Littman and Nathan Keyfitz, *The Next 100 Years* (Cambridge: The Center for Population Studies, Harvard University, 1977.)

projections that did not employ global models assumed that such disasters would be prevented by technical change, but when forecasters are forced to specify their assumptions mathematically in a model, they were all drawn to similar conclusions: it is unlikely that technological advances alone will allow the world sufficient time to solve the problem of rapidly growing population. The technology assumptions or, indeed, the very structure of the models could well be wrong; but those who develop long-term population projections without the use of models have certainly side-stepped this issue. The problems identified by the integrated global models might be solved through improved technology or different social responses, but none of the projections prepared without models explicitly addresses these questions.

Data Base for Initial Population Figures

All of the recent projections use essentially the same data base for base-year population. Information from national sources is collected by the U. N., the World Bank, and the U.S. Census Bureau, and for most countries all three organizations report the same population totals. However, there is very little available information for some countries; it is therefore necessary to prepare estimates based on incomplete data, and these estimates may vary.

Uncertainty about base-year data is not expressed in the ranges reported by the U. N., and the Census Bureau projections incorporate different base-year data only for China. The recent round of censuses has substantially improved the information available for many countries, particularly in Africa, but for many countries the variation in estimates can still be quite large. China, for example, has not had a census since 1953, and there is a 14-percent difference between the U.N. low and Census Bureau high estimates for China in 1980, a difference about equal to the population of the United States. Similarly, the current population of Nigeria has been estimated at anywhere between 65 million and 85 million, and the most recent census in India found 12 million more people than expected. Even though these differences may be quite large for individual countries, however, they are fairly small once they are summed to the global level: the difference between the highest estimate for world population in 1975 (Census Bureau high series of 4,134 million) and the lowest estimate (World Bank estimate of 4,014 million) is only 3 percent.

Estimates of Future Fertility and Life Expectancy

It has generally been true that projection of populations for countries and regions is relatively accurate in the short term (15 to 20 years) and fairly inaccurate in the long term (over 25 years). The reason for this lies in the nature of population change. Population size changes through three mechanisms: births, deaths, and migration. Except for certain special cases, migration is usually not a major factor in population growth, although movements from rural to urban areas can have significant social, economic, and political consequences. Uncertainty in birth and death rates, on the other hand, can be quite large.

Changes in the birth rate have occurred quite rapidly in the past, and since the reasons for changes in the birth rate are poorly understood, projections of birth rates have tended to err on the side of assuming less change than actually takes place. However, even if the projection of the birth rate misses the mark by a significant amount, the short-term projection of the size of total population may still be reasonably accurate.

After 15 or 20 years, however, errors in projecting birth rates begin to have a much larger effect. By that time children born during the first years of the projections would begin to have children of their own, and any overestimation or underestimation of births will become compounded, leading to exponentially increasing errors in the projection. Since changing death rates affect the mortality of children much more than older age groups, this delayed compounding effect also operates on errors in death-rate projections. For this reason the record of population projections beyond 20 years has not been especially good.

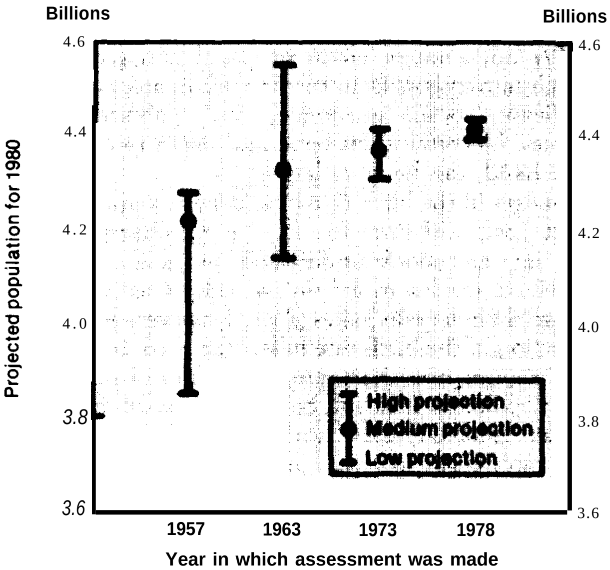
Another crucial factor is the accuracy of the base-year data for birth and death rates. If they are not known with much accuracy, then the projection will have a built-in error and, even if the future change in these rates is correctly forecast, the total error of the projection can be substantial. These factors most seriously affect projections for developing countries, where population data are often scant and unreliable.

