CHAPTER 2

Limitations of Economics

> We must not look for the same degree of accuracy in all subjects: we must be content in each class of subjects with accuracy of such a kind as the subject matters allows, and to such an extent as is proper to the inquiry.
>
> —ARISTOTLE, *Nicomachean Ethics*

The conscious or unconscious view that many economists have of economics as a science comparable to physics tempts them to expect that it can aspire to explaining economic reality with the same precision and predictability that they believe physics has been able to achieve in explaining and predicting phenomena in the universe. This idealization of physics overlooks the fact that in modern physics Heisenberg's uncertainty principle is now accepted as describing a fundamental property of the world. We cannot measure the present state of the universe precisely. Quantum physics teaches that an electron can be a particle or a wave and an electron may suddenly appear unexpectedly. There is an absolute line beyond which it is impossible to ascertain precisely both the exact position and the momentum of a simple elementary particle. As Hawking points out, this means that we cannot have a scientific theory or model of the world that is completely deterministic (1988). Richard Feynman, one of the most brilliant physicists of our generation, commented that physics "has given up on the problem of trying to predict exactly what will happen in a definite circumstance. Yes! Physics *has* given up. *We do not know how to predict what would happen in a given circumstance,* and we believe now that it is impossible, that the only thing that can be predicted is the probability of different events" (1995, 135, italics in original).

In mathematics, Goedel proved that no axiomatic system could be complete. Economics must also realize that it too is subject to limited results. The limits to precise knowledge of an economic situation or problem are approached rapidly. The nature of an economy is such that the mesh of the net that economists can weave to catch reality is much coarser than that of the natural scientists in their realms.

It is central to the argument to make clear the distinction between the terms *accuracy* and *precision.* These are often confused in common usage, with a precise statement often being taken as evidence of its accuracy. The distinction between the two can probably best be seen in my favorite example:

> On Cape Cod, where the pace of life is relaxed, you may ask a craftsman when he can come to build a fence for you. If he answers, "sometime in the autumn," he is being accurate but not precise. If instead he promises "Eight A.M., October 2," he is being precise but not accurate. On October 2, it is highly likely that the fish will be running and he will be out in his boat or it will be a beautiful autumn day, far too nice to spoil by working.

Accuracy conveys the meaning of "correctness," of "true value." *Precision* means the "degree of sharpness" by which a thing or concept is specified, and it may or may not be accurate.

Alfred Marshall and John Maynard Keynes did not believe that it was possible to apply exact mathematical methods to economics because a pervasive part of economic life cannot be precisely measured. As Keynes stated in the footnote to his memorial for Alfred Marshall: "economic interpretation in its highest form requires an . . . amalgam of logic and intuition and the wide knowledge of facts, most of which are not precise" (1925, 25).

The virtue, and the fault, of mathematics is that the meaning of a mathematical symbol, once defined, does not change. Words, on the other hand, can flirt with meanings and coquet with relationships. Words can be deliberately ambiguous when relationships are ambiguous and it is desired to leave them so. Natural language can be more flexible in conveying meaning: it is infinitely richer in vocabulary and consequently can be more accurate, although less precise.

The first part of this chapter will present a summary analysis of why precision is unattainable in grasping the economy. Perhaps the greatest problem some economists will face in this discussion is the difficulty of shifting from the mind-set of precise numbers and well-behaved models of pure theory to the rough, inaccurate data, recalcitrant behavior, and shifting complexities of the real economy.

Although economics has prided itself on its comparability to physics, one of the basic lessons taught in physics is ignored—that it is essential to understand and express the degree of accuracy of each number used. As John von Neumann pointed out: "When a problem in pure or in applied mathematics is 'solved' by numerical computation, errors, that is, deviations of the numerical 'solution' obtained from the true, rigorous one, are unavoidable. Such a 'solution' is therefore meaningless, unless there is an estimate of the total error in the above sense" (1963).

Economists tend to overlook the need to understand how much precision is actually attainable in the accuracy of the numbers used as well as the need to express the margin of error present in an economic statistic. Sampling errors for an indifferent (i.e., not hostile) universe are estimated and stated, but the limits of accuracy in most very rough economic estimates are seldom stated and sometimes not even realized. Most of the data that economists rely on (GDP, costs, prices) are not fully reliable. Yet often economists use these numbers as though they were precisely accurate to the first or second decimal point. Norbert Wiener, the noted scientist, observed that a true science has to begin with a critical understanding of its quantifiable elements and the means adopted for measuring them (1964, 89–90).

