rainfall, first results are very encouraging. If dynamic seeding proves successful on a large scale over many regions of the globe, man will have taken a major step toward water management and the mitigation of severe storms.

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Man and His Environment

Economic factors are more important than population growth in threatening the quality of American life.

Ansley J. Coale

The way our economy is organized is an essential cause, if not *the* essential cause, of air and water pollution, and of the ugly and sometimes destructive accumulation of trash. I believe it is also an important element in such dangerous human ecological interventions as changes in the biosphere resulting from the wholesale use of inorganic fertilizers, of the accumulation in various dangerous places such as the fatty tissue of fish and birds and mammals of incredibly stable insecticides. We can properly attribute such adverse effects to a combination of a high level of economic activity and the use of harmful technological practices that are inconsistent with such a high level.

The economist would say that harmful practices have occurred because of a disregard of what he would call *externalities*. An externality is defined as a consequence (good or bad) that does not enter the calculations of gain or loss by the person who undertakes an economic activity. It is typically a cost (or a benefit) of an activity that accrues to someone else. A fence erected in a suburban neighborhood for privacy also affords a measure of privacy to the neighbor—a cost or a benefit depending on how he feels about privacy versus keeping track of what goes on next door. Air pollution created by an industrial plant is a classic case of an externality; the operator of a factory producing noxious smoke imposes costs on everyone downwind, and pays none of these costs himself—they do not affect his balance sheet at all. This, I believe, is the basic economic factor that has a degrading effect on the environment: we have in general permitted economic activities without assessing the operator for their adverse effects. There has been no attempt to evaluate—and to charge for—externalities. As Boulding says, we pay people for the goods they produce, but do not make them pay for the bads.

To put the same point more simply: environmental deterioration has arisen to a large extent because we have treated pure air, pure water, and the disposal of waste as if they were free. They cannot be treated as free in a modern, urban, industrial society.

There are a number of different kinds of policies that would prevent, or at least reduce, the harmful side effects of some of our economic activities, either by preventing or reducing the volume of the harmful activity, or by inducing a change in technique. Other policies might involve curative rather than preventive steps, such as cleaning up trash along the highways, if we cannot prevent people from depositing it there.

Among the possibilities are steps that would make externalities internal. An example that I find appealing, although it is perhaps not widely practical, is to require users of flowing water to take in the water downstream of their operation and discharge it upstream. A more general measure is to require the recycling of air or water used in industrial processes, rather than permitting the free use of fresh water and clean air, combined with the unmonitored discharge of exhaust products.

Public authorities can charge for unfavorable external effects by imposing a tax on operations that are harmful to the environment. The purpose of such taxes is to reduce the volume of adverse effects by inducing a shift in technique or by reducing the volume of production by causing a rise in

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price. Also, the tax receipts could be used to pay for mitigating the effect. An example of a desirable tax is one imposed to minimize the use of disposable cans and bottles for soft drinks and beer. Not long ago the majority of manufacturers produced these commodities in containers that were to be returned. The producer offered a modest price for returning bottles as an inducement. It has proven cheaper to use disposable glass bottles and cans; recently aluminum cans have rapidly increased in popularity, substituting a container that lasts indefinitely for the tin cans that would sooner or later rust away. Everyone is familiar with the resultant clutter on beaches, in parks, and along the highways. If a tax of 10 cents per unit were imposed on each disposable container, it would clearly be cheaper to go back to returnables. If some manufacturers found it advantageous to pay the 10-cent tax, the receipts could be used to pay for cleaning up highways and beaches.

Another approach that would induce people to give up economic activities with harmful effects on others is to make individuals and corporations financially liable for any damage caused by their operations. The resultant litigation would be an unwarranted windfall for lawyers, but financial liability might be a very potent factor in reducing pollution.

There is general agreement that our knowledge of what affects the environment is wholly inadequate. Because of inadequate monitoring and measurement, we do not know what is happening to the atmosphere or the biosphere; we need research to keep track of what is going on as well as to develop the techniques that will produce the goods we want with fewer of the bads we do not want.

An Economist's Review of Resource Exhaustion

One of the questions most frequently raised about the environmental effects of modern life is the rapid and rising rate of extraction of raw materials. Are we running out of resources?

