Sirenin is an oxygenated sesquiterpene secreted by the female gametes of *Allomyces*, and it acts by attracting the male gametes.

The isolation and characterization of these substances opens the way to studies of the functions they govern and of the manner in which this government is accomplished.

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Feedbacks in Economic and Demographic Transition

A neo-Malthusian and an alternative model of development are compared and tested against the real world.

Harald Frederiksen

Demographic transition and economic development are not independent phenomena. If there is such a thing as a "population problem," it cannot be understood and solved in isolation from the complex process of national development, of which economic development is but one aspect.

Needs and resources for health and family-planning programs evolve in the context of the successive stages of demographic transition and economic development. We have to agree on the nature and magnitude of the interactions between population and economic phenomena at the various stages of national development (called simply "development" hereafter) before we can agree on how much of what is most appropriate and effective in the circumstances in question.

Neo-Malthusian Model

A neo-Malthusian school believes that the process of development is impeded when the rate of population growth is high, and that this high rate of growth is the result of a rapid reduction in mortality, which in turn is the result of alien technology's increasing the effectiveness and efficiency of health services quite independently of levels of production and consumption. Let me quote from some writers who belong to this school.

> The death rate in less-developed areas is dropping very rapidly . . . and without regard to economic change. . . .
>
> The less-developed areas have been able to import low-cost measures of controlling disease, measures developed for the most part in the highly industrialized societies. The use of residual insecticides to provide effective protection against malaria at a cost of no more than 25 cents per capita per annum is an outstanding example. . . .
>
> The death rate in Ceylon was cut in half in less than a decade and declines approaching this rapidity are almost commonplace. The result of a precipitous decline in mortality while birth rate remains essentially unchanged is, of course, a very rapid acceleration in population growth. . . .
>
> In the longer run, economic progress will eventually be stopped and reversed unless the birth rate declines *or the death rate increases* [*1*].

The higher the population growth, the harder becomes the task of breaking through the Malthusian trap. A vicious spiral is set into operation. Because of a high rate of population growth, industrialization is difficult to attain. Because there is no industrialization, the birth rate and the rate of population growth remain high [2].

It may seem indecent to some to suggest that medical research first be concentrated on those diseases whose control

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will do most to improve the happiness and ability to work of people without reducing infant mortality. . . . [3].
. . . Public health measures which can save millions of lives should not be practiced in China on a nationwide scale until the stage is set for a concurrent reduction in the birth rate [4].

Another 10 to 15 points of the initial death rate of 40 per thousand may be attributable to inadequate diet, clothing and shelter, with malnutrition the primary cause. This is of direct concern to economic policy makers because it suggests that extra investments that do *not* increase the food supply, whether directly or indirectly through international trade, may temporarily be preferred to those that do [5].

Thus, a neo-Malthusian model of economic and demographic transition may seem quite plausible, at least when used to explain failure or to predict the probability of failure (Fig. 1). But in order to explain successful development, we have to explain how countries proceed from low to high levels of production and consumption, and from high to low levels of mortality and fertility.

A more humanitarian version of a neo-Malthusian model of successful development would allow some reduction in mortality, but not too rapid a reduction, so that a concurrent and commensurate reduction in fertility would keep population growth to a minimum and raise the formation of capital to a maximum (Fig. 2). Such a model of economic and demographic transition implies that high levels of production could be achieved when consumption, mortality, and fertility are, at best, still at intermediate levels.

Even if it were feasible to achieve high levels of production by some such shortcut, bypassing commensurate improvements in the levels of living and health and commensurate reductions in mortality and fertility, high levels of production alone would hardly meet the criteria for successful development. It remains to be seen, in the real world, whether the neo-Malthusian model is a shortcut to successful development. Yet, as a possible result of uncritical acceptance of the neo-Malthusian model, with its explanation of failure in development, "health programs," says Taylor (6), "which once represented a major effort in American technical assistance, are now being quietly downgraded or phased out in most [underdeveloped] countries except those that are obviously under-populated, such as Ethiopia."

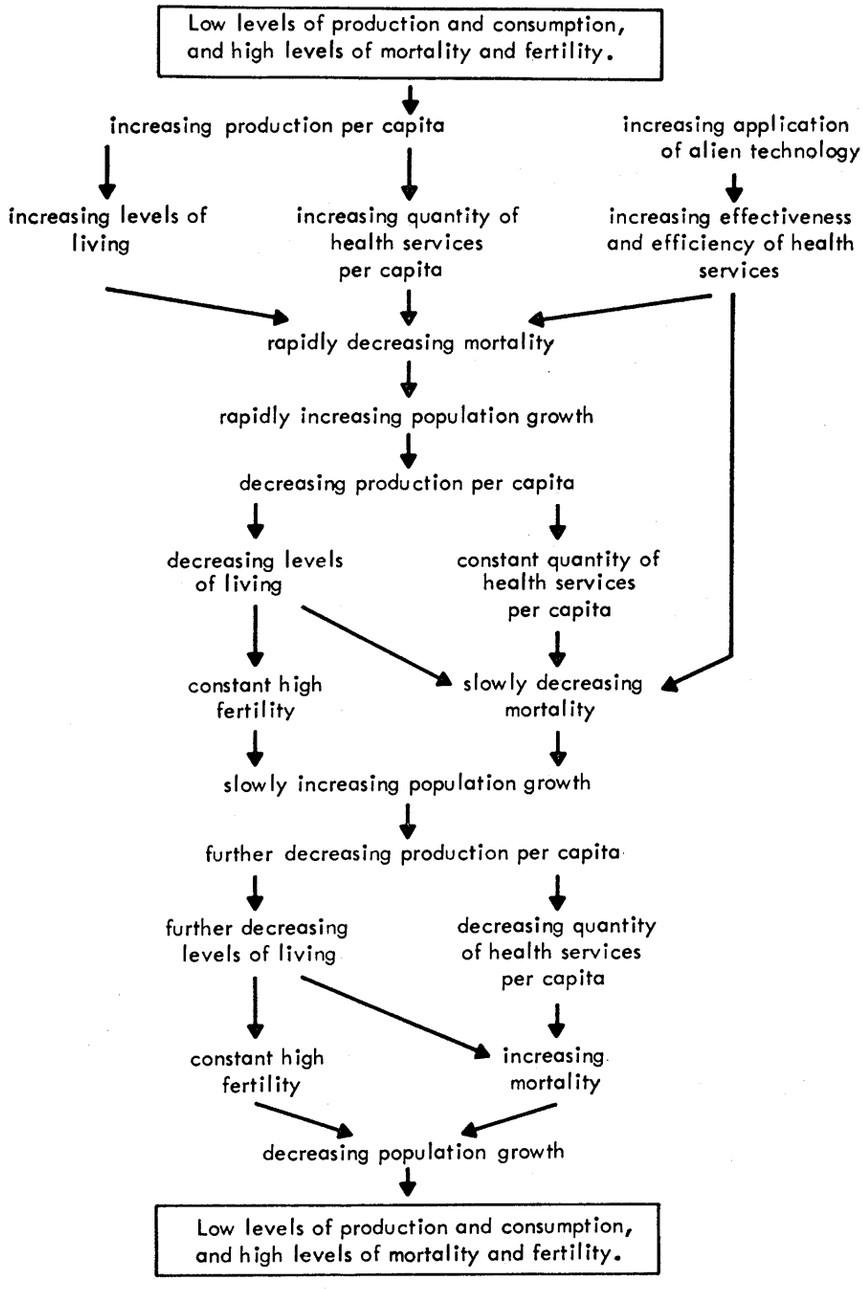

Fig. 1. Neo-Malthusian model of failure of economic and demographic transition.

