Closing Remarks: About Economic Growth—a Variation on a Theme by David Hilbert*

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I feel honored beyond words for having been invited to offer this celebratory symposium some closing remarks. My gratitude toward the organizers, James S. Worley and Anthony M. Tang, is all the greater for two reasons. First, since they both have been my students, I interpreted their invitation as proof that they nonetheless did not want to retaliate against a proverbial wringing examiner. Second, I felt that the invitation meant a rush in the enviable fraternity of the specialists in economic growth. Actually, taking the rush at its face value, I wondered whether there was any reason for my deserving it. After giving it some thought, I came to the conclusion that my main merit may have been that I know firsthand what economic wanting means: I was born and raised in a country that was not only underdeveloped to start with but, worse, devastated by 3 years of war going on in people's own backyards. However, I also remembered that I had after all tinkered occasionally in some analysis of noncapitalist economies, which bears on the essence of economic development. So I was further happy to have an occasion to plug these "secretions of my brain" (to use Pierre Cabanis's bizarre locution).

But my special elation over the invitation was that it offered me the opportunity of joining my other colleagues as well as the alumni of the Graduate Program in Economic Development (GPED), present or corresponding, in applauding not the program itself (which has no ears and no eyes) but those of our faculty who helped its steadily growing success; in succession, William H. Nicholls, Rendigs Fels, Reynold E. Carlson, Anthony M. Tang, and James S. Worley.

And by all means, I should not fail to tell on Jim Worley. He has been director of the program for the longest period, completing now a quarter century. During all that time the program met with many financial snags. (The Ford Foundation, e.g., once decided to divorce the program so as to run, in modern style, after another institution.)

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Jim steered the program with remarkable expertise and, not to forget, with a warm heart for all students in distress. It was only natural for GPED to be spelled "James Worley" by now.

The creation at Vanderbilt of the Graduate Program in its early form signified the recognition of its Economics Department, which under the superb leadership of George W. Stocking, counted at that time among the very top ones, sharing the twelfth rank with Northwestern. But the basic reason was the recent reorientation of a large number of economists, as well as Washingtondom, toward the problem of the economically underdeveloped nations. This reorientation was the consequence of the transformation, unique in history, caused by World War II, as the world, formerly a closed structure, became a totally open one.

We must not ignore, or forget if we already knew it, that the problem of economic development in the strict meaning of the term occupied only a marginal position in the vision of our forefathers. The classical economists from Adam Smith to John Stuart Mill applied their great talent only to argue that mankind will ultimately end in a steady-state system. As to the process by which that tendency would work, they rescued it to a simple shift of income from one socioeconomic class to another, albeit accompanied by a change in the general level. As to Karl Marx's view of economic development, it was even narrower: all future historical change will consist of a social square dance with the workers of the whole world stepping united in the front row, after which the economic problem will be solved for ever in an eternal economic paradise. For much time still to come only the German economic school hinted, mainly through the autarchic accents of Friedrich List, at the possibility of a local and limited qualitative change. The definite change of outlook of the economics profession, the preoccupation with economic growth of which I spoke earlier, took place just as World War II had transformed the world from a closed into an open system. Yet the mutation took a few decades to work itself out. During the 1930s a few well-inspired scholars set out to translate the verbal argument of the classical economists about the redistribution of income into a mathematical diction. The idea of a dynamic economics appeared for the first time during the early 1930s as an innovation due mainly to Charles F. Roos, Harold T. Davis, and the world-reputed mathematician Griffith C. Evans.[1] But I must unparsimoniously stress that all authors of dynamic economic models have taken the name "dynamic" in vain. From the earliest to the most recent, the dynamic models had nothing to do with the phenomenon of true change, the concept that has tormented all true philosophers from Aristotle on. Any so-called dynamic model is at most a kinematic configuration in which change consists only of locomotion, that is, only of change of place.[2] A spade, say, or a dollar, when transferred from one place to another still continues to be a spade or a dollar.

Other authors followed that very furrow with special accents responsible for their names serving to identify the new domain of inquiry. But the economist I have in mind in particular is Sir Roy Harrod, not only for his early insistence (1939) on the necessity of dynamic models in economics[3] but also especially for his illustrating how they could be related to economic growth (1948).[4] The latter idea, over which Evsey D. Domar "happened to stumble" about the same time,[5] gained such a great momentum with the profession that by 1965 Sir Harrod could enounce the first article of the new faith: "Economic growth is the grand objective. It is the aim of economic policy as a whole."[6] But this proclamation, which is thick with far-reaching implications, did not mark, as some may believe, the birth of the new field; it marked its maturity.

And, today, almost 50 years since its elemental charting, that field is a well-established scientific edifice thanks to the supporting contributions of many prominent economists. In being naturally proud of it, we should bear in mind that at any moment the power of any intellectual discipline is limited. Yet all our literary products reveal that we believe the economic science to solve satisfactorily any problem that may come about. The point brings to my mind a highly interesting case that bears on this very issue. I refer to no other discipline than mathematics.