I would first like to note that the distinction between renewable and nonrenewable resources is not a clear one. There are, of course, instances of nonrenewable resources in the form of concentrated sources of energy, such as the fossil fuels. These are reservoirs of reduced carbon embodying radiant energy from the sun that accumulated over many thousands of years. When these fuels are used, the energy that is released is to a large extent radiated into space, and we have no way of reclaiming it. The geological processes that are constantly renewing the fossil deposits of carbon are so slow compared to the rate at which we are burning the fuels that the designation "nonrenewable" is appropriate.

On the other hand, when we think of our resources of such useful materials as the metallic elements of iron, copper, nickel, lead, and so forth, we should realize that spaceship Earth has the same amount of each element as it had a million years ago, and will have the same amount a million years from now. All we do with these resources is to move them around. The energy we use is lost, but the minerals we find useful are still with us. It does not pay to recycle these minerals (that is to use them repeatedly by reclaiming scrap) because the deposits of minerals in the ground or in the ocean are still such a cheap source. It must be noted that the mining of fresh ore is cheaper than the use of scrap in part because miners are not charged for their "externalities." If harmful by-products of mining could not be discharged into streams, if mine tailings were regulated, and erosion-producing or even unesthetic practices forbidden, minerals would be more expensive and recycling more attractive. In the production of any metallic element, the easier sources are exploited first. As mining gets more difficult, the ore gets more expensive, and recycling becomes more nearly competitive. It seems wholly probable that the technology of recycling will be improved.

The surprising fact is that raw materials are not at the moment very costly, and moreover their cost relative to the cost of finished goods has not been increasing. The gross national product in the United States is more than $4500 per capita and the raw materials component per capita is less than $100. The price of raw materials relative to the price of finished goods is no higher now than at the beginning of the century, and if we were running out of raw materials, they would surely be rising in relative expensiveness. A prominent exception is saw lumber, which is substantially more expensive relative to the cost of finished wooden products than it used to be.

The reason that the future of our resource situation always seems so bleak and the past seems quite comfortable is that we can readily construct a plausible sounding estimate of the future demand for a particular raw material, but cannot form such a plausible picture of the future supply. To estimate the future demand, we need merely note the recent trends in the per capita consumption of whatever it is we are concerned about, utilize whatever plausible projection of population we are prepared to accept, multiply the two together and project an astonishingly high rate of usage 50 years in the future. If this demand does not seem overwhelming, we need only make a projection 100 years in the future. What we cannot so readily foresee is the discovery of new sources and of new techniques of extraction, and, in particular, the substitution of other raw materials or the substitution of other industrial processes which change the demand away from the raw material we are considering. Hence it can always be made to appear that in the future we are going to run out of any given material, but that at present we never have.

It is possible to set plausible limits to the stores of fossil fuels that we are likely to discover, and with the very rapid rise in the use of these fuels they will surely become more expensive in some not too distant time. It should be noted, however, that we will not suddenly "run out" of fossil fuels. Long before the last drop of oil is used, oil will have become much more expensive. If gasoline were $5 or $10 a gallon, we would utilize it much more sparingly, with small economical automobile engines, or perhaps the substitution of some non-petroleum-based fuel altogether. In fact, the principal user of our petroleum deposits may be the petrochemical industries. I have given this special attention to fossil fuels because there is no substitute in prospect for such fuels in small mobile units such as automobiles. On the other hand, the supply of overall energy seems to pose no problem. There seems to be ample fissionable material to supply rising energy needs for many centuries, if breeding reactors are perfected. If fusion proves a practical source, the supply of energy can properly be considered limitless.

Another aspect of the relation of the United States economy to resources that is much publicized today is the

fact that we are consuming such a large fraction of the current annual extraction of raw materials in the world. A much quoted figure is that 6 percent of the world's population is using 30 percent of the resources. It is concluded from figures such as these that we are robbing the low-income countries of the world of the basis of their future prosperity—that we are using up not only our resources, but theirs as well. Most economists would find this a very erroneous picture of the effect of our demand for the raw materials extracted in the less developed parts of the world. The spokesmen for the less developed countries themselves constantly complain about the adverse terms of trade that they face on world markets. The principal source of their concern is the low price of raw materials and the high price of finished goods. The most effective forms of assistance that the developed countries (including the United States) give to the less developed countries are the purchases they make from the less developed countries in international trade. A developing country needs receipts from exports in order to finance the purchase of the things they need for economic development. For example, in order to industrialize, a nonindustrialized country must for a long time purchase capital equipment from more advanced countries, and the funds for such purchases come from exports—principally of raw materials. Economists in the developing countries feel that the demand for raw materials is inadequate. Perhaps the most important adverse effect of slowing down the growth of the gross national product in the United States would be that it would diminish the demand for primary products that we would otherwise import from the less developed countries. After all, if a developing country wants to retain its raw materials at home, it can always place an embargo on their export. However, it would be a policy very damaging to economic progress of that very country.

