1

Thinking about growth

Economic growth is one of the oldest subjects in economics and one of the youngest. It was a principal concern of the *Wealth of Nations*, and it filled the thoughts of economists for the next three quarters of a century. As the Victorian Age wore on, however, growth lost its hold on the attention and imagination of the great body of academic economists. It was left to Marx and his followers, whose premature obsession with the demise of capitalism appealed to neither the political tastes nor the scientific bent of the discipline's exponents. And then, after the Second World War, following a hundred years of comparative neglect, there was a resurgence of interest and study that has been proceeding with vigor for the last four decades.

In the new effort, much that had been known a century and more ago had to be relearned. The new effort has had the benefit, however, of far better and more extensive historical and statistical materials and a more sophisticated theoretical framework. The accomplishments of the new research, however, have been modest, which is testimony both to the complexity of the subject and to the limitations of economics and of the other social sciences as well. Yet the study of growth is going on energetically. It is interesting, therefore, to ask what the newer work has added to the older and where the subject now stands.

This sketch of the erratic involvement of economists with economic growth, although it stretches over many pages, is still no more than a sketch. It is spare and unshaded, as a sketch must be. It deals mainly with the causes of economic growth, not its consequences. It looks at

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past work largely in terms of what it has contributed to our present understanding. It deals with growth only as this presents itself in advanced capitalist countries. It concentrates on the increase of productivity, the principal component of per capita output growth; and it sets aside the companion subject of population growth. It is concerned mainly with the overall productivity growth of nations; it neglects the structural change that growth requires, except as a country's capacity to accomplish such change limits its rate of aggregate growth. In all these ways, this sketch of the terrain is incomplete; even so, it serves a purpose, particularly if more complete and detailed maps are not at hand.

I. Growth and the older economists

Adam Smith was the father, not only of modern economics, but more particularly of the political economy of growth. The *Wealth of Nations* in its very title announces Smith's concern with the forces that govern the relative levels of prosperity among countries and that cause some to forge ahead and others to fall behind. His very first chapters are devoted to the advantages of the division of labor and its dependence on the scale of activity and the extent of the market. Smith saw that large-scale activity permitted a specialization and simplification of trades and tasks that raised the skills of workers, saved their time, and enabled clever artisans to devise labor-saving tools and devices; it enlarged the outlet for capital to embody the improved methods, and afforded businessmen a profitable and productive way to employ their savings. In Smith's view, therefore, the advance in productivity was an interactive process that ran from scale of market to the division of labor, thence to the enhancement of skills, the invention of new tools, and the accumulation of capital, finally feeding back to market scale. Smith saw the political institutions under which people lived as the main determinant to their ability to exploit the scale advantages made possible by trade and, therefore, to their ability to make full use of their talents and natural resources.

With few exceptions, Smith thought, the "policy of Europe" should be one of laissez-faire. But the *Wealth of Nations* also displays Smith's lively sense of the tendency of people to multiply their numbers and to press on the physical limits of a stationary supply of land. He thought a nation best off and most progressive when there was still a gap between its population and the maximum number its land could support. Growth tended to be rapid, therefore, when an increasing population and a growing aggregate income were expanding markets and opening the way to a still more intense division of labor.

Smith's theories were developed and refined in the decades after the appearance of his great book. Malthus's famous essay on population, taken together with Ricardo's treatment of diminishing returns in the use of land, sharpened the sense of conflict between population and resources. At the same time, there was a growing appreciation of the possibilities of progress based on the advance of knowledge. John Stuart Mill's *Principles of Political Economy* (1848) gave the economics of growth its definitive statement at the hands of the classical economists.

The organizing theme of Mill's treatise has a distinctly modern ring:

> We may say, then, . . . that the requisites of production are Labour, Capital, and Land. The increase of production, therefore, depends on the properties of these elements. It is a result of the increase either of the elements themselves, or of their productiveness. The law of the increase of production must be a consequence of the laws of these elements; the limits to the increase of production must be the limits, whatever they are, set by these laws. (*Principles*, Ashley edition, p. 156)

What are these laws? On labor, Mill is a Malthusian. Free of restraint, population multiplies rapidly so long as output per head exceeds some minimum standard. "The use [people] commonly choose to make of any advantageous change in their circumstances, is to take it out in the form which, by augmenting the population, deprives the succeeding generation of the benefit" (p. 161). But Mill is a reluctant and somewhat qualified Malthusian. Conceivably people can come to raise their minimum standard. "Every advance they make in education, civilization and social improvement, tends to raise this standard and there is no doubt that it is gradually, though slowly, rising in the advanced countries of Western Europe" (p. 161).