During the nineteenth century an unusually great number of geniuses enriched mathematics with many revolutionary results earlier undreamed of. Because of that level of "perfection," it was generally believed that mathematics contained in itself all its future development, that is, that from then on any problem could be solved by only an able tautological concatenation. So, "by 1900 . . . the mathematicians were almost smug about this achievement".[7] This was the atmosphere in 1900 at the Paris Conference of Mathematics attended by the greatest living mathematicians, from Henri Poincaré to David Hilbert. It was David Hilbert who, so it seems, wanted to proscribe the myth of mathematics as a demiurgic science. To this purpose, in a lengthy paper he listed 23 problems that were still unsolved.[8] That piercing object lesson resounded later in an analogous endeavor concerning natural science. "*At least we can with some confidence, list the things we don't know,* [such as] What is matter? . . . Is this universe of chance or of law? . . . What is memory?" (italics mine).[9] It thus seems that an exercise of the same sort may be put to good purpose for the economics of growth. What would be appropriate in this case is to list those issues whose theoretical status is still either undecided or not properly circumscribed.

First of all, we should consider the widespread indiscriminate use of "growth" and "development" (which also appears in the foregoing paragraphs because of my obligation to preserve the terms from the literature at hand). The point is that in any careful scientific diction the

meanings of the two terms, though somewhat related, differ in essence. Irma Adelman (to refer to a reputed specialist in the field) addresses herself in one breath to "growth" and "development."[10] Yet before anything else she presses the point that "an adequate definition of economic development is not easy to construct" and then settles on the process that determines "the rate of growth of per capita income." This actually is the most popular interpretation of "economic growth," which is found in almost every piece on that theme, for instance, in Domar's 1946 essay as well as in some more recent ones, such as the embracing study by Edward F. Denison, where we read that "By 'economic growth' I shall refer to the increase in the national product, measured in constant dollars," which is "what usually is meant in discussions among economists and in popular discussion."[11]

It stands to reason that in an economic science grown out of a social environment dominated by money value the process of economic development should be reduced to one dimension, the pecuniary. The ground was thus ready for the terminological free shuffle between "growth" and "development." I may therefore digress now to attempt a clarification of that strangely overlooked distraction.

Although biology—the life science par excellence—would prove an excellent tutor, on this matter Joseph A. Schumpeter's vision of the economic process would be even more trenchant. In his main opus where, to my knowledge, the expression economic development occurred for the first time (1912), we find one of Schumpeter's seminal ideas cast as usual in a memorable witticism: "Add successively as many mail coaches as you please, you will never get a railway [engine] thereby."[12] Thus, "growth" is if you get just an increasing number of the same type of mail coaches. And if you pass from traveling in mail coaches to traveling by railway, that is "development." The process of simple growth does not raise many difficulties. If you have a template—say, the negative of a photograph—growth is then limited only by the availability of the necessary materials. But you must have the template. Biologists for ages had struggled with this requirement for cells to grow, and their delight knew no limits when they found out that the molecule of DNA contains its own template.[13]

However, the new microbiology theory based on DNA explained only how from a single cell, the fertilized ovum, an immense number of other cells can be obtained to form a complete organism. Too bad that the new theory not only does not help us to explain the development process, that is, how cells differentiate into muscles, nerves, kidneys, and so forth, but it also actually constitutes a stumbling block on our way.[14] This last process is analogous to the Schumpeterian passing from mail coaches to railway engines. Those who think that there can be no intellectual game in the discipline of economics and especially

those who, like most of us at the present time, read only the literature of the past few years may be taken aback to learn that Schumpeter is the author of the first idea (still untouched) of what supports development. According to him, economic development constantly occurs because of the constant flow of inventions that are the result of the normal activity of our minds and serve as basis for practical innovations. This is how we have passed from mail coaches to railway engines, to automobiles, and to rockets.

This praise of Schumpeter does not pay him full tribute. For this very idea of his resounded independently in biology some 30 years later. A prominent biologist, Richard Goldschmidt, argued to the total displeasure and scorn of neo-Darwinists that a new species does not come about by successive imperceptible modifications of an old one but by the simple emergence of a new individual so different that Goldschmidt likened it with a "successful monster."[15] And to think of it, by the same token, a railway engine is a successful monster in comparison to a mail coach.