Before looking at the errors that stem from the nature of economic data themselves, it is important to realize that there are important sources of error in all numerical computations. A mathematical formulation of reality is not reality itself. It necessarily can represent reality only with certain abstractions and simplifications. Then the model may involve parameters the values of which have to be derived directly or indirectly from observations. These parameters are affected by errors, and these errors cause errors in the result. The model usually will require transcendental operations (like differentiation or integration) and implicit definitions (such as solutions of algebraic or transcendental equations). If they are to be approached by numerical calculation, these have to be handled by elementary processes that correspond to a finite procedure that resolves itself into a linear sequence of steps. All of these steps are approximate, and so the strict mathematical statement we start with is replaced with an approximate one (von Neumann and Goldstine 1963, 482–83). Finally, a fourth source of error derives from the need to round off numbers. There has to be a maximum number of places in the numbers with which we work. These noise variables enter into the computations every time an elementary operation is performed.

Beyond these errors, which are inherent in all numerical calculations, there are special sources of error that flow from the nature of economics as a subject concerned with the economy itself. The natural sciences deal with facts that are in essence independent of human activity. Economics deals with facts that report on or are the result of human activity. This is a fundamental difference.

Several classes of errors result from this. First, economic data are gathered from people. Gathering economic statistics is a two-person game. A planet has no interest in deceiving an astronomer, but a person or economic organization may have an incentive to hold back, conceal, or distort infor-

mation. Mitsubishi suppressed information on defects in its products for twenty years. For the year 2000 census, a Republican Congress forbade the Census Bureau to use the more accurate sampling procedure in counting the American population in order to hold down the number of potential Democratic seats that would result from the decennial reapportionment of the House of Representatives. When a head tax was levied in African countries during colonial times, population numbers were understated—as a government official came into a village to perform the head count, people vanished into the bush on the other side. An underground economy exists in most, if not all, countries in the world. It has become obvious that important economic statistics were distorted or completely falsified in the centrally planned countries before 1989.

There are other sources of error. Economic data are not usually secured from planned experiments but are the by-product of business or government activities. They are not usually produced by specially trained personnel and are often defined in terms of legal rather than economic categories. The data therefore tend to cover categories that are somewhat different from what an economist would like (Morgenstern 1963).

There is usually an unavoidable lag between statistics and events. Some, like stock prices, are available practically immediately, while others may take days, weeks, or months. Because of the different lags, to have key statistics in a useful time frame they have to be estimated. Then, as the data come in, there is a constant need to revise the estimates. When making policy that affects the future, as Cairncross remarked, it is necessary first to forecast the present, and in this process important mistakes can be made (Cairncross 1969).

To deal with problems in the world of reality, economics has to have a proper appreciation of what economic measurements can and cannot do. In economics, we deal with loose concepts. In handling loose concepts, the margins of precision of a statistic must widen as it slips away from describing or measuring the central area of the concept (where theoretically it can be sharp or precise) toward the gray area or penumbra in which most of the real world concepts live.

> In scientific theoretical systems like economics with a logico-mathematical framework, the basic unit is the "individual." This may be a person or a commodity like an automobile. An individual is an entity that either is indivisible into parts or loses its individuality when its parts are separated from each other. *In theory,* the individual is definite and unchangeable—sharply distinguished from its background and sharply demarcated from other individuals and in time. *In reality,* even though we may have no doubt whether a particular entity is an "individual" or not, doubt

> may enter as soon as a time or space dimension comes into play. Indefiniteness in some phase or respect of an individual is completely compatible with definiteness otherwise. . . . When does a motor car begin or cease to exist? How much exactly of its parts can we take away from a car without destroying the individual car? . . . the lack of definitiveness of the individual, either in space or in time, is important in much of economics.
>
> Second, *in theory,* classes and the concepts relating to them are exact: *A* either possesses the predicate that makes it a member of class *P* or it does not. That is, *A* must be either a member of *P* or a member of non-*P.* One cannot say A_n is a borderline case, being just barely a member of *P* and of non-*P.* This violates one of the main principles of logic—something cannot be both *P* and non-*P.* Similarly, one cannot say that A_n is just barely not a member of *P* and also just not a member of non-*P.* This violates another logical principle—a thing must be either a member of *P* or it must be non-*P.* However, once we return to reality, neutral or borderline candidates are common to most of the classes we deal with. (Kamarck 1983, 24–25)

In real life, the classes are usually inexact. Buying a house can be an investment and/or a consumption item. Purchases and mortgage costs of houses are included in the consumer price index, yet some people buy their houses partly or wholly as an investment in the hope of getting a capital gain. One man I know, who has an artist's talent and a craftsman's skill, makes his living by buying houses, improving them, and selling them at higher prices. His "profit" is partly wages and partly capital gain, and in the meantime he has been enjoying a return of implicit rent.