Alternative Model

An alternative model of successful economic and demographic transition would seem to explain more readily the transition from low to high levels of production and consumption, and from high to low levels of mortality and fertility (Fig. 3).

This alternative model assumes that improvements in the standard of living and decreases in the mortality and fertility rates are linked in a process of "concurrent, circular, and cumulative causation" (to use the language of Gunnar Myrdal). This model stresses the human factor in development and views a drop in the mortality rate as part of the solution of the population problem, not as a cause.

A reduction in mortality is considered a necessary, although insufficient, condition for a reduction in fertility. Mortality trends may influence fertility trends by way of two mechanisms: (i) with reductions in mortality, compensatory reductions in fertility are required if the desired family size is to be achieved; (ii) when there is less uncertainty about survival, as well as a higher probability of survival, the desired family size may be reduced.

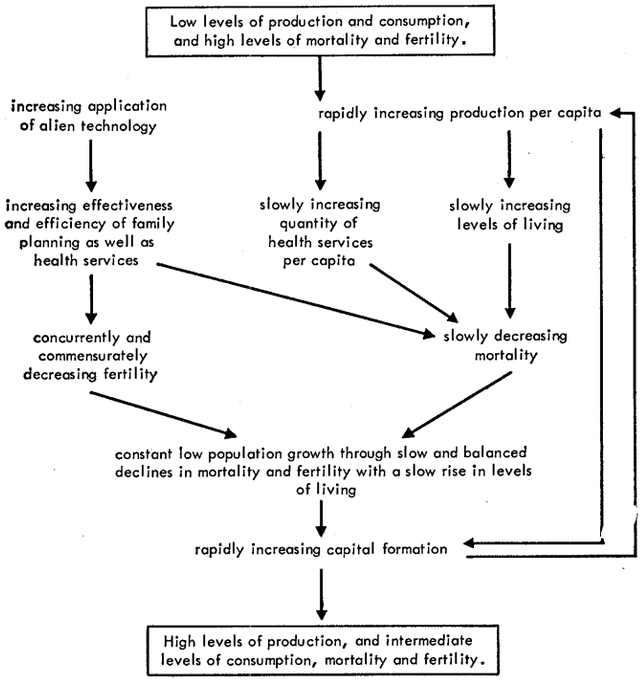

Fig. 2 (above). Neo-Malthusian model of successful takeoff in economic and demographic transition.

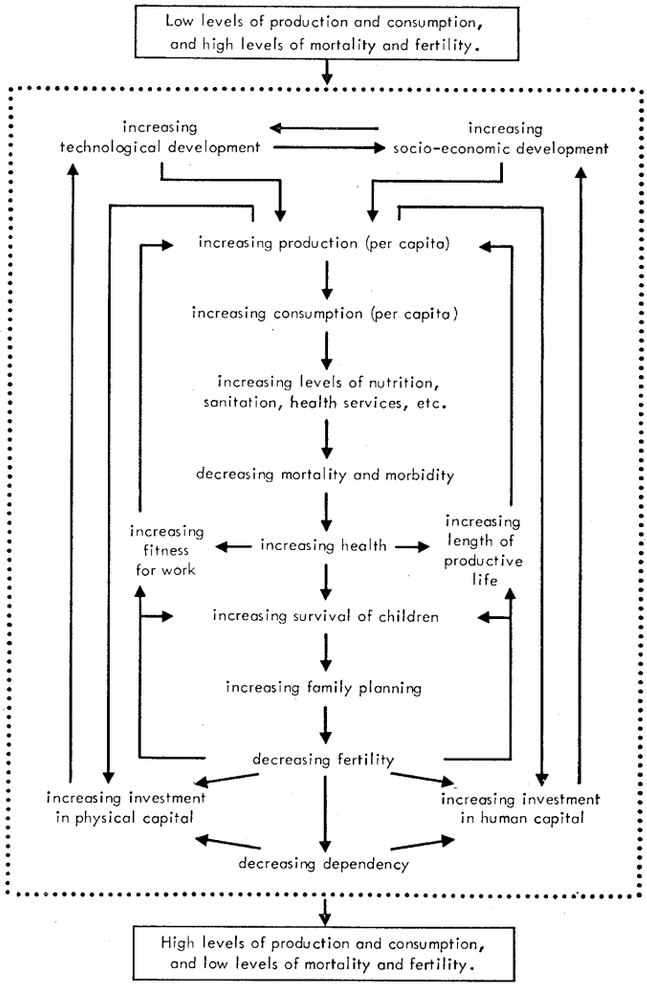

Fig. 3 (right). Alternative model of successful economic and demographic transition from low to high levels of production and consumption, and from high to low levels of mortality and fertility.

In regions where there had been considerable variation in the number of child deaths from family to family, a reduction in overall mortality might result in a reduction in fertility larger than that required to offset the reduced probability of child loss. Thus, a reduction, at the family level, in uncertainty concerning the survival of children might tend to make people want smaller families.

Let me quote from some of the writers who have arrived at similar conclusions.

. . . The removal of any of the particular causes of mortality can have no further effect upon population than the means of subsistence will allow. . . . Of its operation in tending to prevent marriage, by diminishing the demand for fresh supplies of children, I have no doubt [*7*].

To some extent the birth rate is influenced by the death rates in the lower age groups. . . . A reduction in child mortality would probably reduce birth rates after a lag of several decades [*5*].

Low death rates, or conditions underlying low death rates, merit consideration as contributory factors, if not as prerequisites, for low birth rates [*8*].

No efforts of social-economic development can be successful in a disease-ridden population, or will a desire for small families be likely to emerge [*9*].

Mortality varies inversely with economic indicators of the levels of living. In a balancing movement, fertility tends toward approximate equilibrium with mortality. . . . a deliberate reduction in fertility is a sequel to a reduction in mortality which develops individual and collective motivation as well as the need for a commensurate restraint of fertility [*10*].

High fertility has been an adjustment to high and unpredictable mortality. . . . Availability of birth control is largely irrelevant until the desired number of living children is secured [*11*].