Mill noted that population growth rates in these progressive countries had been declining; yet he did not fully trust such hopeful signs. He feared the force of people's power of natural increase.

Capital too tends to increase under the impulse of its earning power. As with the earnings of labor, however, the profit rate must exceed a minimum standard. This threshold level is low where wealth is abundant and people's "effective desire for accumulation" is strong. It is high where business is risky and property insecure.

If labor were the only element in production, output would increase proportionately with population. But capital, since it is also an element in production, imposes a limit, unless it grows at the same rate as labor; but capital cannot long increase faster without swiftly driving the profit rate downward. And since land, which is by definition in fixed supply, is a third element, the increase of both capital and labor must decline and eventually come to a halt, even if they themselves increase in step with one another. They meet diminishing returns as they are employed together with a fixed amount of land; the return to capital is then driven down as rents increase at the expense of profit. The consequent decline in the rate of capital accumulation, together with the rise in the price of food, reduces the real income of workers. The rate of population growth is also reduced. There is, therefore, an inherent tendency for growth to cease:

> It must always have been seen, more or less distinctly by political economists, that the increase of wealth is not boundless: that at the end of what they term the progressive state lies the stationary state, that all progress in wealth is but a postponement of this, and that each step in advance is an approach to it. (p. 746)

Unlike his great predecessors, however, Mill did not believe that the "progress of society must 'end in shallows and in miseries' " (p. 747). Malthus himself had recognized that the increase of population could be brought to a halt before incomes fell to the bare minimum required to support life. It might remain much higher if people came to insist on a higher standard of living. Mill argued that restraints on births were necessary even in progressive countries to prevent population from outstripping the increase of capital. The same restraints, however, might maintain a comfortable condition even in a stationary state, which then would hold out very favorable prospects for the intellectual and moral development of people (Book IV, Ch. VI).

Whether the stationary state that looms before nations is one of comfort or misery, however, loom it does: ". . . we are always on the verge of it, and . . . if we have not reached it long ago, it is because the goal itself flies before us" (p. 746).

The force that, in the last analysis, keeps the stationary state at bay is "improvement in the productive arts" – technological progress, we would say. Mill's discussion reduces the emphasis that Smith had placed on an extension of the market and division of labor. Mill viewed the economies of scale as affording only transitory relief until population becomes dense enough "to allow the principal benefits of combination of labor" (pp. 191–92). Thereafter, progress becomes a race:

> Whether, at the present or any other time, the produce of industry proportionally to the labour employed, is increasing or diminishing . . . depends upon whether population is advancing faster than improvement, or improvement than population. (p. 191)

Mill's shift of emphasis reflects the seventy-five years that had passed between Smith, who wrote only on the eve of the Industrial Revolution, and the mid-nineteenth century, when powered machinery, the railroad, the steamship, and the electromagnetic telegraph had begun to create a sense of the further possibilities of technological progress.

> Of the features which characterize this progressive economical movement of civilized nations, that which first excites attention, through its intimate connexion with the phenomena of Production, is the perpetual, and so far as human foresight can extend, the unlimited, growth of man's power over nature. (p. 696)

Mill's view of the matter is ample and spacious, and it has taken later economists some time to regain his sweeping view, if, indeed, they have.

> Improvement must be understood . . . in a wide sense, including not only new industrial inventions, or an extended use of those already known, but improvements in institutions, education, opinions and human affairs generally, provided they tend, as almost all improvements do, to give new motives or new facilities to production. (p. 192)

Mill, like his predecessors, laid great stress on the institutional arrangements and public policies of national economies. He was particularly concerned with four matters: the security of property as a condition of saving and investment; the capacity of people for effective cooperation as a basis for the conduct of industry on a large scale; the proper principles of taxation – to make taxes as little arbitrary, burdensome, and distortional as possible – and finally, the proper extent and limits of the principle of laissez-faire.

As to the last, Mill felt torn. He maintained the common conviction of political economists from Hume and Smith forward that individuals should enjoy the greatest possible scope to engage in trade and to contract freely with one another. Yet he insisted that this principle was itself limited in extent and admitted of exceptions. He treated the subject at length; but in an essay on growth, four instances of desirable public activity or intervention stand out:

> The protection of those kinds of goods that belong to people in common but are used by all individually – the environment.
> The provision of goods or the support of services whose social utility exceeds their private – education and scientific research (besides lighthouses and buoys).
> The regulation of activities that can only be done by "delegated agency" – for example, by joint stock companies – and the regulation or public provision of services that are natural and practical monopolies – gas and water companies, railroads, canals.
> More generally, the provision of such facilities, important to the public interest, that private individuals might provide, but will not because, "in the particular circumstances of a given age or

> nation," the public is either "too poor to command the necessary resources, or too little advanced in intelligence to appreciate the ends, or not sufficiently practiced in joint action to be capable of the means" (p. 978).