The indefiniteness of individuals and the inexactness of classes are both covered by Max Black's term, *loose concepts.* This describes cases in which there is no point at which a unique sharp transition can be made from a case that clearly belongs to a class and a borderline case or a case excluded from the class. In the economy, an economic empirical concept and its opposite could be regarded as lying at opposite ends of a spectrum: one can clearly distinguish between both ends, but any dividing line drawn between them as they shade toward each other can only be arbitrary. The concept and its opposite are distinct, but they are not *discretely* distinct. There is no void between them but a penumbra.

For example, "unemployment" is a loose concept. The boundaries of the concept have to be set arbitrarily when one is counting the number of persons included in the class "unemployed." An arbitrary (and not logically unique) decision has to be taken in deciding how long a person has to be without work and trying to find work to be considered unemployed. The two opposites, employed and unemployed, are clear, but there is no one

point in the border area where a sharp line can be drawn between them. In many less developed countries, the unemployed are in large part people who have migrated to the city because their incomes while "unemployed" there are greater than their subsistence income in the village would have been. Similar looseness is true of other economic concepts. Central banks find it necessary to invent new measures of money supply as a growing number of different means of payment have evolved and come into use. In the last generation, these have included NOW accounts, money market fund accounts, credit cards, and so on, and today an Internet payment system is being developed.

Imprecision of concept (indefiniteness of individuals and inexactitude of classes that concepts refer to) rules in many sectors of the economy. The national accounts are a good example. Measurement of the output of primary products is close to being precisely accurate. These products tend to be generally uniform or change slowly over time and are usually sold in fairly competitive markets. Manufactures tend to be changeable in quality over time, but their markets are much less perfect. Price deflators are a problem in measuring real output over time. The difficulties are well known, and their resolution is inevitably arbitrary. In services, which now make up much more than half of total product, measurement of some is extremely difficult and unsatisfactory. General government, households, and nonprofits do not sell their output, so no proper measure of it can be constructed. In practice, output is held to be equivalent to employment costs. The figure for labor earnings is taken to measure the contribution to national income, net national product, and gross national product. In the health sector, too, because of the need to rely on the medical profession for information on the product to be purchased, third-party payments, restrictions on competition in the profession, and so on, expenditures on the sector cannot be accepted as properly measuring its output.

The balance of trade and payments accounts also have a multitude of measurement problems. Trade and exchange barriers have come down across the world, making measurement of trade more difficult; trade in services, which is hard to track, represents a growing share of total trade; and the figures on capital flows, always notoriously inaccurate, with globalization and the accompanying explosion in electronic transactions, have become even less reliable. The result is that the global balance of payments never balances (total world imports have been higher than total world exports by as much as 3 percent in recent years). Alien spaceships, rather than kidnapping terrestrials, are bringing in goods and services from outer space!

The subject matter of economics does not possess constancies and

immunity to significant historical change. Not only do the structural relationships change over time, often unpredictably and irregularly, but the economy is buffeted by unpredictable, often arbitrary and irrational political and economic changes at home and abroad (e.g., consider the oil-producing countries in 1973, 1979, and 2000). The agents involved in the structural relationships often reach outside the economy and use their influence in the political sphere to get the economic parameters changed for their own benefit.

In working with loose concepts, the use of customary methods of logical reasoning forces one to make demarcations in the neutral or borderline cases that are not clear. But one must recognize that these demarcations are arbitrary or judgmental. There are no logical rules that precisely locate the borderline. As long as this is borne in mind, one can reason using loose concepts and reach useful conclusions as long as one is not deceived with illusions of precise accuracy. It is necessary to recognize that often the closest that economics can come to portraying some reality is in the form of a rough, simple model. These models need to be considered not as algorithms or effective procedures providing us with precise solutions to economic problems but as heuristics. They are plausible approaches or rules of thumb for attacking particular problems or illuminating some aspect of the structure of reality. They may give us reasonably approximate solutions. They cannot dictate or determine the precise single right decision, but they can assist us in making rational and effective decisions.