The frequency of births in a population can be understood in terms of three groups of factors that influence parents' desires for births. First there is a family size goal or a number of surviving children that parents want. This goal is determined by a host of environmental factors that modify the relative attractiveness of many versus few children. Second is the incidence of death, mainly among offspring, which necessitates a compensating adjustment in birth rates to achieve any specific family size goal. Third is the effect of uncertainty in the family formation process where births, deaths, and remarriage are unpredictable [*12*].

In nations with traditionally high child mortality, this desire of fathers to have sons who will outlive them acts as a deterrent to restriction of family size [*13*].

It was generally agreed that in high mortality countries, the thing *not* to do is blanket the country with a massive family planning program. . . . programs will usually not emerge in countries where the population perceives that the high rate of infant mortality is either high by their standards or is not declining [*14*].

Although the world-wide population explosion has been created by a decline in death rates paradoxically a further decline in mortality in the less developed nations may be an invaluable aid for curbing the current rate of population growth [*15*].

The authors quoted above seem to support one or other of the basic assumptions (concerning the interactions between mortality, fertility, and levels of living) which underlie the alternative model of successful development. But those authors may or may not support the alternative model, which puts these basic interactions together in a concurrent, circular, and cumulative process of transition from low to high levels of production and consumption, and from high to low levels of mortality and fertility (Fig. 3).

Comparison of the Models

Comparison (Fig. 4) of the neo-Malthusian model (Fig. 2) and the alternative model (Fig. 3) indicates three essential differences.

The neo-Malthusian model views a reduction in mortality as an increase in population growth, whereas the alternative model notes the transitory nature of the "population explosion" and emphasizes the improvement in health, productivity, and longevity.

The neo-Malthusian model explicitly or implicitly assumes that levels of mortality are now *quite independent* of levels of living, whereas the alternative model assumes that levels of mortality are still *quite dependent* on levels of living, although the relative effectiveness of health services increases with increasing levels of living.

The neo-Malthusian model ignores any dependence of fertility trends on mortality trends, whereas the alternative model assumes that reductions in mortality develop the need and desire for family planning.

Empirical Test of the Models

At any given point of development, the economic growth rate per capita approximates the economic growth rate minus the population growth rate. This may have led some to equate the population problem with excessive population growth. But it does not follow that a decrease in the population growth rate would be associated with a commensurate increase in the economic growth rate per capita.

Cross-sectional comparison of nonlinear regression lines for population growth rates, economic growth rates, and economic growth rates per capita, for 67 countries, plotted by gross national product per capita, indicates no obvious correlation between population growth rates and economic growth rates per capita (Fig. 5).

The *linear* correlation of the rate of population growth with the rate of economic growth *per capita* for the 67 countries was only weakly negative ($r = -0.32$), even though the population growth rate serves as denominator for the dependent variable. In contrast, the linear correlation of the rate of economic growth with the rate of economic growth per capita was strongly positive ($r = 0.88$). The linear correlation of the rate of population growth with the rate of economic growth was only slightly positive ($r = 0.15$).

A statistical significance test was performed only for the latter correlation—that between the rates of population growth and of economic growth—since only these two variables are not algebraically related to each other. The correlation ($r = 0.15$) was not significant even at the 5 percent level of probability.

Actually, the rate of *per capita* economic growth is a poor indicator of development. A low rate of economic growth per capita can be the result of a balance between high or low rates of economic and population growth and thus may be found in countries with *any* rate of economic growth, and with any rate, and at any level, of development.

Moreover, the rate of population growth is a poor indicator of the "population problem," or of its solution, since this rate tends first to rise and then to fall in the course of the modernization process.

Rather than rely exclusively or primarily on the population growth rate as a basis for understanding, measuring, and influencing the demographic transition, it would be better to rely on the birth rates and death rates from which the population growth rates are derived.

Thus, in the real world, successful development is associated with increasing levels of consumption and of capital formation and with decreasing levels of mortality and fertility—first mortality, then fertility (Fig. 6).

Incidentally, the rise in the crude death rates toward the higher values for gross national product per capita is a result of the aging of the populations, which in turn is a result of the declining birth rates. If the death rates could have been adjusted for the differences in age distributions, there would not have been such an apparent rise in the death rates at the higher values for gross national product per capita. Unfortunately, not enough comparable detailed data were available to permit adjustment of the death rates for differences in the age distributions.

The objection might be raised that these comparisons are cross-sectional, and that these relationships that existed at a point in time would not hold true in longitudinal comparisons over a period of time.

The historical tendency for mortality trends to vary inversely with the standard of living and for fertility trends to maintain or restore approximate balance between mortality and fertility is indicated by the economic and demographic transition that has occurred in France over the past two centuries (Fig. 7).

A similar tendency toward approximate balance between mortality and fertility has been observed in Japan (Fig. 8), where the demographic transition began much later than it did in France. Whereas France was the first country to enter into the process of demographic transition, Japan was one of the latest countries to complete it.

When one compares the experience of France and of Japan, it seems that the process of transition has been accelerated. Whereas improvements in the standard of living and reductions in mortality have accelerated, the lag

Neo-Malthusian Model

Dependent Variables	Independent Variables		
	Levels of living	Mortality	Fertility
Levels of Living		⊕	−
Mortality	○		+
Fertility	−	○	

Alternative Model

Dependent Variables	Independent Variables		
	Levels of living	Mortality	Fertility
Levels of living		⊖	−
Mortality	⊖		+
Fertility	−	⊕	

Fig. 4. Neo-Malthusian and alternative models of demographic and economic interaction. The circles focus attention on those interactions which are essentially different in the two models. Plus or minus signs indicate a positive or negative association.

between mortality and fertility may have remained more or less constant. Thus, we are observing more violent, but transitory, "population explosions." Once the fertility trend turns downward, the reductions in fertility are also accelerated.

Japan, it might be argued, was a rapidly developing country at the time of its demographic transition, and it was for this reason that the transition could take place in Japan as late as it did, but modern medicine has since changed the course of demographic transition and the prospects for development in the less developed world.

Kirk has noted (*16*) that the later phases of the demographic transition (that is, definitive declines in birth rates to low or moderate fertility) have now reached almost all people of European ethnic background, but that Costa Rica and, until recently, Chile have been exceptions. Kirk made his statement in 1967; information subsequently made available indicates that Costa Rica and Chile are beginning to complete the historic process of demographic transition first observed in Europe. Thus, in the 5 years between 1962 and 1967, Costa Rica experienced about a 10 percent reduction, and Chile about a 20 percent reduction, in fertility.

It might be objected that Costa Rica and Chile, while they may be developing countries, are of European ethnic background, and that their experience may differ from that of countries of non-European background. It is for this reason that the case histories of Ceylon and of Mauritius are cited here, since these countries were first selected by the neo-Malthusian school to bolster their views.