Note that the effect of our high demand for raw materials is a different matter from the desirability of the domestic control of mineral resources within the developing countries. Selling oil on the world market provides immense economic advantages to a developing country. Whether foreign interests should be represented in the extraction of raw materials is another question.

Population Growth in the United States

I shall begin a discussion of populaton with a brief description of recent, current, and future population trends in the United States. Our population today is a little over 200 million, having increased by slightly more than 50 percent since 1940. I think it is likely to increase by nearly 50 percent again in the 30 years before the end of the century.

This rate of increase cannot continue long. If it endured throughout the next century, the population would reach a billion shortly before the year 2100. Within six or seven more centuries we would reach one person per square foot of land area in the United States, and after about 1500 years our descendants would outweigh the earth if they continued to increase by 50 percent every 30 years. We can even calculate that, at that rate of increase, our descendants would, in a few thousand years, form a sphere of flesh whose radius would, neglecting relativity, expand at the velocity of light.

Every demographer knows that we cannot continue a positive rate of increase indefinitely. The inexorable arithmetic of compound interest leads us to absurd conditions within a calculable period of time. Logically we must, and in fact we will, have a rate of growth very close to zero in the long run. The average rate of increase of mankind from the inception of the species until the present is zero to many decimal places. If we agree that 10,000 years from now we can have no more than one person per square foot, and that the population of the world will at a minimum exceed that of Richmond, Virginia, we can say that the average annual growth of population will be within one per thousand of zero.

The only questions about attaining a zero rate of increase for any population is when and how such a rate is attained. A zero rate of increase implies a balance between the average birth and death rates, so the choice of how to attain a zero rate of increase is a choice between low birth and death rates that are approximately equal. The average growth rate very near to zero during mankind's past history has been attained with high birth and death rates—with an average duration of life that until recently was no more than 30 or 35 years. I have no difficulty in deciding that I would prefer a zero rate of growth with low rather than high birth and death rates, or with an average duration of life in excess of 70 years, as has been achieved in all of the more advanced countries of the world, rather than the life that is "nasty, brutish, and short." The remaining question then is *when* should our population growth level off.

A popular answer today is "immediately." In fact a zero rate of increase in the United States starting immediately is not feasible and I believe not desirable. The reason is the age composition of the population that our past history of birth and death rates has left to us. We have an especially young population now because of the postwar baby boom. One consequence is that our death rate is much lower than it would be in a population that had long had low fertility. That is, because our population is young, a high proportion of it is concentrated in ages where the risk of mortality is small. Therefore, if we were to attain a zero growth rate immediately, it would be necessary to cut the birth rate about in half. For the next 15 or 20 years, women would have to bear children at a rate that would produce only a little over one child per completed family. At the end of that time we would have a very peculiar age distribution with a great shortage of young people. The attendant social and economic disruptions represent too large a cost to pay for the advantages that we might derive from reducing growth to zero right away.

In fact, a more reasonable goal would be to reduce fertility as soon as possible to a level where couples produced just enough children to insure that each generation exactly replaced itself. If this goal (early attainment of fertility at a replacement level) were reached immediately, our population would increase 35 to 40 percent before it stabilized. The reason that fertility at the mere replacement level would produce such a large increase in population is again the age distribution we have today. There are many more people today under 20 than 20 to 40, and when the relatively numerous children have moved into the childbearing ages, they will greatly outnumber the persons now at those ages, and when the current population under age 20 moves into the old ages, they will be far more numerous than the people now at the old ages. Thus to move the population to replacement would be to insure approximately that the number of children

under 20 will be about the same as it is today, but that the number above that age will be substantially higher. The net effect is the increase of 35 to 40 percent mentioned just above. It is the built-in growth in our age composition that led me to state earlier that I think an increase in the order of 50 percent of the U.S. population is not unlikely.