> Take the standard old-fashioned Cambridge Massachusetts Keynesian model: From the empirical evidence, its open economy variant is enormously useful for understanding the real world. It has old-fashioned micro foundations; lot of the assumptions are *ad hoc,* essentially empirical observations like the effect of changes in disposable income and changes in wealth on current consumption. (Bator 1998, 205)

> The genius of macroeconomics consists of felicitous oversimplification, which is traded off for concrete conclusions that are much harder if not impossible to obtain from less simplified models. (Baumol 2000, 11)

Paul Samuelson has written that he has learned how treacherous "economic laws" are (e.g., Colin Clark's law of a 25 percent ceiling on government expenditure and taxation) (1964, 336). However, we can ascertain particular patterns of economic behavior in quantifiable form for particular times and economies. We can ascertain tendencies and trends that provide a basis for action or prediction. Such prediction can never be as precisely accurate in its time dimensions or results as prediction in the physical sciences because a "trend" is not a law—it can change suddenly. Unlike those of physicists or astronomers, our predictions need to include the consider-

ation of possible changes in our parameters as well as our variables. Precise data are not indispensable for the analysis of policy making. Merely knowing the probable direction of change is often important. Data do not have to be precise to make possible a prediction as to whether things will go up or down, whereas it is impossible to predict exactly how far or at what speed the change will occur. It may be vital to know whether some variable is likely to increase or decrease and whether the probable consequences are large or small, while the precise magnitude of the change is impossible to ascertain and not necessary for the decision. While it would be ideal always to be able to apply a quantitative calculus to economic analysis, when economic reality makes this impossible a qualitative calculus is often useful and may even be sufficient.

Sets of independent rough data that reinforce each other provide more assurance than a single set of precise data that are suspect. The great mathematician Karl Friedrich Gauss observed that a lack of mathematical learning is revealed by unlimited precision in computation.[1] Going beyond the possible margins of precision in an analysis involves us in the manipulation of noise and self-deception.

Limitations of Scope

The discussion so far has focused on the limitations economics has in measuring the economy. With considerable hubris, there is a trend among some economists to believe that economics is competent to analyze practically the whole of human activity, both inside and outside the economy. The claim is that "economics has been imperialistic and . . . economic imperialism has been successful" and "The most aggressive economic imperialists aim to explain all social behavior by using the tools of economics" (Lazear 2000, 103).

Gary Becker has blithely argued that economic theory explains the whole of human society, that political, legal, and social institutions can be explained as the efficient outcome of rational individuals pursuing their preferences.[2] According to Becker, "the economic approach provides a framework applicable to all human behavior—to all types of decisions and to persons from all walks of life" (1981, ix). Economics has a theoretical system capable of explaining law, crime, politics, marriage, and even parent-child and sibling relationships within a family (Stigler 1988). Poor, uncomprehending Henry James, in contrast, admonished us to "Never believe that you know the last thing about any human heart."

The "imperialistic" economics assertion that all human behavior is

driven by an attempt to maximize utility in every circumstance is a good example of cultural myopia: it ignores custom, tradition, ethical restraints, and self-destructive emotional reactions and demonstrates a cramped view of human nature. Ronald Coase has a more cruel explanation: "The reason for this movement of economists into neighboring fields is certainly not that we have solved the problems of the economic system; it would perhaps be more plausible to argue that economists are looking for fields in which they can have some success (quoted in Posner 1993, 207).

Economic forces do affect human behavior in many contexts, and some economic concepts (opportunity cost, economic incentives, etc.) may help in explaining it, but there is far more to human behavior than economic theory can explain by itself (as we will explore in chapter 4). But the issue we wish to explore briefly here is the opposite of economic imperialism: the inadequacy of economic theory alone to fully comprehend and analyze the economy.

A central question that has concerned economists for centuries, certainly since Adam Smith, is what forces affect the wealth of nations. At present, a majority of the human population lives in the less developed countries, almost all in the tropics. Is this fact significant for the economic development of these countries? Economists have generally paid no attention to the effect of climate on the economy. This neglect may have been due to a reaction against Yale professor Ellsworth Huntington, who argued that human achievement was directly determined by the weather (his ideal climate bore a strong resemblance to that of New Haven). But as Charles P. Kindleberger has pointed out: "The arguments against Huntington are telling, but the fact remains that no tropical country in modern times has achieved a high state of economic development. This establishes some sort of presumptive case—for the end result, if not for the means" (1965, 78).