Many writers—too many to be cited here—have attributed the dramatic postwar decline in mortality in Ceylon solely or largely to the eradication of malaria. Newman (*17*), who has studied the case history of Ceylon more than most, has concluded that eradication of malaria has accounted for 42 percent of the postwar decline in the death rate of Ceylon. Titmuss and Abel-Smith (*18*) have attributed most of the dramatic decline in mortality between 1946 and 1947 in Mauritius to eradication of malaria.

If the sequence of events in Ceylon and Mauritius had demonstrated that economic development is no longer a prerequisite for a decline in the death rate, it might have seemed plausible to

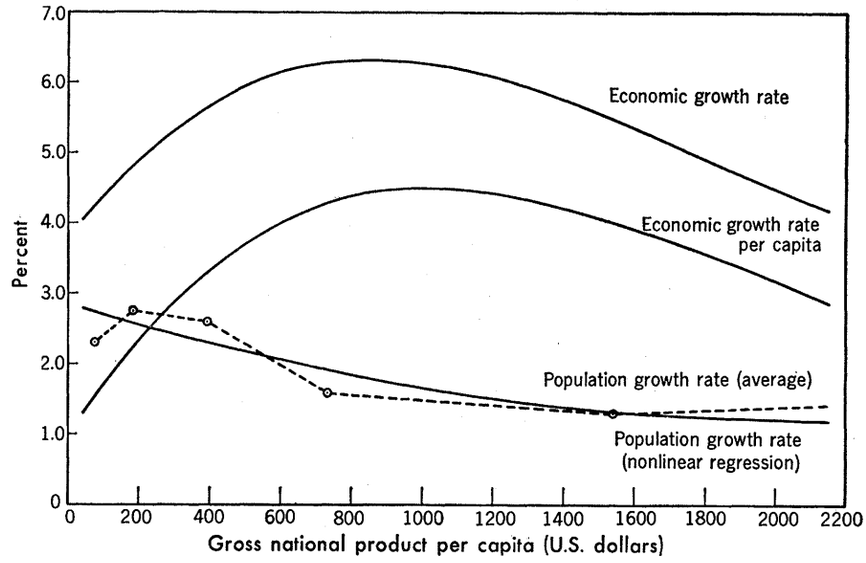

Fig. 5. Nonlinear regression lines (third degree) for population growth rates (1958–1966), economic growth rates (1960–1965), and economic growth rates per capita (1960–1965), by gross national product per capita (1965), for 67 countries. [Sources of basic data, United Nations and World Bank]

postulate that modern public health measures would tend to reduce per capita income as well as mortality, should economic development lag; it might have seemed plausible to infer that per capita income would rise with a rise in mortality. But the postulation of such determinants and consequences of mortality trends is not confirmed by the experiences of Ceylon and Mauritius (*10*).

Although the postwar decline in the death rate in Ceylon, from 20 to 14 per 1000 in the single year from 1946 to 1947, approximately coincided with a campaign of spraying with insecticides, the spectacular decline in mortality was about the same for the area without malaria, not protected by insecticides, as for the area with malaria, protected by insecticides (*19*). It has also been shown (*8*) that the decline in mortality was associated with a commensurate development of the econ-

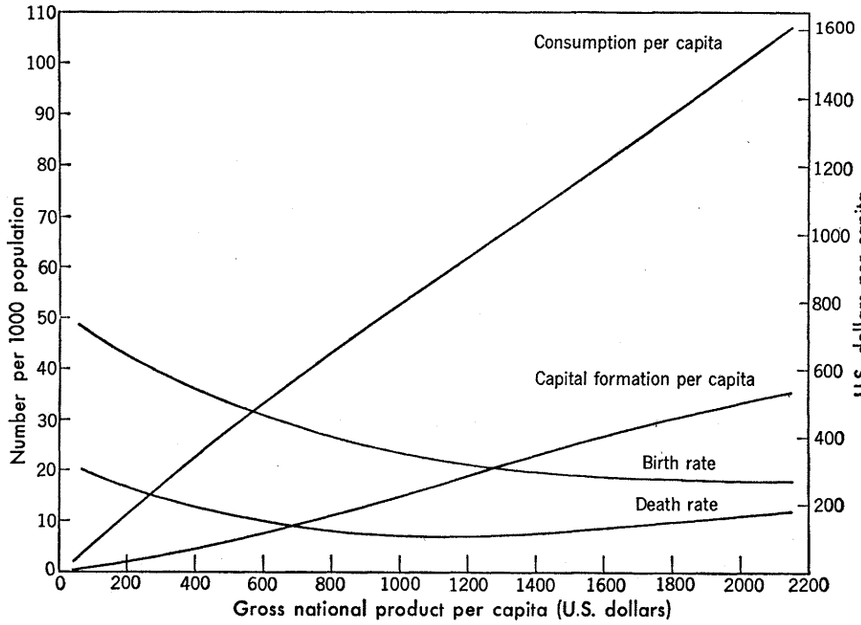

Fig. 6. Nonlinear regression lines (third degree) for economic and demographic variables by gross national product per capita (1965), for 67 countries. [Sources of basic data, United Nations and World Bank]

omy and rise in the standard of living.

Moreover, the birth rate declined from a postwar peak of 39.8 per 1000 in 1951 to 31.6 in 1967. In the 5 years between 1962 and 1967, Ceylon has experienced a greater than 10 percent decline in birth rate.

The postwar drop in the death rate in Mauritius, from 30 to 20 per 1000 in the single year from 1946 to 1947, was also attributed mainly to the use of insecticides. But the spraying campaign was started in 1949, 2 years after the dramatic 1947 decline in the death rate. Moreover, the per capita production of sugar, virtually the sole export of the island, rose sharply as mortality declined.

Mauritius may follow the pattern of demographic transition displayed in the course of history in the West.

First, the inverse relationship between (i) the mortality rate and (ii) the standard of living indicated by the per capita proceeds (in 1939 rupees) from sale of the principal cash crop suggests that reductions in mortality are still dependent on commensurate improvements in the standard of living. Improvements in health services may be involved, but only as a part of general improvements in living standards (Fig. 9).

