37. T. H. Jukes, *Amer. Scientist* **53**, 477 (1965).
38. C. Stern, *Principles of Human Genetics* (Freeman, San Francisco, 1960).
39. H. J. Muller, *Studies in Genetics* (Indiana Univ. Press, Bloomington, 1962).
40. H. Callan, *J. Cell Sci.* **2**, 1 (1967).
41. C. Bresch, *Klassische und Molekulare Genetik* (Springer, Berlin, 1964); D. E. Comings and R. O. Berger, *Biochem. Genet.* **2**, 319 (1969).
42. J. Paul and R. S. Gilmour, *J. Mol. Biol.* **34**, 305 (1968).
43. J. B. S. Haldane, *Genetics* **55**, 511 (1957).
44. J. L. King, *ibid.*, p. 403; R. D. Milkman, *ibid.*, p. 493; J. A. Sved, T. E. Reed and W. F. Bodmer, *ibid.*, p. 469.
45. J. A. Sved, *Amer. Naturalist* **102**, 283 (1968); J. Maynard Smith, *Nature* **219**, 1114 (1968).
46. J. B. S. Haldane, *Proc. Cambridge Phil. Soc.* **23**, 838 (1927); M. Kimura, *J. Appl. Probability* **1**, 177 (1964).
47. G. L. Stebbins, *Processes of Organic Evolution* (Prentice-Hall, Englewood Cliffs, N.J., 1966).
48. V. M. Sarich and A. C. Wilson, *Proc. Nat. Acad. Sci. U.S.* **58**, 142 (1967).
49. A. L. MacKay, *Nature* **216**, 159 (1967).
50. M. O. Dayhoff and R. V. Eck, *Atlas of Protein Sequence and Structure 1967–1968* (National Biomedical Research Foundation, Silver Spring, Md., 1968).
51. H. Subak-Sharpe, W. M. Shepherd, J. Hay, *Cold Spring Harbor Symp. Quant. Biol.* **31**, 583 (1966).
52. H. Subak-Sharpe, R. R. Burk, L. V. Crawford, J. M. Morrison, J. Hay, H. M. Keir, *ibid.*, p. 737.
53. J. Josse, A. D. Kaiser, A. Kornberg, *J. Biol. Chem.* **236**, 861 (1961).
54. M. N. Swartz, T. A. Trautner, A. Kornberg, *ibid.* **237**, 1961 (1962).
55. We thank Dr. Motoo Kimura for suggestions and comments. The work discussed here was done with support from the U.S. Atomic Energy Commission and from the National Aeronautics and Space Administration (grant NGR 05-003-020 to the University of California, Berkeley).

Birth Control for Economic Development

Reducing human fertility can raise per capita income in less-developed countries.

Stephen Enke

There is a growing interest in the possibilities of lowering birth rates in order to raise per capita incomes in many of the less-developed countries. Described below is one economic-demographic method of assessing what reduced human fertility might contribute to increased economic development. Justifications of government programs to increase voluntary contraception are also considered (*1*).

In less-developed countries, one-half or more of annual increases in national output is being "swallowed" by annual increases in population, with income per head rising very slowly. Most of these countries have natural increases of from 2 percent to 3 percent a year. Hence they are doubling their populations every 35 to 23 years. This results not from rising birthrates but from falling death rates during the past 25 to 40 years—mostly attributable to improved health measures.

Some of their governments have decided that they cannot afford to wait for a spontaneous decline in fertility, resulting perhaps from more education, greater urbanization, and improved living. Instead, a few governments are encouraging voluntary use of contraceptives. The objective is economic development.

Many questions remain. How effective in raising incomes per head is reducing fertility as compared with other investments of resources? Could and should governments of less-developed countries encourage voluntary contraception?

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Income per Head

One measure of successful economic development is a rising income (output) per head of population (*2*). It is ordinarily associated with other indicators of increasing welfare such as greater annual investment. Another measure is fewer people living in poverty.