Kindleberger put his finger on the issue: it was right to reject Huntington's explanation but not the reality of the malevolent influence of the tropical climate. Accepting this reality as given, I took advantage of the wide-ranging knowledge and experience available to me in the World Bank to investigate why the tropical climate hampered countries in their economic development. The results were published in 1976 as a bank-sponsored book, *The Tropics and Economic Development.* Until recently, economists almost universally continued to ignore the obvious fact of the association of tropical climate and poverty. Professor Rati Ram, however, after making an empirical investigation of my "provocative" proposal that a county's geographical location in the tropics handicapped its ability to develop, concluded that: "the relationship of almost every measure of a country's well-being with its distance from the equator appears remarkably

strong. In many cases, the distance variable alone can explain nearly half of the cross-country variation in income and other measures of well-being" (1997, 1443).

In the last few years, nine other economists applying sophisticated econometric tools have independently discovered that, yes, a country's location in the tropics is strongly related to its poverty. Henri Theil and Dongling Chen developed a simple latitude model to explain per capita GDPs based on purchasing power parities. They concluded: "This comparison suggests that latitude may be viewed, statistically speaking, as the principal component of the rich/poor distinction among the countries of the free world (1995, 327). Theil and several collaborators carried this study further:

> The major conclusion to be drawn . . . is that affluence tends to decline when we move towards the Equator from the temperate zones in either the Northern or the Southern Hemisphere. Needless to say, this tendency is not without exceptions nor is it constant over time. Nevertheless, its existence as a tendency in the non-Communist world in the last several decades cannot be denied. (Theil et al. 1996, 28)

Robert E. Hall studied "Levels of Economic Activity across Countries" and found that: "Distance from the equator is the single strongest predictor of long-term economic success in our specification. Being located at the equator like Zaire or Uganda is associated with a reduction in output per worker by a factor of 4.5 relative to the Scandinavian countries" (1997, 176). Xavier X. Sala-I-Martin's "I Just Ran Two Million Regressions" determined that: "Absolute Latitude (far away from the equator) is good for growth" (1997, 181). Jeffrey D. Sachs and Andrew M. Warner found that: "Countries with tropical climates and landlocked countries have lower steady-state incomes and, therefore, lower growth from any initial level of GDP per capita" (1997, 187). Finally, Paul Collier and J. W. Gunning write: "Sub-Saharan Africa is predominantly tropical. There is some evidence that this has reduced African growth" (1999, 72).

By this time, with all these authoritative studies, it should be accepted that a country's location in the tropics does contribute to its poverty. This is an important finding, but standing alone what policy recommendation does it imply? One cannot advise a government that it should move its country into a temperate zone. Only if we understand what it is about the tropical climate that creates the obstacles to development can suitable policy actions be taken. We need to know which forces at work are responsible.

The causes of this phenomenon cannot be explained by using pure economic theory. Economics by itself is helpless in coping with this highly important fact, which affects the living standards of hundreds of millions of

people. It is necessary to supplement economics by drawing on other disciplines to bring out what it is about the tropics that causes the problem. Only then will it be possible to consider what can and should be done. The focus will be on Africa because that is the preeminent tropical continent in terms of area and problems.[3]

Geography and climate isolated sub-Saharan Africa from the rest of the world and Africans from one another until very recently, and they still impose high transport costs. Access is not easy. Where the desert does not come down to the sea, there is mostly swamp or lagoon. European ships visited the Nigerian coast for more than three centuries before they discovered that a major river, the Niger, emptied into the swamps and lagoons they encountered.

Of all the continents, Africa has the shortest coastline compared to area and very few natural harbors. As most rivers fall off the escarpment near the coast, it is seldom possible to penetrate the interior by sailing upriver. While the coastline of Africa was known centuries before that of North America, it was not until about a hundred years ago that the main outlines of the interior were mapped.

The tropical nature of much of the continent has also been a major obstacle. Yellow fever and malaria killed traders. Trypanosomiasis killed horses and cattle. This ruled out animal transport over most of tropical Africa. Commerce and travel had to depend on human porters, the slowest and most inefficient of all transport modes (Stanley in his search for Livingstone averaged only four miles a day). The only trade with most of tropical Africa over thousands of years was in products of great value and little bulk—gold and ivory—or slaves, a commodity that provided its own legs. The Indian Ocean slave trade lasted into the twentieth century. It still exists in the southern Sudan and Mauritania (see chapter 8). The difficulties of transport and prevalence of the slave trade account for the high degree of ethnic fragmentation that has made nation building so difficult.