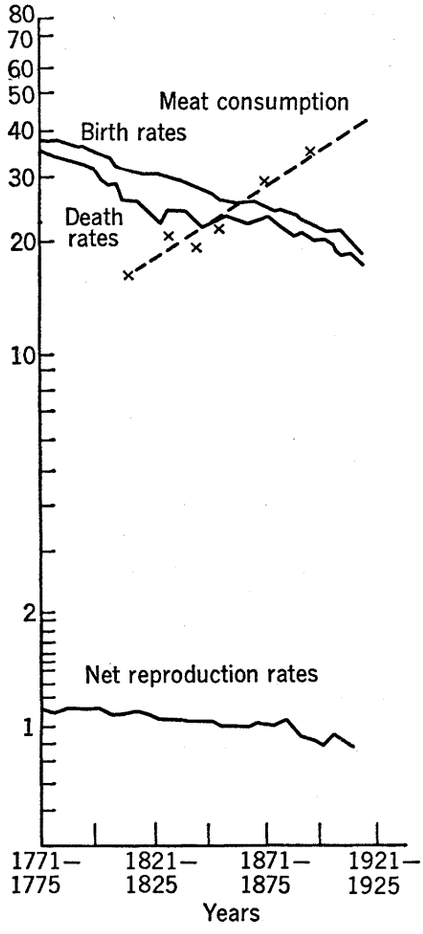

Fig. 7. Average annual number of births per 1000, number of deaths per 1000, and net reproduction rates in the 5-year periods 1771 to 1775 and 1906 to 1910, and annual consumption of meat and animal fat (in kilograms per capita) between 1812 and 1910, in France. [For sources of basic data, see (*22*)]

Second, the fertility trend has now turned downward, decisively so, about 20 years after the dramatic downturn in the death rate. From a postwar peak of 49.7 per thousand in 1950, the birth rate declined to 30.4 in 1967. In the 5 years between 1962 and 1967, Mauritius experienced about a 20 percent decline in the birth rate. This seems to confirm the experience of other countries: a reduction in mortality is a precursor of, and perhaps a prerequisite for, a reduction in fertility in the course of demographic transition (Fig. 10).

Thus, Mauritius experienced a population explosion. As the word implies, an explosion is a transitory phenomenon. The sharp increase in the rate of population growth calls for individual and collective decision making. With lower mortality, the traditional and practical family size can be achieved with lower fertility. Moreover, the lessening of uncertainty about whether one's children will survive, and the greater overall probability that they will, may induce parents to want fewer children than they have wanted in the past. Thus, reduction in mortality, by influencing the decision concerning family size as well as facilitating its realization, may operate by way of two mechanisms to develop motivation toward a reduction in fertility.

In the course of economic and demographic transition, a reduction in mortality induces a population explosion which may, in turn, induce a commensurate reduction in fertility, thereby restoring approximate balance between mortality and fertility.

The qualitative nature and directions of the feedbacks in the alternative model (Figs. 3 and 4) seem to be consistent with the relationships observed in the real world, as indicated by longitudinal as well as cross-sectional observations, and by historical as well as contemporary case histories (Figs. 5 and 10). Let me say again that case histories of Ceylon and Mauritius were first cited by those who wanted to bolster their neo-Malthusian views. But the actual events in these countries seem to refute the neo-Malthusian model and to support the alternative model of economic and demographic transition.

Additional empirical evidence for the alternative model has been presented elsewhere (*10*, *20*).

Dynamics of Transition

The dynamic equilibrium of economic and demographic transition in the postwar era may be indicated by empirical equations describing the quantitative and qualitative relationships between changes in mortality, fertility, and living standards in 21 countries, for which comparable data were available.

The equations imply that the prospective rate of natural increase can be estimated on the basis of the rates of fertility and mortality in the base year and the relative change in per capita product at constant prices.

The relative change in natality n in year t can be expressed in terms of natality n and mortality m in the base year o:

$$\frac{n_t}{n_o} = \left[\frac{a}{(n_o - m_o)^b}\right]^{t-o}$$

(a and b are constants).

The relative change in mortality m in year t can be expressed in terms of the relative change in per capita product (at constant prices) p in year t:

$$\frac{m_t}{m_o} = \left[\frac{c}{\left(\frac{p_t}{p_o}\right)^d}\right]^{t-o}$$

(c and d are constants).

When the equations for relative changes in natality and mortality are combined, the rate of natural increase, $n - m$, in year t can be expressed in terms of natality n and mortality m in the base year o and the relative change in per capita product (at constant prices) p in year t:

$$n_t - m_t = n_o\left[\frac{a}{(n_o - m_o)^b}\right]^{t-o} - m_o\left[\frac{c}{\left(\frac{p_t}{p_o}\right)^d}\right]^{t-o}$$

The empirical derivation of the equations and of the constants a(= 1.028), b(= 0.016), c(= 1.085), and d (= 0.018) are described elsewhere

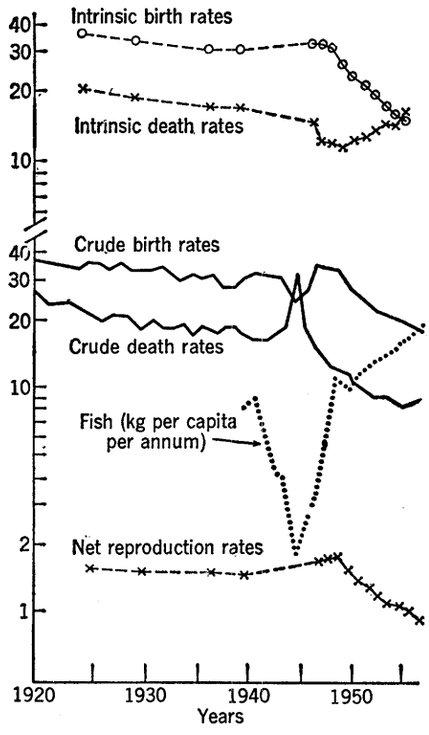

Fig. 8. Processed fishery products (in kilograms per capita per annum), crude and intrinsic birth rates and death rates (in number of births or deaths per 1000), and net reproduction rates, for Japan, for the period 1920 to 1957. [For sources, see (*23*)]

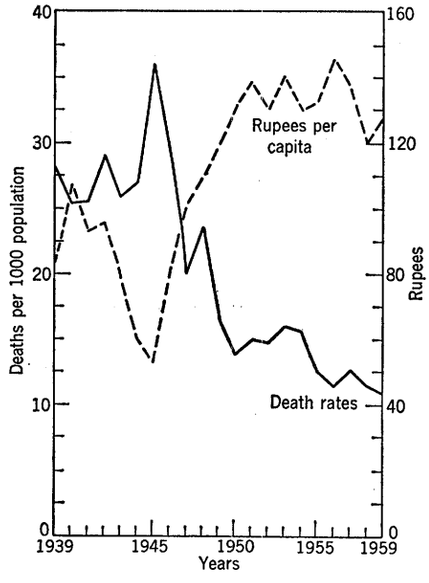

Fig. 9. Levels of mortality and levels of living, as indicated by the sales proceeds from sugar production (in constant rupees per capita) for Mauritius, for the period 1939 to 1959. (Constant rupees at 1939 prices were computed from the consumer price index for manual workers.) [Source of basic data, *Yearbook of Statistics* (Central Statistical Office, Colony of Mauritius, 1946–1959)]

(*20*). The parameters can hardly be expected to predict the trends in vital events in all countries at all times, at least with any great degree of accuracy. For one thing, the values of the constants were derived from data uncorrected for differences in the age distributions. Second, the process of economic and demographic transition is constantly accelerating, as indicated by comparisons of the tempo of transition in developing countries with the tempo of the historical process in Europe.