One problem still remained. For biological speciation a well-documented criticism of the neo-Darwinist continual imperceptible change was first voiced by a very interesting economist, Fleeming Jenkin. Anticipating Goldschmidt, Jenkin objected to Darwin's idea that speciation is brought about by continual but imperceptible changes.[16] And it is known that his protest seriously disturbed Charles Darwin himself.[17]

Schumpeter, who certainly mastered a vast literature from many fields, very probably had no knowledge of that hardly noticed piece by Jenkin. Yet in Schumpeter's discussion of development we find the basis of Jenkin's criticism splendidly covered. Innovations consisting, say, of a mere rearrangement of a display window cannot certainly be the carriers of genuine economic development such as that from the horse cab to the superjet. So after completing the classification of the general types of innovation, Schumpeter pressed the point that innovation must not consist of a small, insignificant change. And to the dissatisfaction of all positivists of all walks of life, he argued that "small innovation" cannot possibly be defined analytically any more than "entrepreneur"—another famous Schumpeterian concept—can. Evolution, which is what economic development actually is, needs saltations, needs the emergence of successful "monsters."

This brief refresher brings to light several things. First, it is probably a sectarian propensity that has made us think of Alfred Marshall as the economist who visioned the economic process as a basically biological one. While insisting that biology is the Mecca of the economist, Marshall in his vision used only a couple of superficial biological parables. Schumpeter, by contrast, never mentioned any sisterhood between economics and biology; instead he worked out a perspective

applicable to both because both are life sciences. Second, Schumpeter supplied an indisputable example of the need of dialectics in science. Actually, dialectical concepts are the first in order of importance even in physics. A glowing example within the theory of economic development is the dialectical method devised and practiced by Simon Kuznets. I feel great pride for having exalted that method before it was crowned by a Nobel Prize.[18]

While keeping the preceding observations in mind, we may now turn our attention to dynamic growth models. Although their origin rests with Sir Harrod and Domar, some 50 years ago, the original pattern has hardly been modified. I may then begin with the more popular of the two, Domar's:

$$dP/dt = I\sigma, \quad dY/dt = (dI/dt)/\alpha, \tag{1}$$

where P = national product, Y = the national income, I = the capital investment, α = the marginal propensity to save, and σ = the potential social average investment productivity. This system is dynamic only because it involves derivatives with respect to time. In effect, it is a purely kinematic configuration as explained in note 2. From it, under various additional assumptions we may arrive at some specific results. With the corresponding algebra there can be no quarrel. But other aspects may be called in question in a manner similar to David Hilbert's discretion.

Let us recall that Albert Einstein is reported to have said that what you have done is valuable only if you can communicate it meaningfully to a barmaid. So, our barmaid might now say, "I do not see at all why my own pay and my boss's income are not shown in your National Income." The answer that Lord Keynes taught us—to reason with aggregates—would certainly not satisfy her. Neither would it satisfy me or Sir Harrod.[19] To be sure, I do not propose to expel aggregation from all our economic arguments. But its extensive inclusion to the limit, that is, to total national product, income, saving, etc., hides the most important elements of economic development, such as the shift from one type of cooking or traveling to another. The general habit of thinking only in aggregate terms would blind us to another vital issue, namely, how to help an economy in depression. Since no depression has ever plagued all sectors at the same time and with the same intensity, an indiscreet general monetary injection (as strongly advocated by some) would be tantamount to flooding your whole house if you just want to fill the bath tub and water your house plants. As an instructive counter example I may cite the case of the financial crisis of Chrysler Corporation a few years ago. Would it not have been utterly ridiculous to expand the total credit in order to save that enterprise?

Even growth, understood as simple accretion, let alone development, resists being fully represented by a dynamic system of the type generally used in economic theory. The first to teach us this lesson was Karl Marx, who used two diagrams of reproduction (his more felicitous term for growth): of simple and of expanded reproduction.[20] By expanded reproduction Marx intended to explain how growth comes about. But, we should mark the point well, he only showed how an already growing system keeps on growing. That is, the source of growth is growth itself. Marx thus failed to explain what is the prime cause of growth or the equivalent: how a growing system may grow faster. The reason is that on that problem as well on that of labor value he abandoned his dialectical stance to resort to analytical demonstrations, which was the source of some of his epistemological troubles.[21] To use a topical illustration for the point I want to bring home, let us think of a spaceship on its way to the moon. As we all know, it moves on a dynamic trajectory determined by some particular system of differential equations. (Actually, Marx's expansion diagram is a fully analogous case.) Yet the real meaning of differential equations seems to be surprisingly ignored by most users. For simplicity, let us consider the differential equation $y' = ay$. Like absolutely all differential equations this one, too, represents not one integral (a trajectory) but an infinite family of them (fig. 1). In the case at hand this family is represented by $y = Ce^{at}$. A different value of the arbitrary value C deter-