Income (output) per head is a ratio. Governments have sought to raise this ratio by increasing its numerator—investing in factories, dams, and highways, and the like—in order to increase the annual national output of goods and services. However, where politically feasible, governments can also raise the ratio of output per head by decreasing the denominator. A comparison of economic effectiveness can be made of changing the denominator as well as the numerator.

In a very simple arithmetic calculation, an imaginary less-developed country may be expected, in 1980, to have a national output (V) of $2500 million and a population (P) of 12.5 million for a yearly output per head (V/P) of $200. The government may decide to spend an extra $2.5 million a year for 10 years starting in 1970 to raise V/P. It can use these funds to increase output (ΔV) or to decrease population (ΔP) from what they would otherwise be (*3*). If the significant rate of return on traditional investments is 10 percent annually, an investment of $25 million from 1970 to 1980 will yield a ΔV in 1980 of $2.5 million, so that $\Delta V/V$ is 0.1 percent, or 1 in 1000.

Alternatively, the $2.5 million per year might have been spent on birth control. If the annual cost of an adult practicing contraception is $5 (*4*) and the annual fertility of contraceptive users is otherwise typically 0.25 live births, then in 1980 the population (12.5 million) would be 1.25 million smaller than expected. Thus $\Delta P/P$ is 10 percent or 1 in 10.

Apparently the amount of money spent each year on birth control can be 100 times more effective in raising output per head than the amount of money spent each year on traditional productive investments—for $V\Delta P/P\Delta V$ here equals 100. Had the rate of return on investments been 20 percent annually instead of 10 percent, had the annual cost of birth control been $10 instead of $5, or had the otherwise fertility of "contraceptors" (*5*) been 0.125 instead of 0.25, this superior effectiveness ratio would have been 50 to 1 instead of 100 to 1. Had all three parameters been altered by a factor of two to weaken the argument, the expenditures on birth control would still appear 12.5 times more effective.

The explanation is that it costs fewer

resources to prevent a birth than to produce a person's share as a consumer in national output. Calculations of this kind do not convince everyone, however, for they exclude so many of the economic and demographic interactions that could be expected from reduced fertility (*6*).

Developa: A Less-Developed Country

In order to assess the impacts of declining human fertility, a more complete economic-demographic model is needed as is applied here to a typical less-developed country named Developa. Any computer model should include at least the demographic and economic interactions shown in Fig. 1.

Specifically, the demographics involve projections of rates of mortality and fertility by age and sex, and data on the initial age and sex distribution of the less-developed country. Age and sex distributions can be calculated at 5-year intervals. Given the labor force participation coefficients by age and sex, the available labor force (L) can be computed.

The economics involve a national production function that relates number of employed workers (N), capital stock (K), and improving technology (t) to national output (V). Annual savings that increase K are related positively to V and negatively to P. An increasing K not only raises output per worker but reduces the surplus labor ratio (L/N).

A frequently used national production function is of the type

$$\log V = \log z + n \log N + k \log K + y \log (1 + t)$$

where V, N, and K are defined as above, z converts for units, y is years, and n and k are so-called output elasticities of labor and capital respectively. Thus, if n is 0.5, a 10-percent increase in N will occasion a 5-percent increase in V. In this formulation t is an annually compounded shift factor that increases the productivity of labor and capital by the same multiplier.

In such a model the demographics affect the economics through a changing age distribution. Declining fertilities reduce the ratio of children (who consume but do not produce) to work-age adults (who do produce when employed with enough capital). Also more is saved and invested from a given V when P is smaller (*7*).

Let us consider a nonexistent nation called Developa with the attributes typical of a less-developed country which has, in 1970, a population of 10 million and an income per head of $150. The crude birthrate is 44 per 1000 a year. When this model is used, what are the economic consequences of alternative fertility projections, given various parameters? Only two conditions are considered for fertility. When fertility is high the gross reproduction rate is 3.025 throughout (*8*). When fertility is low the gross reproduction rate falls from 3.025 in 1970 to 1.95 in 1985 and 1.48 in A.D. 2000. (The crude birthrate falls from 44 to 31 and 26, respectively.) Life expectancy at birth increases slowly from 53.4 years in 1970 to 56.6 in 1985 and 59.0 in A.D. 2000.