But the equations were remarkably accurate in predicting or explaining the recent changes in the levels of fertility, mortality, and natural increase in Chile and Costa Rica. The recent dramatic turn in the trends of vital events in Chile and Costa Rica would have been missed had it simply been assumed "that current trends continue."

The population projections for Costa Rica, published by the United Nations in 1966 but based on data available in 1963, implied a rate of population growth of 3.9 percent in 1965 (an average annual rate of 4.0 percent between 1960 and 1965 and 3.8 percent between 1965 and 1970). The United Nations has since reported that the actual rate of population growth in 1965 was 3.1 percent. By substituting, in the foregoing equations, the birth rate and the death rate in 1960 and the relative change in per capita gross national product at constant prices between 1960 and 1965, we would estimate the 1965 population growth rate to be 3.3 percent in 1965.

Of course, the estimate of the death rate, and the rate of population growth derived therefrom, require economic data first available sometime after 1965, and for this reason this part of the equation is explanatory rather than predictive. But the estimate of the birth rate (number of births per 1000 population) obtained by means of this equation can be based solely on demographic data available in the base year. Such an estimate, for Costa Rica, based on the 1960 birth rate of 48.4 per 1000 and the 1960 death rate of 8.6, yields an estimated birth rate of 41.3 in 1965, which quite closely approximates the actual birth rate of 40.5 for

Of course, no one factor in the equation can be successfully manipulated tion can be successfully manipulated independently of the other factors, in the expectation that the other factors will automatically respond, as if this were simply a matter of arithmetic.

Demographic Policy for Demographic Transition

The solution of the "population problem" is not simply the achievement of a low rate of population growth, which could be the result of a balance between either high or low birth rates and death rates. All humanitarian considerations aside, only low death rates matched by low birth rates will provide maximum returns from investment in human resources and keep to a minimum the burdens of child dependency.

Of course, the desired demographic changes are no more automatic than the desired economic changes. The systematic extension of information and facilities favoring the use of efficient, effective, and acceptable methods of regulating family size is the appropriate response to spontaneous motivation to limit family size—motivation which increases as rates of survival increase.

Thus, improvements in the standard of living, as well as desired changes in mortality and fertility rates, will result from an interplay of effort in both the demographic and the economic aspects of economic and demographic transition.

Health measures and family plan-

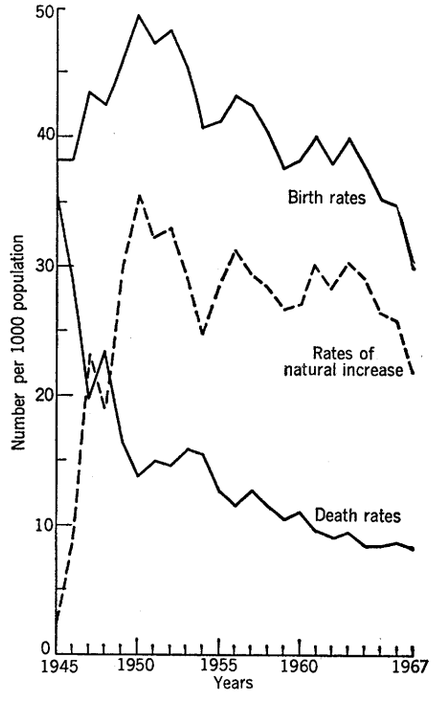

Fig. 10. Rates of birth, death, and natural increase for Mauritius, for the period 1945 to 1967. [Source of basic data, *Demographic Yearbook* (United Nations, New York, 1954–1967)]

ning, by their effects on morbidity, mortality, and fertility, can accelerate the economic transition from low to high levels of production and consumption. They can also accelerate the demographic transition from high to low levels of mortality and fertility by restoring the balance between mortality and fertility at the lowest level of mortality attainable with the available resources. With such understanding, the allocations for health services would be limited by the availability of resources rather than by a fear that health services might be too effective.

The availability of resources for competing sectors of development would be decided by empirical review of the combinations of allocations to determine which combination had achieved a given level of development in the past and seemed to be necessary and feasible for achieving the next level.

Relative Costs and Benefits

The question remains, How should we or can we plan optimum efforts in view of the unlimited needs competing for the limited resources available? If we are to set realistic health targets, we must consider political, social, economic, and demographic, as well as administrative, factors. We must consider noneconomic as well as economic costs and benefits, and we must start with the given set of circumstances, not with rarefied abstractions.

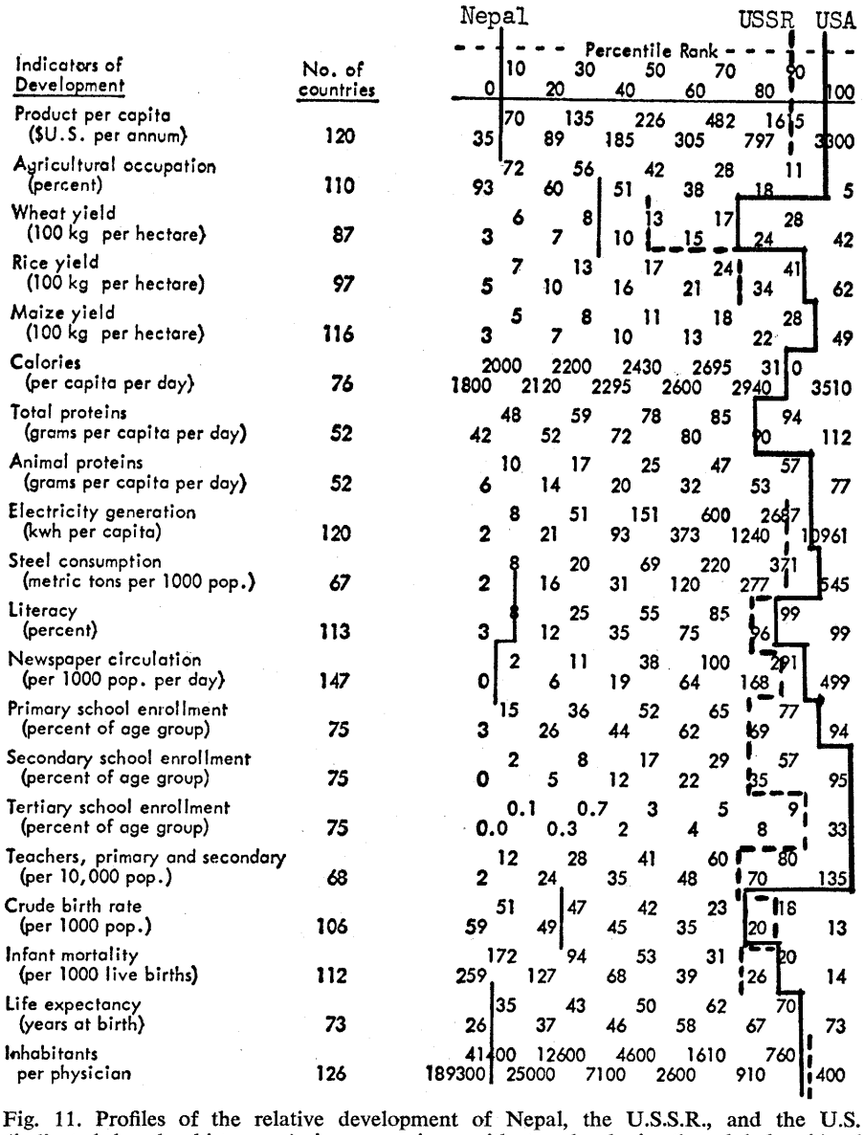

Fig. 11. Profiles of the relative development of Nepal, the U.S.S.R., and the U.S. (indicated by the histogram) in comparison with ten levels in the global grid of sectoral development, indicated by the deciles in the rankings of indicators from the latest year, and the maximum number of countries, for which comparable data are available. [For sources, see (*24*)]