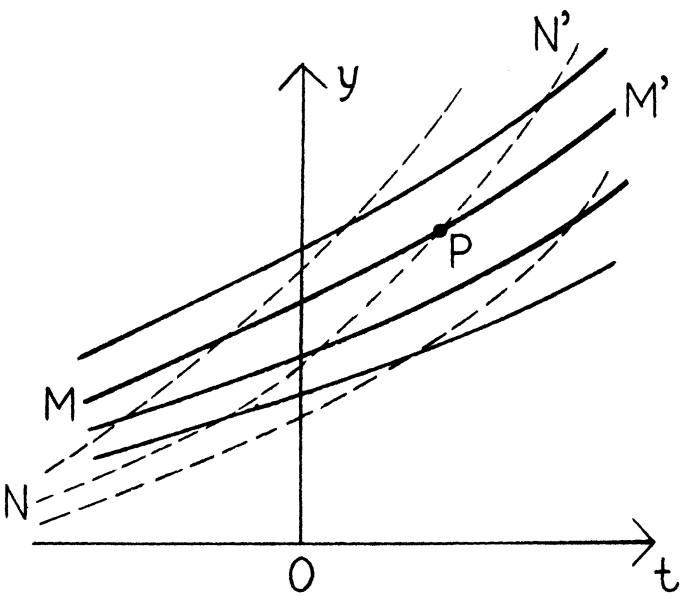

FIG. 1.—The meaning of a differential equation

mines each trajectory on which *one* system governed by that differential equation moves. Like a spacecraft, a chosen system, P, must move in continuation on its proper trajectory, say, $y = C_o e^{at}$ (MM' in fig. 1), with the speed $y' = C_o a e^{at}$, which is greater the greater C_o is. But in growth theories, growth means for a system to move to a situation of higher speed, a situation that may be represented by a similar differential equation, say, $y' = by$, with $b > a$. The meaning of this last equation is the family of trajectories represented by the interrupted lines in fig. 1. Of course, economically the system P would be in a superior economic condition if it could continue on a trajectory, such as NN', of the new family. Policy advisers caught this point without any ado and came forward with the simple counsel: just change the old determining parameters of the system so as to satisfy the new equation (with $b > a$); the system would then instantaneously start to grow at a higher speed.[22] That this idea cannot work beyond the margin of a writer's page should be plainly obvious. To change the trajectory of a spacecraft without any delay is a notoriously impossible operation. Think also of an economic system that we may call stationary, in which case the family of trajectories MM' would be parallel to the axis Ot. Could it, in fact, be instantaneously transferred on another accelerated trajectory?

The activities of economists, as I observed some 10 years ago, follow three distinct types.[23] First, there are the mathematico-imaginative ones which, for example, assume that capital remains the same forever without any maintenance flow or, more surprising, that the set of traders has a power even greater than that of the arithmetical continuum.[24] Protests against such endeavors have been issued even by physicists, 100 years ago by the pundit Lord Kelvin in the introduction to his *Treatise of Natural Philosophy* and, more recently, by a remarkable physicist, who noticed that even in physics many a clever mathematical model bears little relation to reality.[25] And there is hardly any great economist, whether Knut Wicksell or Alfred Marshall, who has not denounced the danger of the unjustified uses of mathematics. To rephrase Frank Knight: many members of our profession are first neither mathematicians nor economists.[26] It seems that pronouncedly mathematical lucubrations may help economists attain some clear-headedness ordinarily at the pain of stubborn nearsightedness. To wit, Thomas Hobbes, although he failed to master mathematics, was an eminent social scholar. The converse is true of the modern economists active only in the mathematical field.

Next, there is the category of mechanico-descriptive, which consists of the proper kind (as that envisioned by Ragnar Frisch) of econometric studies. The best example is the input-output system of Wassily Leontief, which made him so celebrated that on one visit the local newspapers carried the headline "Leontief in Madrid." As I ob-

served earlier, not even this extraordinary "secretion of the brain" could serve our inquiry about self-generating economic development.

Finally, there is the analytico-physiological approach, which endeavors to submit the economic process in its totality to a physiological analysis akin to that of biology, the domain characterized by a continuous novel role of its parts. Needless to recall now that the archetype of this category is provided by Schumpeter's rather than by Marx's analyses. Most historical studies (let us not forget those of Simon Kuznets) belong to the same category praiseworthy for its greater success than all others.[27]

To acquire an insightful perspective of the nature of the economic process, we must bear in mind that economics is "essentially a historical science," as Frederick Engels proclaimed or, as Joseph Schumpeter put it more epitomically, "Economic life is a unique process that goes on in historical time and a disturbed environment."[28]

History, as it seems to me, is a sequence of absolute surprises all explained ex post, however. It was a great surprise, therefore, when a simple analytical portrayal was proposed for history, first, I believe, by Robert M. Solow, closely followed by J. E. Meade.[29] The novelty as we find it explained by Solow is to include in the standard production function an additional variable, t, "to allow for [historical] technical change":

$$Q = F(K,L; t), \tag{2}$$

where "Q represents output and where K and L represent capital and labour inputs in 'physical' units." Both Solow and Meade, as well as the subsequent initiated, assume the partial differential of F to exist. It would be too good for this apparently pivotal device to be serviceable. Let us therefore try to tease out its folds.