The most important special characteristic of the tropics is that because of its continuous heat and the absence of frost life and reproduction go on throughout the year. The West Nile encephalitis virus threat in New York and New England in 2000 ended "with the first killing frost." In the tropics, no winter temperatures constrain continuous reproduction and growth of all kinds of life: weeds, insects, birds, parasitic fungi, spider mites, eelworms, microbes, viruses, pests, and parasites that prey on humans, their animals, and their crops.

Life across most of the tropics takes on an infinite multiplicity of forms. Fierce competition results, and only a few individuals of a species in each generation survive in any one place. The number of species in a given

area is a large multiple of that found in the temperate zone (e.g., of twenty-five major insect pests that afflict maize worldwide, twenty-one are found in Africa and only five in the United States). The conditions are ideal for rapid evolutionary adaptation to exploit new opportunities. Malaria, AIDs, Ebola, and West Nile encephalitis all originated in Africa.

Insects and the parasites carried by them are poikilothermic, their speed of development varying directly with temperature. The life cycle of bacteria, protozoa, and other pathogens is also ecothermic. In temperate zones, the aquatic stage of mosquitoes takes weeks, in the tropics days; and the extrinsic incubation period of yellow fever virus, for example, varies from three weeks to a few days according to the temperature. Bacillary dysentery is spread by house flies. At 16°C, it takes forty-four days for the fly to develop from egg to adult. The timing drops to ten days at 30°C. The result is an exponential increase in the tropics compared to the temperate zone (e.g., if only ten fertile females survive in each generation, in forty-four days the resulting difference will be on the order of ten thousand to ten).

Studies in the tropics find high percentages of people harboring parasites, usually averaging around 2 infections per person. Millions of people are afflicted with hookworm (ancylostomiasis, which infects a billion people worldwide), roundworm, whipworm, tapeworm, pinworm, Guinea worm, and various varieties of filariasis (250 million people infected). About 120 million people have the grotesque elephantiasis (or lymphatic filariasis), with the number of people at risk placed at around 1 billion. Bilharzia, or schistosomiasis, affects some 200 million people; and malaria affects 500 million worldwide, with around 1 million dying annually in Africa.

Some idea of the magnitude of the African health problem is illustrated by river blindness (onchocerciasis). This disease, which affects only (!) about 20 million Africans, turns productive adults into burdens on their communities and depopulates fertile river valleys. Blood-feeding black flies inject a nematode into human beings. (A related fly afflicts northern New England and Canada, but in these regions the fly cannot carry the worm.) During a fifteen-year lifetime in her human host, the female nematode produces millions of microfilariae. Some migrate to the eyes, causing blindness. The flies reproduce near rivers, hence the name river blindness.

In 1974, I helped inspire the World Bank to begin to initiate an international program to eradicate river blindness in Africa. Success may finally be achieved by 2010. Mectizan, a livestock drug, is effective against the disease. If 95 percent of the people in an infected area take Mectizan once a year over a twelve- to fourteen-year period, the disease can be eliminated. More than 10 million people in Africa are receiving the medicine.

The total cost of eradicating this relatively minor disease has been more than $500 million so far, even though the pharmaceutical company Merck is donating the drug. Little progress has been made to date on the more important and widespread parasitic diseases; in large part because the countries are poor and it is not profitable to find and produce drugs to help treat the victims.

Most African countries are highly dependent on agriculture. Ideal conditions, under which the right amount of water is available in the right place at the right time, occur naturally only rarely in the tropics. Rainfall, which determines the seasons, is usually too much or too little. It is erratic both year to year and within each season. The billions of dollars in damage that was caused by tropical storms in North Carolina in 1999 is a graphic example of what tropical rains can do. Trypanosomiasis, which is carried by the tsetse fly, bars half of tropical Africa to cattle and horses. There is less food protein, and human muscles must do the work of the farms alone.

In the semihumid tropics, the period before the rains break is the driest, windiest, and hottest time of the year, so loss of water through evaporation and transpiration is high. This makes preparation of the dry, hard ground for planting particularly arduous. Moist soil is easier to work, and in temperate climates cold weather precipitation charges the soil with a reserve of water. In Africa, when the tropical rains do come, so do the predators and parasites, so everything has to be done at once.