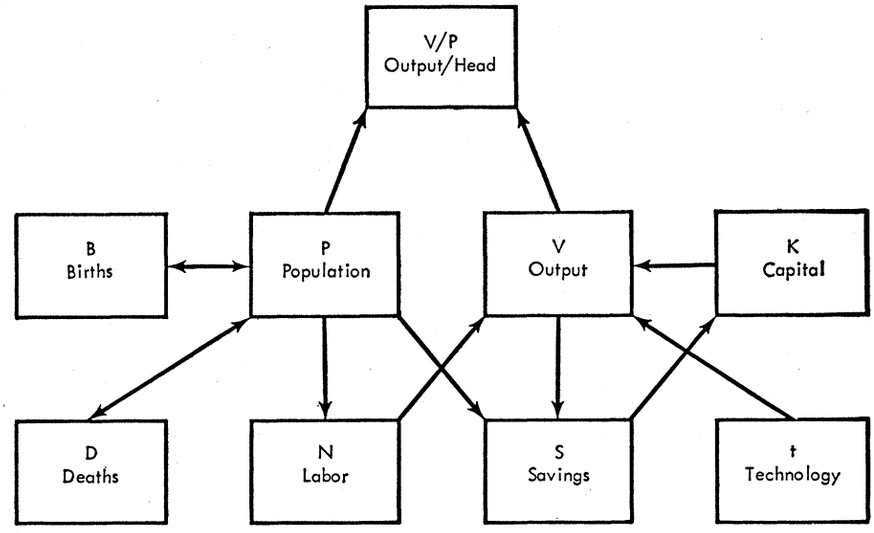

Fig. 1. Population and output per head.

The consequences of these contrasting projections for fertility over 30 years are shown in Table 1, starting with 1970 as a common base, for 1985 and A.D. 2000 (*9*). In both cases there is an improvement in output per head because of increasing capital per worker and contributions from improving technology—the latter compounding to 1.56 over the 30 years. However, when fertility is high, annual V/P increases only 1.63 times to $245, whereas when fertility is low it increases 2.36 times to $354 by A.D. 2000.

The number of persons living in "poverty"—defined arbitrarily as the state of being able to afford not more than $75 worth of goods and services a year—hardly changes when fertility is high. Saving-from-income increases nationally from 6.6 percent in 1970 to 18.1 percent by A.D. 2000 when fertility is low. The capital per worker

Table 1. Declining fertility for economic development.

Item	1970	1985		2000	
		High fertility	Low fertility	High fertility	Low fertility
P, population (10^9)	10.0	15.9	14.1	25.9	18.1
V, output ($\$10^9$)	1.50	2.92	2.99	6.33	6.43
V/P, income per head ($)	150	183	212	245	354
L, available labor (10^9)	3.86	6.09	6.09	9.77	8.66
N, employed labor (10^8)	3.28	5.41	5.49	9.01	8.26
Unemployment rate (%)	15.0	11.2	9.8	7.8	4.6
K, capital stock ($\$10^9$)	3.50	6.08	6.39	14.2	16.7
K/N, capital per worker ($)	1066	1126	1165	1572	2023
SV, savings from income (%)	6.60	10.3	12.3	14.5	18.1
Earnings per worker ($)	228	270	273	352	389
Return on capital (%)	15.0	16.8	16.4	15.7	13.5
Children/population (%)	40.4	44.5	37.4	51.9	30.6
Dependency rate* (%)	88.8	90.8	68.9	92.8	54.4
Living in "poverty"† (10^8)	2.50	2.53	1.45	2.20	1.18

* Young and aged divided by work-age population. † Personal income of less than $75 per year.

increases from $1066 to $2023. Hence in A.D. 2000 a worker earns $389 a year with low fertility as against $228 in 1970.