According to the definition of equation (2) we can apply it to any economy and to any historical time, even the Mongol empire in the year 1239! But the familiar case of modern Switzerland would serve as a very strong acid test. As a first step, let t have two values, $t = 1862$ and $t = 1959$, for which (2) can be written:

$$Q_{1862} = F(K,L,1862),\ Q_{1959} = F(K,L,1959). \tag{3}$$

As we are instructed, the difference $Q_{1959} - Q_{1862}$ should represent the economic growth fostered by technological change within the invariant territory of the economy of Switzerland. A disturbing question now springs up. If there have been technological changes, capital as well as labor must have changed fundamentally, certainly from horse cabs to automobiles, for instance. It is therefore analytically ludicrous to denote by the same symbols, K and L as well as and especially F, qualita-

tively different economic structures. The correct representation of the actual structure Solow and Meade had in mind is

$$Q_{1862} = F_{1862}(K_{1862}, L_{1862}),\ Q_{1959} = F_{1959}(K_{1959}, L_{1959}). \qquad (4)$$

There is no time variable in this proper representation, the indices express the date and the qualitative differences. Clearly then even a sophomore would explode at the mathematical fallacy of associating partial differentials with the differences of two essentially different functions: $Q_{1959} - Q_{1862}$ ($= \Delta Q$?). In Sir Harrod's opinion what we have here are "nothing more than aspirations to have such equations" as (3).[30] Lord Keynes's verdict was pseudo-mathematics but even that was not a sufficient decrying.[31] On that peculiar mathematical basis, Robert Solow concluded not just that the United States' gross output per man doubled from 1909 to 1949—which was within the range of ordinary conjecture—but that precisely "87½ percent of the increase [was] attributable to technical change and the remaining 12½ percent to increased use of capital."[32]

An additional flaw of the Solow-Meade innovation is the complete omission of material resources on which growth, even more so than technical progress, is absolutely dependent. But around 1960 this omission fit the temper fostered by the seemingly inexhaustible supply of minerals, and of mineral fuels in particular. For Solow, however, the omission reflected his incredible dogma that "the world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe."[33] I do not know what anyone may say about it today after the historical disruption of the old distributional pattern of oil resources now dominated by the Middle East. But the fact that natural resources because of their uneven international distribution help or hinder economic conditions cannot be doubted any more. It was because of this growing recognition that many mathematical economists thought of including in the standard production function a sign, no more than a sign, for the factor ordinarily called energy:

$$Q = f(W, K, L, e), \qquad (5)$$

where W, K, and L stand for work, capital, and land, respectively and e stands for energy.[34] It is an easily alluring formula because it serves as support for those who, like Robert Solow and his partisans, argue that it does not matter if resources become scarcer: the same level of Q can be maintained forever by substituting some other factor instead.[35] Of course, a mathematical construct, if fallacious, would always breed fallacies. Formula (5) is fallacious because it allows for a flow factor to be substituted for some fund factor (like the classical example of gold metal and the melting oven). But in spite of the standard theory of

production, flow and fund factors do not belong to the same dimensional category.[36] Besides, without an increasing flow of resources, on which growth necessarily feeds, Solow could not perform the miracle of producing and maintaining additional capital equipment—or even additional workers![37]

Ever since the earliest writings in economics, it has been indisputable that if an economy increases its capital equipment it will be capable of a greater national product. But to increase capital is a formidable operation, as any wanting economy knows only too well. Yet there is a point that is surprisingly ignored by theorists as well as practicing specialists. Commodities are not produced by commodities but by processes, by factories. Now if you have a factory, you can produce commodities virtually without waiting, just as you can hear a tune immediately as you open the music box. Unfortunately, however, there is no factory to produce factories, that is, processes. The waiting imposed on us in this case, for the production of an additional factory, is unavoidable.[38] Time, a long time waiting, is the number one headache of any growth or development planner.

There is something that bears on what I have just said. In the course of its development a country may reach a situation in which the role of the imaginary factory that would manufacture factories is fulfilled by a complex of enterprises each specialized in one construction phase of an ordinary factory. This situation pinpoints W. W. Rostow's fruitful idea of "The Take-Off into Self-sustaining Growth."[39] And I am sure that most of those struggling with the development of some underdeveloped economy are groping (in Walras's sense) in that direction, however unwittingly.

In certain (but numerous) situations capital is limitative, which means that its increase is both necessary *and* sufficient for an increased product.[40] It is limitative in a particular case of overpopulation, namely, when the population is so great that the marginal productivity of a substantial number is zero while an employment smaller than that limit cannot produce a sufficient product per capita. In such an economy, part of the population may disappear without the national product suffering at all thereby. During the 1930s several careful studies revealed that in Bulgaria, Poland, and Romania about half of the population was superfluous in this sense. The situation shook my faith in the theoretical armamentarium I had acquired mainly in the United States. Since I thus held that marginal pricing was an absolutely necessary practice for the best allocation of resources and since, if it was applied, the employment would naturally be insufficient, I came to the horrible conclusion that a country with that kind of overpopulation was caught in a trap. My eyes were opened by the facts. For as the great but totally forgotten Richard Jones advised economists, I looked. And what I saw was that marginal pricing was not operating to any influential degree.