The Accuracy of Past and Present Projections

The 1950's and 1960's were a period of rising population growth rates, and U.N. projections made during this period generally underestimated future population. Past U.N. projections of world population for 1980 illustrate this point: the latest assessment in 1978 projected the 1980 population at 4.41 billion; in 1957 it was projected at 4.22 billion (4.3 percent less than the latest estimate); in 1963 at 4.33 billion (1.8 percent less); and in 1973 at 4.37 billion (0.9 percent less) (see fig. A-6).

The major factor affecting these estimates was inaccurate base-year data on death rates, which were 10 or 12 percent lower than estimated. Birth rates, which were estimated more accurately for the base year, have declined more rapidly than predicted. The current esti-

Figure A-6.—United Nations Population Projections for 1960 Prepared Over the Past 25 Years



SOURCES: **1957 and 1963:** *World Population Prospects* **as** *Assessed in 1963 (New* **York: United Nations, 1966), 1973:** *Se/ecfed Wor/d Demographic Indicators by Countries, 1950-2000 (New* **York: United Nations, 1975). 1978:** *Wor/d Popu/atlon Trends and Prospects by Country, 1950-2000, Summary of the 1978 Assessment (New* **York: United Nations, 1979),**

mates of population size, birth rates, and death rates are much improved over what they were in the 1950's and 1960's, but large uncertainties still remain, particularly with the LDCs.

The uncertainty over present birth rates also contributes to uncertainties about future birth rates. In the 1980-2000 period birth rates will probably decline for almost all 'countries of the world, but projecting the amount of that decline is made difficult by at least four factors:

- uncertainty about how much birth rates have already declined up to the present;
- uncertainty about how many countries will adopt serious family planning policies and how strong those efforts will be;
- uncertainty about how much family planning efforts have contributed to past declines in birth rates; and
- uncertainty about how relevant the experience of family planning effectiveness in countries that have already adopted such efforts will be in those countries which have not yet done so.

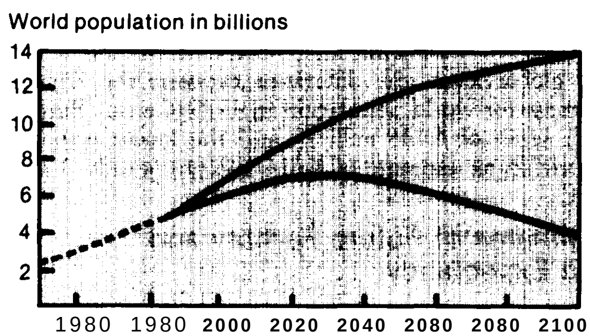
Most of the uncertainty is about birth rates in the developing countries, notably in Africa where there is almost no experience with strong family-planning programs. It is simply impossible to know whether the family-planning experience of countries in Asia and Latin America will be repeated in Africa.

Michael Stoto of Harvard University has calculated the average error in individual country projections made by the U.N. in 1957, based on the difference between predicted and actual growth rates for 40 countries for four time periods: 1955-60, 1955-65, 1955-70, and 1955-75. He found that the absolute average error in annual growth rates for all four time periods was about 0.46 percent, or about 25 percent of the absolute average annual growth rate for the world (about 1.9 percent).[9] The Futures Group has repeated these calculations for the period 1970-75, using projections made by the U.N. in 1973 and actual growth rates taken from its 1978 assessment, Using the same 40 countries, but eliminating those for which no new data are available since 1972, they found an absolute average error of 0.27 percent. Most of the improvement is probably due to the improved quality of base-year data available for the 1973 forecasts, which were used in UNIOWM, If these errors are representative of the kind of errors we can expect in the future, projections of population size 20 years into the future should have an uncertainty range of 10 to 20 percent.

In the longer term the accuracy is much lower. This is due to the greater uncertainty about fertility and mortality trends, the compounding of errors made in the short-term forecasts, and uncertainty about the effects of the rest of the world system (food availability, economic development, pollution) on population growth. The range of projections shown in the studies discussed here–from a projection of steadily growing population reaching a level of 8 to 14 billion, to a projection of population growth and collapse—is representative of the kind of uncertainty that exists in trying to project 50 to 100 years into the future, even if we are willing to exclude such disasters as nuclear war (see fig, A-7).

'J. Stover, op. cit.

Figure A.7.—Increasing Range of Uncertainty in Longer Range Projections of World Population



NOTE: For illustrative purposes only; see table A-1 and text for explanation.

SOURCE: Office of Technology Assessment.