These various estimates are only suggestive. Their exact magnitudes are unimportant. What is significant is that combinations of alternative parameters indicate that declining fertility rates do contribute to economic welfare (*10*). The absolute population size does not matter as much as the population growth rate. If a population doubles in 25 years, it does not mean that output will also double in that period. The labor force may double, but not all may be employed as productively if there is not a doubling of capital. Twice as much labor and capital will not double output if there is a scarcity of equally useful land. Were it not for a slow improvement in technology, most rapidly growing populations would be hard put to raise their per capita incomes (*11*).

Conversely, a slowing rate of population growth accords more economic benefits than a slow growth rate, and hence part of the former's gains cannot last beyond a few decades. As fertility rates decline, the ratio of unproductive children to work-age population declines substantially. With low fertility in Developa, this ratio decreases from 0.83 in 1970 to 0.49 in A.D. 2000. With high fertility the ratio rises from 0.83 to 0.87. Fewer children per family give each family member more potential consumption from the same family income. But actual consumption should rise less than the potential consumption. The difference is "released" for investment.

With low fertility Developa can have a population of 18.1 million by A.D. 2000. Table 2 indicates what would happen if its leaders for some reason wanted this same population sooner, by 1989 instead, and so encouraged a continuation of the high-fertility rates of 1970. In 1989 V/P is $197 instead of $354 in A.D. 2000 and S/V is 11.5 percent instead of 18.1 percent. A worker's average annual earnings are $287 instead of $389. The ratio of the sum of the young and old dependents to the number in the work-age population is 0.914 instead of 0.554. Technology has had only 19 years instead of 30 years to make its contribution. This comparison at the same population size indicates that a slower population growth favors economic welfare.

Costs and Benefits

The stipulated decline in fertility might be due entirely to increased use of contraceptives. It should then be possible to estimate very approximately, from the reduction in births, the number of women using contraceptives and the cost in resources of their doing so. How do these costs compare with the economic benefits?

It is hazardous to estimate the number of adults who must be using contraceptives in order to achieve a given birth decrement. And the cost per "contraceptor" a year is sensitive to the mix of methods used—a coil being cheaper than pills after several years, for example. Nevertheless very crude estimates of the cost for contraceptors in Developa, assuming conditions of low fertility, are that in A.D. 2000, for instance, there will be 2.8 million "contraceptors" whose use of contraceptives will cost $14 million (*12*).

Estimating benefits is simpler if there is agreement on how to define them. Contraception results in a smaller population commanding more income per head because national output is little affected. It seems reasonable to ignore persons who would otherwise have been born, had it not been for contraception, and to consider only the living population. Thus Developa in A.D. 2000, with low fertility, has a population of 18.1 million and an income per head $109 higher than it would have been without contraception. The economic "benefit," defined as population times positive difference in income per head, in that year is $1.97 billion.

How can benefits and costs be compared? The ratio of benefit to cost in a particular year has little meaning. In A.D. 2000 it happens to be 146, but the benefits enjoyed in that year were due to previous expenditures, whereas the costs of that same year will only bring benefits afterward. If benefits and costs are accumulated over the 30-year period, which makes a comparison more meaningful, the ratio is 82 to 1. This understates the case, for with no subsequent costs there will be benefits after A.D. 2000. Possibly significant to policy-makers with short time horizons is that the benefit-cost ratio is already 22 to 1 in the 5th year (1975).

Table 2. Unfavorable economic results of fast population growth (at same population).

Item	1989 (High fertility)	2000 (Low fertility)
P, population (10^9)	18.1	18.1
V, output ($\$10^9$)	3.57	6.43
V/P, income per head ($)	197	354
L, available labor (10^9)	6.89	8.66
N, employed labor (10^9)	6.22	8.26
L-N/L, unemployment rate (%)	9.8	4.6
K, capital stock ($\$10^9$)	7.44	16.7
K/N, capital per worker ($)	1196	2023
S/V, savings from income (%)	11.5	18.1
Earnings per worker ($)	287	389
Return on capital (%)	16.8	13.5
Children/population (%)	44.7	30.6
Dependency rate* (%)	91.4	54.4
Living in "poverty"† (10^9)	2.37	1.18

* Young and aged divided by work-age population. † Personal income of less than $75 per year.