Any person who could do some useful job was employed, be it on the limit of marginal productivity, and received an income based on the principle of average pricing (rather, of average income). No one was unemployed while willing to work. At that time, I recalled the Louvre painting *Les glaneurs* by Millet. To the modern reader, I have to explain that in the precapitalist West European countries the gleaners picked up the ears of corn lost by the reapers. They received an income greater than what they gleaned. The national product was then as well as in my own time pushed to its highest potentiality. Marginal pricing would certainly have been the worst practice.[41] Yet we all, especially the mathematical theorists, cannot even think that marginal pricing, in effect the Walrasian system, is not our philosopher's stone, to be used by any would-be development planner. To be sure, two of the most acclaimed mathematical economists have demonstrated that the Walrasian system has a solution in which every participant is not worse and is usually better off than initially.[42] But they failed to make it clear that initially everyone was already endowed with a sufficient income forever. What poor, undeveloped country would be in that situation?

The institution of average pricing seems, however, to be the only way of relieving the pressure of population. Yet it would be a mistake to believe that it is a permanent solution. It is only a temporary resource. Without the least doubt, the cardinal problem for the welfare of mankind is that of population. As long as population keeps growing, any plan for economic development will fall apart as the keen and careful scholar, Joseph J. Spengler, warned long ago.[43] And in spite of the crusade led by Paul R. Ehrlich, we have preferred to share Karl Marx's belief that overpopulation is just a mirage of capitalism.[44] Isn't it hard to explain why precisely a Communist government, China's, adopted strict Malthusian measures?

Chasing away any memory of those economists (and perhaps sociologists as well) who found delight in expatiating on the idiocy of all traditional peasants, we may abide a while by the conclusion of my story from Romania, which is that not all economies are governed by the same socioeconomic customs. What was the original cause of those differences is so complex that it has generally been shunned. Yet not only the institutionalists, such as Thorstein Veblen and Gunnar Myrdal, but all illuminati of our discipline as well have insisted that the policy required to get growth going, say, for India may not be appropriate for Nigeria, or for Brazil.[45]

The point that the noneconomic factors (those we customarily call "institutional") are not only the elements at the bottom of these differences but also the primordial ingredients of any development process was marshaled out with great convincing power by Bert F. Hoselitz.[46] While I agree with him in that the introduction of developmental innovations does affect the extant institutional arrangements of various

orders, my advice to the would-be planner will be to find out first the kind of institutions that can, as they exist, serve the implementation and the reinforcement of the plan. This constitutes a staunch conviction of mine for which I can offer a truly elucidating example. Within their natural territory, the Japanese had no mineral resources to speak of, their agricultural land was also so scarce that they had to "farm" the seas for food. Yet their economic development started as a miracle and continued like that. But the true miracle was that Japan's economy "took-off" on the back of a silk moth. A few other nations had that moth and even better conditions but failed to take the same advantage of it.

At this juncture I must stop to forestall one possible misinterpretation of what I have said. I definitely do not advise a development planner to decide first upon some cultural patterns that might boost the plan and strive to make people behave accordingly. Such an operation has failed every time it has been tried out. As a glaring proof, consider Nikita Khrushchev who, 20 years after the Revolution, recognized that the Party had not been able to breed the Soviet man.[47] What about after 70 years? From what I believe, Mohammed would be reversed by modern technology: it would be easier to move the mountain to where Ali stands than to persuade Ali to walk to the mountain.

Considering the scope of my remarks it seems that the limits of the rational actions pursuing economic development are rather narrow, especially if we think of the little that would remain of the vast literature of purely mathematical exercises after we sift them. What remains is not much; however, it is truly essential. You remember my oblique remarks about aggregates. Kenneth Boulding exposed with his usual wit almost all criticisms ever addressed to national income.[48] No doubt, using the national income as the measure of general well-being we are informed that we must be better off by the increase in crime (which results in more prisons) and by a greater army. Accordingly, Japan must be poorer now than if she had a large army. But, paradoxically, her spectacular growth after World War II was due in part to that condition.[49]

There is, however, one recipe that development economists have used with appreciable success. It was presented in a volume from the late 1920s by Mihail Manoilescu, a former compatriot of mine. In an engineering manner, the engineer Manoilescu proved that labor is far more productive of value in industry than in agriculture. As one would now guess, Jacob Viner blew his top about that attack on the old classical faith every time he had occasion.[50] Yet today we generally stand by the principle of economic development by industrialization, even if we have forgotten the name of Manoilescu (as we ordinarily do for most old path breakers). To my knowledge, the most powerful verification of that recipe was achieved by the research program con-

ducted at the Vanderbilt Economics Department by William H. Nicholls and Anthony M. Tang. They were fortunate to have as their object the development of the Mid-South United States triggered by the industrial organizations attracted there by the Tennessee Valley Authority. Of course, the famous recipe worked quickly and efficiently there because massive investments were forthcoming from a sector of the same national economy.