Health planners can dream of comprehensive and integrated health services, both curative and preventive, for achieving the ideal state of health as defined by the World Health Organization. But in the real world, available resources are limited. Moreover, it is in the less developed parts of the world that the needs are greatest, and the resources least.

In planning health services as integral parts of national development, it would be necessary or desirable to compare the costs and benefits of alternative programs, having different objectives, in different sectors of the economy, as well as the costs and benefits of alternative programs, having the same objectives, within the health sector. We must determine the optimum allocations for all sectors in the context of multiple needs competing for inadequate resources.

But, in practice, cost-benefit analysis may be neither a practical nor a valid method of deciding whether a more efficient and more effective program is an appropriate alternative for a less efficient and less effective program when the two do not have the same objective.

For one thing, we may lack a common unit of measurement for comparing the costs and benefits of programs in the health sector with those of programs having different objectives, in other sectors. In theory it may seem possible to quantify the various benefits in dollars, but what seems possible in theory may not prove feasible in practice.

Moreover, we lack understanding of, or agreement on, the innumerable interactions of the multiple factors in the complex process of development. For example, death control and birth control programs may be placed in competition for limited funds. In such a predicament, the dilemma can be resolved neither by moral arguments nor by cost-benefit analysis. Simple comparisons of the ratios of the costs and benefits of these arbitrary alternatives would be meaningless and misleading.

On the basis of simple arithmetic, we find that either more deaths or fewer births would lower the rate of population growth. But a low rate of population growth may be the result of a balance between either high or low birth rates and death rates. Only a balance between low birth and death rates will give the highest possible ratio between producers and dependents. And, as discussed above, only a prior

reduction of mortality will develop the motivation needed for limiting family size.

Thus it is clear that cost-benefit analyses must be based on valid alternatives and not on simple assumptions and speculations which tend to ignore the dynamic nature and sequence of the interactions between economic and demographic factors. We might feel assured that a good analyst would take second- and third-order benefits into account. Yet, again, what seems possible in theory may not prove feasible in practice.

Again (to cite a comparison of the costs and benefits of another popular pair of specious choices), it has been variously calculated that the expenditure on a program of birth control of either $1 or $5 from each $100 spent on development can double the rate of per capita economic growth achieved by the whole expenditure. But could we really double economic growth merely by increasing our investment in contraception? If that were possible, we might concentrate on contraception and eliminate investments in all other sectors of development. Although the popular notion that an ounce of contraception is worth a pound of development has some validity, this does not mean that birth-control programs could or should invariably be substituted for programs that have a less favorable cost-benefit ratio. The setting of priorities is not simply a mathematical problem.

Of course, within a given sector, a more effective and efficient program may be substituted for one that has the same objective but a less favorable cost-benefit ratio, provided the proposed alternative is otherwise appropriate and acceptable.

Actually, there is little need for complex and controversial economic and demographic arguments to justify appropriate action in response to spontaneous motivation to restore the balance between mortality and fertility. We all know the absurd consequences projected by extrapolations of imbalances between current mortality and fertility trends.

Although intersectoral cost-benefit analyses may not be particularly feasible, such analyses may be undertaken intrasectorally in conjunction with an empirical method, described next, for intersectoral linking of targeting and budgeting in a multisectoral system of development.

Profiles of Relative Development

So far, no comprehensive model of development for obtaining the best possible allocations among the innumerable needs competing for limited resources has been generally accepted and successfully applied. In the absence of such a model, analysis of national

Table 1. Evolution of environmental health problems; predominant patterns of disease, mortality, and fertility; goals, type and scope of health services; and the state of nutrition.

State of society	Environmental health problems	Predominant patterns of disease, mortality, and fertility	Goals, type and scope of health services	State of nutrition
Traditional	Largely rural environment with contamination of water and food; proliferation of insects and rodents; periodic food scarcities.	Endemic infections, parasitisms, infestations, nutritional deficiencies. High death rate and high birth rate.	Indigenous systems of medicine based on traditional practices and beliefs.	Undernutrition as a result of food scarcities in a subsistence economy with practices and preferences of food production and consumption of a traditional, but youthful, society.
Early transitional	Largely rural environment with contamination of water and food; proliferation of insects and rodents; adulteration of foods and drugs; food scarcities.	Endemic infections, parasitisms, infestations, nutritional deficiencies. Intermediate death rate and high birth rate.	Medical relief and family planning in key centers; control of endemic diseases and environmental sanitation in selected areas; nationwide extension of categorical health services (malaria and smallpox eradication) requiring only minimal cooperation from the public and only minimal judgment from auxiliary staff with stereotype duties (residual spraying and vaccination).	Potential improvements in nutrition in areas of the monetary economy through possible modification of social, economic, and agricultural policies favoring the consumption of a variety of nutritious foods; facilitation of the extension of modern practices of agriculture, food technology and marketing, nutrition education, child-feeding and school lunch programs to the minority of the population within the scope of the nutrition programs of the health, education, and agricultural services.
Late transitional	Rural environment still resembles that of traditional society, whereas the urban environment resembles that of modern society.	Endemic diseases prevail at reduced levels in rural areas, whereas the disease patterns of urban areas resemble those of modern society. Low death rate and intermediate birth rate.	Comprehensive and integrated systems of preventive and curative health and medical services in key centers, with nationwide extension of medical relief, family planning, nutrition, basic sanitation, health education, and communicable disease control.	Continuing improvement of nutrition as a by-product of economic growth and as the result of progressive extension of nutrition programs nationwide, including the production of protein-rich foods and the fortification of staples.
Modern	Largely urban environment with pollution of air, water, and food, plus hazards from use of cigarettes, alcohol, food additives, new drugs, and narcotics.	Bronchopulmonary and cardiovascular diseases, malignant neoplasias, mental illness, accidents, obesity. Low death rate and low birth rate.	Nationwide extension of complex systems of comprehensive and integrated preventive and curative health and medical services, requiring a prosperous society and an enlightened public, as well as ample health manpower, qualified to exercise independent judgment.	Overnutrition as a result of an abundance of foods in an industrial economy of an affluent, sedentary, and aging society.

and sectoral "profiles of the relative development" of human and natural resources provides an objective and practical method for setting realistic, although tentative, targets and budgets (*21*). Such profiles facilitate comparison between countries or regions with respect to a number of variables, each of which can serve as an indicator of the level of development (Fig. 11).