Extent of Program

Still in Developa, the low-fertility policy requires widespread use of contraceptives, so much so that the practicality of such a birth control program must be questioned (*13*).

The resource costs of the program are comparatively insignificant. From 1970 to A.D. 2000, the costs that yield $16.6 billion of benefits are $202 million, a figure about 0.2 percent of the accumulated national income of the 30 years. These costs per head of population range from under 20 cents in the 5th year to slightly over 75 cents in the 30th year and average about 50 cents annually.

Hence, birth-control programs are not a serious rival for funds. Most less-developed countries annually use for economic development resources worth approximately $10 per capita. Even an extensive contraceptive program would leave about 95 percent of development budgets available for traditional spending (*14*).

The real question is not adequacy of funds, or even of specific resources such as paramedics and clinics eventually, but whether enough women and men will voluntarily practice effective contraception. Under a policy of low fertility the gross reproduction rate should decline steadily from 3.025 and is halved by A.D. 2000. In 1985 22 percent of the population between 15 and 49 years of age would have to be practicing birth control. In A.D. 2000 this group would be about 30 percent of the men and women of these ages.

These percentages are considerably below comparable estimates for developed countries. But they are far above anything yet achieved in any less-developed country.

A less extreme and more attainable program would reduce the gross reproduction rate from 3.025 in 1970 to 2.60 in 1985 and 2.25 in A.D. 2000. With medium fertility V/P by A.D. 2000 is \$285, compared to \$245 with high fertility and \$354 with low fertility. Assuming medium fertility, among women and men 15 through 49 years old, necessary contraceptive users would be approximately 8 percent in 1985 and 16 percent in A.D. 2000.

How large a percentage of the relevant population will ever practice contraception voluntarily is unpredictable. Fortunately, no minimum participation is necessary to attain some benefits, with even 5 percent practicing being better than none. And clearly this percentage can be influenced by government.

Other Ways To Hasten Development

The economic-demographic model described above demonstrates that there are other ways of raising individuals' incomes than that of reducing human fertility. If families saved and invested slightly over twice the percentage of their incomes than was assumed, the same increases in income per head would be approximated with unchanged fertility. Or, if families would innovate technological improvements a little less than twice as rapidly as supposed, about the same economic gains could be realized without birth control (*15*).

However, calculations of the proportionate increases in saving and technology that would give the same income increases per head as fertility reduction have no practical significance. Arithmetical equivalents are not real alternatives in this case. Families will not save and innovate more because they do not have fewer children.

If there is any association at all among progeny, savings, and innovation, it is more probably one that favors birth control. One could argue that the sort of family that chooses among alternatives, can discipline itself, and manages its affairs is likely to have fewer children, invest more savings, and innovate more improvements. The doing of one may indirectly even induce the others.

Governmental Encouragement of Contraception

Could and should the government of a less-developed country encourage contraceptive use? Any such government could do many things to increase contraceptive practice. A government can at least have information and devices available at clinics. But it can also subsidize the retail sale of contraceptives and pay doctors to insert coils and perform vasectomies. It can pay bonuses to married women who remain nonpregnant, to "finders" who bring women to clinics for a coil insertion, and to fertile men or women who volunteer for sterilization. It can also educate and exhort through various advertising media.

A given expenditure that reduces fertility contributes so many times more to raising personal incomes than conventional development investments that a government can afford many activities if it increases the number of "contraceptors." If the percentage of adults using contraceptives remains small, despite government encouragement, at least something will have been gained. Government must then resort more exclusively to traditional investments for dams, and the like.

Many people raise the objection that promoting birth control is not a proper activity of government, arguing that whether adults do or do not have more children is their affair alone. Yet many governments encourage larger families. Some almost seem to have a policy of compulsory pregnancy and birth, with laws not only against abortion but also against furnishing contraceptive information or devices. Governments also have many programs that incidentally favor larger families —programs such as free schooling, public housing, and military conscription (which takes away the labor of sons).