So, you see that you will still have to use aggregates. But they must be used sparingly and with the same care as Simon Kuznets taught us. Exclusive regard for national income as the most reliable indicator, something of a Dow Jones of well-being, may blind the planner to an abominable situation. To use Brazil as an example, it grew during the 1970s by as much as 12% per capita per year. Given that a large proportion of her population—70%, a rational estimation—did not share at all in the increase in national income, it means that the income of the privileged increased annually by about 40% per capita! We have here an explanation of how, while we brag about the increase in national income, the mass of people "is still as poverty-stricken as ever—a passive gloomy onlooker at the increasing well-being of the exclusive circle that delights in the Square Dance of effective Demand, which alone moves faster and faster each day."[51] Although I know that many insuperable difficulties stand in the way of a general betterment of mankind's well-being, my fervent hope is that at least this square dance will be brought to acceptable proportions.[52]

Notes

* I wish to express here my gratitude to Frances Rich for her sustained effort in typing this manuscript and to Ranganath Murthy, my research assistant, for his help in preparing the final version.

1. A footnote is necessary to inform the reader that the achievements of these authors are passed over even in the *IESS* (*International Encyclopedia of the Social Sciences*), which abounds in omissions of the same kind.

2. A kinematic system represents only "pure motion, without reference to the masses or the forces involved in it" (*The Random House Dictionary* [New York: Random House, 1967]). The reason for the refusal of Sir Roy Harrod (*Towards a Dynamic Economics* [London: Macmillan, 1948]) to regard several prominent models, such as that of Frank H. Knight and Sir John Hicks, as dynamic has the same basis.

3. Roy F. Harrod, "An Essay in Dynamic Theory," *Economic Journal* 49 (March 1939): 14–33.

4. Harrod, *Towards a Dynamic Economics*.

5. Evsey D. Domar, *Essays in the Theory of Economic Growth* (New York: Oxford University Press, 1957), chap. 4.

6. Roy F. Harrod, *Reforming the World's Money* (New York: St. Martin's, 1965, p. 76.

7. Morris Kline, *Mathematical Thought from Ancient to Modern Times* (New York: Oxford University Press, 1972), p. 1025.

8. David Hilbert, "Sur les problèmes futurs des mathématiques," in

Compte Rendu du Deuxième Congrès International des Mathématiques, 1900 (Paris: Gauthier-Villars, 1902), pp. 58–114. Several of those problems have been solved by now as was the familiar one about the four colors.

9. William H. Whyte, *The Organization Man* (New York: Simon & Schuster, 1956), p. 229. We should also retain that there exists even an *Encyclopaedia of Ignorance,* ed. Ronald Duncan and Miranda Weston-Smith (Oxford: Pergamon Press, 1977).

10. Irma Adelman, *Theories of Economic Growth and Development* (Stanford, Calif.: Stanford University Press, 1961).

11. Domar, chap. 3; Edward F. Denison, *The Sources of Economic Growth in the United States and the Alternatives before Us* (New York: Committee for Economic Development, 1962), p. 3.

12. Joseph A. Schumpeter, *The Theory of Economic Development* (1912; reprint, Cambridge, Mass.: Harvard University Press, 1934), p. 64.

13. James D. Watson, *The Double Helix* (New York: Atheneum, 1968).

14. Nicholas Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge, Mass.: Harvard University Press, 1971).

15. Richard Goldschmidt, *The Material Basis of Evolution* (1940; reprint, New Haven, Conn.: Yale University Press, 1982). The idea has recently made a vigorous comeback, with several contemporary biologists endorsing it (see Stephen J. Gould, "The Return of the Hopeful Monster," *Natural History* 86 [June/July 1977]).

16. Fleeming Jenkin, "Darwin and the Origin of Species," *Papers Literary Scientific, etc., by the Late Fleeming Jenkin,* ed. Robert Louis Stevenson (London: Longmans & Green, 1887).

17. Francis Darwin, ed., *The Autobiography of Charles Darwin* (New York: Dover, 1958).

18. Nicholas Georgescu-Roegen, *Analytical Economics: Issues and Problems* (Cambridge, Mass.: Harvard University Press, 1966).

19. Harrod, *Towards a Dynamic Economics* (n. 2 above).

20. Karl Marx, *Capital,* vol. 2 (Moscow: Foreign Language Publishing House, 1957).

21. Georgescu-Roegen, *The Entropy Law and the Economic Process.*

22. Wassily W. Leontief made use of the above idea in his dynamic input-output model: *Studies in the Structure of the American Economy* (New York: Oxford University Press, 1953). Compare Nicholas Georgescu-Roegen, "Dynamic Models and Economic Growth," in his *Energy and Economic Myths* (New York: Pergamon, 1976).