Profiles of individual countries are entered on global grids of development, which are constructed by ranking any number of variables from all countries for which comparable data are available; the deciles thus obtained are used to construct the grids.

For example, the first indicator in the global grid is the product per capita. Data for this variable from 120 countries are ranked in the first two horizontal rows of Fig. 11, from left to right. The top entry in the first vertical column (the 0-percentile column) indicates that none of the 120 countries had a per capita product of less than $35 in 1965. The top entry in the second vertical column (the 10-percentile column) indicates that 12 countries (10 percent of 120) had a per capita product of no more than $70. And the top entry in the last vertical column (the 100-percentile column) indicates that all 120 countries had a per capita product lower than $3300. The profile of the relative development of a particular country (Nepal, the U.S.S.R., and the United States) is indicated by the histogram in the grid. For example, Nepal had a product per capita of less than $70.

Variables have been included in the grid without regard to any hierarchy or classification. The variables or indicators are simply a diverse collection of characteristics of a society or economy, some of which might be considered costs or benefits, inputs or outputs, causes or effects, needs or resources, means or ends. The preparation of development profiles requires neither classification of the variables nor understanding of the nature and extent of their interactions—neither explicit nor implicit assumptions other than recognition of a tendency toward balance or complementarity in the development of human and natural resources. Whether progress is the inevitable result of free enterprise or the intended result of a planned economy, if and when a system or policy or fortuitous combination of factors results in development, the balance in the development of human and of natural resources is remarkable.

For different countries, paths of development are usually and essentially the same, but the path may be followed with greater or lesser speed. Harmonizing the objectives and choosing the best possible targets may accelerate the passage from traditional to modern stages of society and economy.

Since grids such as Fig. 11 have no time scale, it is not possible to schedule the achievement of individual targets within fixed periods. Rather, the profiles suggest, for example, that it might be realistic to choose as a target reductions in infant mortality from 127 to 68 per 1000 live births coincidentally with an increase in the product per capita from $89 to $185 a year.

The observed balance in the development of human and natural resources permits us to decide what is necessary or desirable and feasible at the various stages of development, even though we lack a comprehensive mathematical model of development. In effect, the open-ended nature of the grid permits approximation of a comprehensive model of development, albeit associatively rather than structurally.

The method of analysis is discussed more fully elsewhere (*21*).

Evolution of Goals and Services

Integration of planning, programming, and budgeting of health services into a system for accelerating development may confirm the belief that differences between a sound economic point of view and a bona fide humanitarian point of view are more apparent than real. Of course, there are situations where the two are irreconcilable. In such situations, the deliberate political decision may be to choose a humanitarian policy rather than the most economic alternative. However, in the long run it may not be politically opportune or economically feasible to consistently ignore either humanitarian or economic considerations.

Fortunately what is necessary or desirable from the economic and the humanitarian points of view may, and usually does, turn out to be essentially the same, when analyses of the relative costs and benefits are based on targets or budgets for programs that are possible and feasible, valid and appropriate in the context of the evolving needs and resources. And what is necessary or desirable and feasible from the economic and humanitarian point of view may, in the long run, be a safe and sound position from the political point of view as well.

Thus, the best or only way to obviate or resolve conflicts, apparent or real, between independently derived economic and health plans would be to devise and adopt a method of planning health services and investments as integral parts of a multisectoral system for accelerating the development of an economy and a society. Such planning must be based on an understanding of the quantitative and qualitative evolution of feasible goals and optimum programs in the context of evolving needs and resources at successive stages of development.

Disease and reproduction tend to occur in definable patterns that closely reflect the degree of modernization of the society (Table 1). Where the patterns are not compatible with the process of modernization, we can attempt to modify the patterns and make them compatible.

The ideal health policy would be one of short-term and long-term planning such that the manpower and organization of the health services, designed to attack the most prevalent diseases that are amenable to attack, would evolve along with the needs and resources in the complex process of economic, social, and demographic transition.

There are various alternative strategies and tactics that might be pursued by the health services. Before we try to determine the relative cost effectiveness of alternatives we must decide which of the many alternative programs are valid paths to the agreed-upon objectives; this decision, in turn, must be based on consideration of what alternatives are both possible and feasible.

This requires, first, consideration of the nature of the problem, which may call for epidemiologic study. Then the possibilities of prevention must be determined; this involves determination of the link in the chain of transmission or causation that is most readily broken by the possible means of prevention.

But what is possible may not be feasible. The feasibility of goals and services evolves with the needs and the resources (Fig. 11 and Table 1). And once we decide which alternative is feasible, we still must set tentative targets or budgets for the alternative pro-

grams before we can analyze the relative costs and benefits.

The profiles of relative development permit the setting of tentative but realistic targets, as well as tentative but realistic budgets for health services. Such empirical targeting and budgeting makes it possible to keep costs to a minimum and to achieve maximum benefits, by permitting cost-effectiveness analyses to be based on the empirically derived targets as well as budgets.

Summary and Conclusions

The feedbacks in a neo-Malthusian and in an alternative model of economic and demographic transition are compared with each other and tested against the real world. On the basis of the empirical evidence, it is postulated that the population problem is not simply a high rate of growth. Nor is its solution simply a low rate of growth, which could be the result of a balance between either high or low rates of mortality and fertility.

Reductions in the mortality rate are part of the solution, rather than the cause, of the problem. Mortality rates tend to vary inversely with levels of consumption and production. Moreover, reductions in mortality seem to be prerequisites for compensating reductions in fertility to achieve the desired family size.

Of course, the desired demographic changes are no more automatic than the desired economic changes. The systematic extension of information and of facilities favoring the use of acceptable methods of regulating family size is the appropriate response to spontaneous motivation to limit family size.

Successful development results in, and from, a balance between mortality and fertility at the lowest mortality rate attainable with the resources available. With improved health and greater longevity increasing the returns from human resources, and with decreasing fertility decreasing the burdens of dependency, the maximum improvements in the standard of living and the desired changes in mortality and fertility will result from interplay of efforts in both the demographic and the economic areas.

Strategy and tactics for national development evolve with the needs and resources. "Profiles of relative development" in the multiple sectors of national development may indicate what targets and budgets are necessary or desirable and feasible at successive stages.

Paths of development may be usually and essentially the same for different countries, but the path may be followed with greater or lesser speed. Harmonization of the objectives and wise choice of targets may accelerate the passage from traditional to modern stages of society and economy.

Health measures and family planning, as integral parts of the complex process of modernization, can accelerate and must complete the economic and demographic transition from low to high levels of production and consumption, and from high to low levels of mortality and fertility.

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