A government that really wished to be neutral with regard to family size would often have not only to legalize contraceptive distribution but also to offset the incidental encouragement of fertility by social welfare programs through subsidizing birth control to some extent. Finally, if governments wish to give people more control over their lives, public health programs should not only reduce the risks of premature death but also the risks of unwanted progeny (*16*).

Summary

Most less-developed countries have population increases approaching 3 percent a year. Death rates have fallen dramatically in the past several decades, but annual birthrates remain at around 4 percent of population. Income per head is rising slowly.

Enough is known about the main parameters that a demographic-economic computer model can be used to assess the effects of declining fertility rates on various indices of economic welfare in a typical less-developed country. Thus halving in 30 years a 3.025 gross rate of reproduction results in income per head increasing 3.0 percent a year instead of 1.7 percent a year with no fertility change. Halving fertility also results in a third more capital per worker after 30 years.

A large birth-control program might directly cost about \$5 a year per "acceptor." About 25 percent of the population aged 15 through 49 would have to practice contraception on an average to halve the gross reproduction rate in 30 years. During this period the total cost might be roughly \$200 million for a less-developed country that started with a population of 10 million. Accumulated benefits could be \$16 billion. The benefit to cost ratio is roughly 80 to 1.

References and Notes

1. Many of the ideas and calculations presented here stem from research under contract and on overhead at TEMPO, General Electric's Center for Advanced Studies, in Santa Barbara, California, where my colleagues A. De Vany, W. E. McFarland, and R. A. Zind furnished valuable assistance.
2. National income is national output except for international debt service.
3. This 10-percent rate of return is not compounded for two reasons. First, such compounding would imply that income from capital is entirely saved and invested, although it is otherwise assumed that only a small and varying fraction of income in general is saved and invested. Second, investments have a so-called "gestation period" in reality, the increment in output not commencing sometimes for several years after the investment of funds begins (for example, construction of factories). For simplicity, and because these two considerations are countervailing, they have been ignored. Their net effect if included would have favored the argument.
4. Contraceptive pills, wrapped and packaged, are now available to governments for about 25 cents a monthly cycle; distribution probably doubles this cost. Latex condoms wrapped in aluminum foil are available to governments at about \$2.50 in the United States and \$1.25 in Japan per gross. The new plastic condoms may be cheaper. Distribution costs through regular commercial channels could be around \$0.60 per dozen. The intrauterine device costs about a penny to make and from \$5 to \$10 to insert (by public health doctors). In India, vasectomies are being performed at a direct cost less than \$10. Direct costs per acceptor-year are sensitive to the mix of methods used and the number of years that a person uses each method. If half of all acceptors use

condoms or pills and the other half take intrauterine devices or vasectomies, over a 5-year period the direct acceptor-year cost is less than $4.