A sensible choice in reducing our growth rate to zero then is between early or late attainment of fertility at the replacement level. Is there any reason that we should not attempt to attain a fertility at replacement as soon as possible? My own opinion is that an early move in that direction is desirable, but for the sake of completeness, I must point out that there is a non-negligible cost associated with attaining a stationary population—the population that will exist with fertility at replacement after the age distribution left over from the past has worked out its transitory consequences.

A stationary population with the mortality levels that we have already attained has a much older age distribution than any the United States has ever experienced. It has more people over 60 than under 15, and half the population would be over 37 rather than over 27, as is the case today. It would be an age distribution much like that of a health resort.

Moreover, if we view the age pyramid in the conventional way, with the number of males and females being drawn out as in the branches of a Christmas tree (age representing altitude of the tree) the pyramid for the stationary population is virtually vertical until age 50 because of the small number of deaths under the favorable mortality conditions we have attained. In contrast, the age distribution of the United States to date has always tapered more or less sharply with increasing age. The stationary population with its vertical sides would no longer conform in age composition to the shape of the social structure—to the pyramid of privilege and responsibility. In a growing population, the age pyramid does conform, so there is a rough consonance of shape between diminishing numbers at higher ages and the smaller number of high positions relative to low positions. In a stationary population there would no longer be a reasonable expectation of advancement as a person moves through life. I have indicated that sooner or later we must have a stationary population, so that sooner or later we must adjust to such an age composition. I am pointing to this disadvantage to show that there is a choice between moving more gradually to a stationary population at the expense of a larger ultimate population size in order to continue to enjoy for a longer time the more desirable age distribution of a growing population.

Connection between Population and Pollution

The connection between the current growth in our population and the deterioration of our environment of which we have all become aware is largely an indirect one. The problem has arisen because we are permitting the production of bads (pollution, or negative externalities) along with goods. There seems little doubt that the rapid increase in the production of goods has been responsible for the rapid increase in the production of bads, since we have made no effective effort to prevent the latter from accompanying the former. But per capita increase in production has been more important than population growth. It has been calculated that if we were to duplicate the total production of electricity in the United States in 1940 in a population enjoying the 1969 per capita usage of energy, the population could be only 25 million rather than 132 million people there were in 1940. Population has increased by 50 percent, but per capita use of electricity has been multiplied several times. A similar statement can even be made about the crowding of our national parks. The population has increased by about 50 percent in the last 30 years—attendance in national parks has increased by more than 400 percent.

A wealthy industrial urban population of 100 million persons would have most of the pollution problems we do. In fact, Sydney, Australia, has problems of air and water pollution and of traffic jams, even though the total population of Australia is about 12 million in an area 80 percent as big as the United States. Australia is actually more urbanized than the United States, in spite of its relatively small population and large overall area.

If we have the will and intelligence to devise and apply proper policies, we can improve our environment and can do so either with the current population of 200 million, or with the population that we will probably have in another 50 years of 300 million. On the other hand, if we ignore environmental problems and continue to treat pure air and water and the disposal of trash as if they were free, and if we pay no attention to the effects of the techniques that we employ upon the balance of nature, we will be in trouble whether our population grows or not. There is no doubt that slower population growth would make it easier to improve our environment, but not much easier.

Policies That Would Affect the Growth of Population

We must, at some time, achieve a zero rate of population, and the balance should surely be achieved at low birth and death rates rather than at high rates. If, as at present, only about 5 percent of women remain single at the end of the childbearing span, and if 96 percent of women survive to the mean age of childbearing, and if finally the sex ratio at birth remains about 105 males for every 100 females, married couples must have an average of about 2.25 children to replace themselves. What kinds of policies might be designed to assure such a level of fertility or, more generally, to produce the fertility level that is at the moment socially desirable?

I begin with a set of policies that are consistent with general democratic and humanitarian principles, although a minority of the population would oppose them on religious grounds. These are policies that would, through education and the provision of clinical services, try to make it possible for every conception to be the result of a deliberate choice, and for every choice to be an informed one, based on an adequate knowledge of the consequences of bearing different numbers of children at different times. A component of such a set of policies would be the development of more effective means of contraception to reduce the number of accidental pregnancies occurring to couples who are trying to avoid conception. These are policies that call for a substantial government role and I think that an effective government program in these areas is already overdue. I personally believe that education in the consequences of childbearing and in the techniques of avoiding preg-

nancy, combined with the provision of contraceptive services, should be supplemented by the provision of safe and skillful abortion upon request. It is clear that the public consensus in favor of abortion is not nearly as clear-cut as that in favor of contraception, and I know that the extent and the strength of the moral objection to induced abortion is much greater. Nevertheless, I am persuaded by experience in Japan and eastern Europe that the advantages of abortion provided under good medical auspices to cause the early termination of unwanted pregnancies are very important to the women affected, as is evident in the fact that when medically safe abortion has been made available at low cost, the number of abortions has initially been as great or greater than the number of live births. Later there is a typical tendency for women to resort to contraception rather than repeated abortions.