Because of the multiplicity of species and the rapid evolutionary potential, there is a high probability that any new plant or animal introduced into an area by humans will attract some new pest. Without a "closed season," all sorts of pests may thrive throughout the year. Weeds, parasitic fungi, insects, spider mites, eelworms, and bacterial and viral diseases drastically reduce crop yields. Locusts may arrive in swarms up to 80 by 40 kilometers in size and devour everything where they land. Locusts are restricted to the tropics, as they can fly only when their thoracic muscle temperature is at least 25°C. After the harvest, serious losses can result from storage pests and rats.

The soil has to be protected against the sun, which burns away the organic matter, and against the direct blows of the torrential rains, which crush the structure of the soil, seal off the underlying soil from the air, and either leach out the minerals or trace elements needed for plant growth or carry them so far down that plant roots cannot reach them. Generally, soils are poor in Africa because they contain little organic material. Even in dense forests, soils are usually thin, with little fertility. The interchange between decaying and living plants is precarious, and there are very few reserves.

In much of the humid tropics, the soil is laterite, which is agriculturally poor or virtually useless. In these areas, shifting tillage cultivates fields for a few years, then allows them to revert to bush jungle to restore their fertility over periods that may last as long as twenty-five years. Alluvial and recent volcanic soils are more fertile. Forest soils that are high enough to escape the heat of lower altitudes may also be fertile and rich in humus. Tree crops, by shading the soil and protecting it from the direct impact of rain, avoid many of these problems and make permanent farms possible. Livestock is subject to most temperate zone diseases as well as tropical parasitic, nutritional toxic, and organic afflictions.

Geophysical and geochemical techniques used in mineral searches were for the most part developed for the temperate zones. Humid tropic parameters require a different structure of inference. Different instruments may be needed since extremes of heat and humidity can ruin delicate equipment.

In the humid tropics and the former humid but now arid southern edges of the Sahara, mineral formations are overburdened with soil. Rain and high temperatures have led to the formation of laterite and other soil mantles that hide the underlying rock. Dolomite, limestone, gypsum, and salts of potassium and sodium are relatively soluble and hard to locate in areas with high rainfall. Most of the minerals found are surface concentrations resulting from weathering: bauxite, some iron ores, manganese, nickel, tin, and diamond placers.

The obstacles of the tropics are not insuperable. The tropics force a rapid pace of evolution, which creates vulnerability for Africans, their crops, and their animals. But this same velocity of change could be harnessed by research. The Southeast Asian country of Malaysia, for example, basing its agriculture on tree crops and with a long-term research effort, has coped successfully with its tropical problems. Its natural rubber has been able to compete successfully with synthetic rubber. With higher rural incomes and the payoff from its oil, it has been able to move successfully into the industrial age.

Research on cures or prevention of tropical diseases, on control of natural predators, and on the other problems of tropical agriculture is clearly the answer to the question of what can be done to help tropical countries overcome the poverty stemming from their locations. It is also clear that successful results, as in the case of coping with river blindness, can only be achieved with considerable time, effort, and investment.

This discussion of the tropics illustrates that understanding an economy may require supplementing economics with other disciplines. A similar case can be made for calling on organizational theory to help us under-

stand the corporate sector of the economy; on history and political science in the analysis of the public sector; and on other noneconomic disciplines for other aspects of an economy.[4] As David Cutler observed, "If you think only as an economist, you'll produce silly answers. And if you don't consider economics at all, you'll produce silly answers" (Powell 1998, 3).

I was surprised and pleased in the final stage of preparing this book to discover a lecture by Lionel Robbins at the London School of Economics on the same key as the theme of this chapter. He told the students that economists had it in their power to make a significant contribution to the discussion of the leading questions of the day.

> But if they are to do this, they must transcend themselves as economists. If we are to throw helpful light on the great problems of our time, still more if . . . we are from time to time to serve our term of public service, we must be prepared to go beyond our subject. . . . we must be prepared to study many other disciplines. We must study political philosophy. We must study public administration. We must study law. We must study history. . . . I would say, too, that we must also study the masterpieces of imaginative literature; . . . a man will learn more which is relevant to the study of society from the great dramatists and novelists than from a hundred textbooks on psychology—valuable as these may sometimes be. (1954, 17)