23. Nicholas Georgescu-Roegen, "Dynamic Models and Economic Growth."

24. Nicholas Georgescu-Roegen, "Methods in Economic Science," *Journal of Economic Issues* 13 (June 1979): 317–27, where I pointed out that, as Georg Cantor had shown, even an infinite three-dimensional space cannot comprise more than a denumerable set of objects (such as a trader).

25. Joseph Silk, *The Big Bang* (San Francisco: Freeman, 1980).

26. Georgescu-Roegen, *Analytical Economics.*

27. Ibid. Two reviewers have taken me to task for the above conviction.

28. Frederick Engels, *Herr Eugen Duhring's Revolution in Science* (New York: International Publishers, 1976, p. 408); Joseph A. Schumpeter, "The Historical Approach to the Analysis of Business Cycles" (paper delivered at Universities National Bureau Conference on Business Cycles Research, November 25–29, 1949).

29. Robert M. Solow, "Technical Change and the Aggregate Production

Function," *Review of Economics and Statistics* 39 (August 1957): 312–20; J. E. Meade, *A Neo-Classical Theory of Economic Growth,* 3d ed. (London: George Allen & Unwin, 1962).

30. Roy F. Harrod, "Scope and Method of Economics," *Economic Journal* 48 (September 1938): 383–412.

31. John Maynard Keynes, *The General Theory of Employment, Interest and Money* (New York: Harcourt Brace Jovanovich, 1964).

32. Solow, "Technical Change," p. 320.

33. Robert M. Solow, "The Economics of Resources or the Resources of Economics" (Richard T. Ely Lecture), *American Economic Review* 64 (May 1974): 1–14, esp. 11. The above opinion, highly curiously, was expressed only shortly after he learned about the important role of the entropy law in mankind's life.

34. The authors who carried further this innovation are too numerous to be listed here. But, most interestingly, two very recent authors, David F. Heathfield and Sören Wibe, *An Introduction to Cost and Production Functions* (Atlantic Highlands, N.J.: Humanities Press International, 1987), adopt (eq. 5) as the basic form and, furthermore, speak of it as Leif Johansen's model.

35. Robert M. Solow, "Is the End of the World at Hand," *Challenge* 16 (March/April 1973): 39–50.

36. For the above issue, see Nicholas Georgescu-Roegen, "The Economics of Production" (Richard T. Ely Lecture), *American Economic Review* 60 (May 1970): 1–9; reprinted in Georgescu-Roegen, *Energy and Economic Myths.*

37. Nicholas Georgescu-Roegen, "Comments on the Papers by Daly and Stiglitz," in *Scarcity and Growth Reconsidered,* ed. V. Kerry Smith (Baltimore: Johns Hopkins University Press, 1979).

38. Georgescu-Roegen, *The Entropy Law and the Economic Process* (n. 14 above), Chap. 9.

39. W. W. Rostow, "The Take-Off into Self-sustaining Growth," *Economic Journal* 66 (March 1956): 25–48.

40. Nicholas Georgescu-Roegen, "Economic Theory and Agrarian Economics," Oxford Economic Papers, n.s. 12 (February 1960), reprinted in Georgescu-Roegen, *Energy and Economic Myths.* Limitative should not be confused with Ragnar Frisch's "limitational" which is a necessary but not sufficient condition.

41. Ibid.

42. Kenneth J. Arrow and Gerard Debreu, "Existence of Equilibrium for a Competitive Economy," *Econometrica* 22 (July 1954): 265–90.

43. Joseph J. Spengler, "The Population Obstacle to Economic Betterment," *American Economic Review* 41 (May 1951): 343–54.

44. Compare Paul R. Ehrlich and Ann H. Ehrlich, *Population, Resources, Environment* (San Francisco: Freeman, 1972).

45. Harrod, *Reforming the World's Money* (n. 6 above).

46. Bert F. Hoselitz, "Economic Growth and Development: Noneconomic Factors in Economic Development," *American Economic Review* 47 (May 1957): 28–41.

47. Quoted in Georgescu-Roegen, *The Entropy Law and the Economic Process.*

48. Kenneth E. Boulding, "Fun and Games with the Gross National Product: The Role of Misleading Indicators in Social Policy," in *The Environmental Crisis,* ed. Harold W. Heilfrich, Jr. (New Haven, Conn.: Yale University Press, 1970).

49. It is instructive for our general weltanschauung to be reminded that the absence of any regular army helped the early economic growth of the United States, too.

50. Nicholas Georgescu-Roegen, "Manoilescu, Mihail," in *The New Palgrave Dictionary* (New York: Stockton Press, 1988).

51. Georgescu-Roegen, *Analytical Economics* (n. 18 above), with the proper apology for quoting myself.