The reason I favor abortion is that such a high proportion of births that occur today are unwanted, and because a large number of desperate pregnant women (probably more than a half a million annually) resort to clandestine abortions today, with high rates of serious complications. In contrast, early abortion, under skilled medical auspices, is less dangerous than tonsillectomy, and substantially less dangerous than carrying a child to full term.

In recent years the number of births that were unwanted in the United States constituted about 20 percent of the total (an unwanted birth was defined as one in which the woman said that conception occurred either as a result of a failure of contraception or in the absence of contraception but without the intent to become pregnant as soon as possible, when at the time the conception occurred the husband or wife or both did not want another child then or later). The rate at which women are having children today would lead to a completed family size of slightly under three children. If all unwanted births were eliminated, the number of children born per married woman would be about 2.4 or 2.5 on average. This is very little above replacement, and when allowance is made for the likely possibility that women understated the proportion of births that were unwanted, it is probable that the elimination of unwanted births would bring a fertility at or below replacement.

If it is true that the elimination of unwanted pregnancies would reduce fertility very nearly to replacement, it must be conceded that this outcome is fortuitous. It is highly unlikely that over a substantial period of time the free choice by each couple of the number of children they want would lead exactly to the socially desirable level of fertility. The erratic behavior of fertility in America and in other advanced industrialized countries in the last 30 or 40 years is ample evidence that when fertility is voluntarily controlled, the level of fertility is subject to major fluctuations, and I see no logical reason to expect that on average people would voluntarily choose a number of children that would keep the long-run average a little above two per couple. In other words, we must acknowledge the probable necessity of instituting policies that would influence the number of children people want. However, there is no need for haste in formulating such policy, since, as I have indicated, improved contraceptive services combined with a liberal provision of abortion would probably move our fertility at present quite close to replacement, and a gradual increase in population during the next generation would not be a major addition to the problems we already face.

Policies intended to affect people's preferences for children should be designed within the framework of our democratic traditions. They should be designed, for example, to encourage diversity and permit feedom of choice. An average of 2.25 children does not require that 75 percent of couples have two children and 25 percent three, although that would produce the desired average. Another possibility is a nearly even division of family size among zero, one-, two-, three-, four-, and five-child families. The ideal policy would affect the decision at the margin and not try to impose a uniform pattern on all. I do not think that people who prefer to have more than the average number of children should be subject to ridicule or abuse.

It is particularly difficult to frame acceptable policies influencing the number of children that people want. While it is still true that so many large families result from unwanted pregnancies, the unwanted child that is the most recent birth in a large family already faces many deprivations. The psychological disadvantages of the unwanted child cause some of our most serious social problems. In addition to these psychological disadvantages, the unwanted child in a large impoverished family faces an inadequate diet, much below average chances for schooling, and generally inferior opportunities. I hardly think it a wise or humane policy to handicap him further by imposing a financial burden on his parents as a result of his birth.

When unwanted births have become negligible in number, we could imagine trying to design a policy in which the couple is asked to pay some part of the "externalities" that an additional birth imposes on society. In the meantime, I suggest as a desirable supplement to better contraception and free access to abortion the extension of more nearly equal opportunities in education and employment for women, so that activities outside of the home become a more powerful competitor to a larger family. We should start now devoting careful attention to formulation of policies in this area—policies that could increase fertility when it fell too low as well as policies to induce people to want fewer children.

Some aspects of the deterioration of our environment appear to be critical and call for prompt action. We need to start now to frame and apply actions that would arrest the careless destruction of the world in which we live. We also need policies to reduce promptly the incidence of unwanted births. In the long run we shall also need ways to influence the number of births people want. To design policies consistent with our most cherished social and political values will not be easy, and it is fortunate that there is no valid reason for hasty action.