5. A "contraceptor" is a person who voluntarily accepts (uses) contraceptives.
6. The above numerical example was the basis for President Johnson's statement to the United Nations General Assembly in San Francisco that $5 spent on birth control was worth $100 used for economic development.
7. The original precursor of the model used here was described by S. Enke [*Raising Per Capita Income Through Fewer Births*, General Electric-TEMPO, Santa Barbara, Calif., 1968)].
8. The gross rate of reproduction is the number of female live births a representative woman would be expected to have if she survived to age 50.
9. In these calculations t is 0.015, n is 0.5, and k is 0.35. That n and k sum to less than unity implies diminishing returns to workers and capital because of land-resource scarcity. Annual savings for investment equal 0.25 V minus $35 P approximately.
10. Income per head of population slightly exaggerates improvements in economic welfare when it rises because of shifts in age distribution from children to work-age adults. In equivalent consumer units a child is here 0.75 of a work-age adult. In the low-fertility case the increase in income per equivalent consumer is from $171 in 1970 to $394 in A.D. 2000.
11. S. Enke, *Quart. J. Econ.* **77**, 55 (1963).
12. Suppose the birth decrement is X and the fertility rate is y. Then a first crude approximation of the number of "contraceptors" is X/y. However, there may have to be three fewer conceptions for each two births, because of abortions and miscarriages. And of every three women of fertile age, only two may be at risk of pregnancy, with the other one being either not exposed to intercourse, sterile, or already pregnant at the time. Given these ratios, these two effects cancel, leaving the X/y relation. Few contraceptive methods are perfectly reliable in practice, and this may raise X/y by 1.1 times. Thus, if y is 0.2, for every one birth less there must be 5.5 women attempting contraception. At $5 per contraceptor a year, the cost of preventing a birth is then $27.50.
13. K. Davis, *Science* **158**, 730 (1967).
14. See S. Enke, *Econ. J.* **76**, 44 (1966).
15. S. Kuznets stressed savings and innovation as substitutes for contraception [*Proc. Amer. Philosoph. Soc.* **3** (No. 3), 170 (1967).
16. Useful readings include B. Berelson *et al.*, *Family Planning and Population Programs* (Univ. of Chicago Press, Chicago, 1966); P. Demeny, *Demography* **2**, 203 (1965); P. M. Hauser, *The Population Dilemma* (Prentice-Hall, Englewood Cliffs, N.J., 1963); E. M. Hoover and M. Perlman, *Pakistan Develop. Rev.* **6**, 545–566 (Winter 1966); G. Ohlin, *Population Control and Economic Development* (Organisation for Economic Cooperation and Development, Paris, 1967); C. Tietze, "Effectiveness, Acceptability and Safety of Modern Contraceptive Methods," *Paper No. 205* (World Population Conference, Belgrade, 1965) and *Studies in Family Planning* (occasional papers published by the Population Council, New York).

Scientific Research and the Innovative Process

The dialogue between science and technology plays an important, but usually nonlinear, role in innovation.

William J. Price and Lawrence W. Bass

The process of change is a central feature of the individual and organizational environments of modern man. The creating of new attitudes, new ways of doing things, new forms of social relationships, new products, new industrial practices—in short, innovation in the broad sense of the word—demands our attention, not only because of the results of change but also because of the extent to which the process of change is becoming a way of life.

Understanding the innovative process is therefore of paramount importance. The part played by technology—and we use this term to include product- or process-directed applied science—is generally understood and accepted, but what about basic research which has as its principal goal the discovery and organization of knowledge? Does scientific research play a central role in the innovative process, and, if so, how?

The conventional views based on the idea that innovation usually starts from new understanding give the answer "yes." We also believe that the answer is certainly "yes." It has become increasingly clear, however, especially through several recent studies, that the demonstration of the role of science in innovation requires focus on the nature and intensity of the dialogue between the scientific and technological communities, rather than on a preoccupation with the role of new scientific knowledge as the fountainhead from which innovation springs.

Innovation, Invention, and Research

The innovative process includes invention. Invention is the creation of an idea and its reduction to practice; innovation is the bringing of the invention into widespread use.

Scientific research is characterized by the continuous accumulation and ordering of new knowledge. Each research contribution generally builds on what has gone before. Concurrently, ordering takes place through laws and theories evolving within the scientific disciplines.

The process of sophisticated invention is related to orderly arrangement in the continuum of knowledge, because such invention requires the existence of a body of relevant information before ideas can come to fruition. Since the process of invention requires, however, a simultaneous connection of the knowledge with an external situation for potential utilization of the invention, it is a special case of ordering. Nevertheless, the dependence of invention on the relevant body of science means that innovation can be related to the search for new understanding, particularly in radically new technologies, such as the transistor and nuclear-energy technologies.

World War II undoubtedly had a profound influence on conventional views concerning the relationship of science and technology. Many persons who were engaged in scientific research when the war broke out helped exploit scientific knowledge, thus bringing about many important innovations in a short time. Unfortunately, from the standpoint of understanding the role of science in innovation, the fact is often overlooked that, during the war emergency, the vast majority of the scientists involved were working not as basic researchers but as technologists.

It is not surprising, therefore, that innovation is often viewed as an orderly process, starting with the discovery of new knowledge, moving through various stages of development, and eventually emerging in final, viable form.

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