No one can read, or reread, Mill without feeling how far he and the other classical economists had anticipated contemporary work, how much we may learn from them, and also how much we had forgotten during the century-long hiatus when growth studies were neglected.

II. Growth and economics during the hiatus

One of the strong impressions one takes from Mill is his ambivalence about the balance of growth forces. He sensed that population growth was beginning to be limited, but he feared the strength of the human capacity and drive to multiply. He perceived the possibilities of human kind's growing mastery over nature and of the cumulative advance of the industrial arts, but he was unsure of their pace and continuity. The result was his vision of a race between population and improvement whose winner was uncertain.

This ambivalent attitude gradually disappeared as the last century wore on. In Britain, in the United States, and in a gradually widening sphere in Europe incomes rose from decade to decade. Power and machinery applied to industry increased productivity in agriculture as well as manufacturing. Applied to transportation, it opened new lands and brought food and raw materials cheaply to more populous countries. The population response became weaker while technological advance continued at a rapid pace. Even the dismal science learned to smile; it absorbed the century's wider faith in unbounded Progress.

Yet the place of growth in the studies and writings of economists did not expand. Quite the contrary! Perhaps because economic growth had become absorbed into a more general vision of human progress, it was no longer seen as a problem. Or perhaps it was displaced by other pressing concerns. Higher incomes, more widespread education, and the extension of suffrage – all concomitants of economic growth itself – made working people a stronger political force. Correspondingly, the claims of labor and, more generally, the question of income distribution became more urgent issues. Or perhaps economists were seduced by the logical coherence of the neoclassical theory of relative prices and resource allocation, which came to seem such a solid construction on its static foundations. The theory treated a nation's institutions, its population, and its technology, the

central elements of the growth process, as autonomous data. They were viewed as the constraints and conditions to which prices and resource allocation adjusted. But the causes of their changes were not subjects for economists to investigate, and their implications were mainly neglected. Neoclassical theory, therefore, imposed boundaries on economics, at least on the science that economists had the ambition to build. It left growth outside its borders. Even the subject of scale, the division of labor and increasing returns – Adam Smith's basic insight – came to be viewed as just a problem for the theory of the equilibrium of relative prices. And Allyn Young had to write a famous essay (1928) to remind economists that it was something more, part of an interactive and cumulative process involving capital accumulation, productivity growth, rising incomes, and the extension of markets, an element in economic growth as well as a problem for static theory. Finally, whatever impulse there was to break out of the borders of static theory was absorbed by the troubles that engulfed the industrial world after 1914. Two great wars, the postwar hyperinflations, and the Great Depression provided a quarter-century of distractions for those economists who were minded to study something other than the conditions of general equilibrium.

To all this Joseph Schumpeter was an honorable and notable exception. His early classic, *The Theory of Economic Development* (1911), argued that in the absence of population growth and technological advance neither a positive interest rate nor net profit would persist. Profit is, indeed, the reward for the successful introduction of new methods and products. If economic activity followed an unceasing repetitive round, there would be no function for entrepreneurs and no occasion for profit. And interest would disappear as continued accumulation embodying an unchanging technology drove the marginal product of capital to zero.[1]

Schumpeter's arguments were intended first of all to enlarge the foundations of the neoclassical theory of factor prices. As a positive contribution to the economics of growth, they repeated and reinforced the older views about the tendency of gross profit (interest plus net profit) to a minimum and the dependence of net capital accumulation and the return to capital on the rate of improvement.

Schumpeter went further. He distinguished between "invention," or the advance of knowledge useful in production, and "innovation," which was the exploitation of such knowledge, the actual introduction of new products or new methods in commercial operations. The older economists had treated both as autonomous developments, but Schumpeter argued that innovation was an economic activity, the peculiar function of entrepreneurs. His view implied that market competition included rivalry in the introduction of new products and processes. Relative prices, therefore, were in flux, constantly disturbed by the same market competition that in the received theory was thought to establish their equilibrium.

Schumpeter taught that innovation was the central element in the economics of growth. As such, he stressed the requirements for successful innovation: open markets to permit the appearance of "new men" and "new firms," access to credit, and sufficiently stable macroeconomic conditions so that businessmen could gauge their markets and their prices and costs without an undue sense of risk. Schumpeter saw business cycles, particularly the longer waves of accelerated growth and retardation and the financial distortions they brought in their train, as part of the innovatory process. He was among the first to suggest that the uncertainties accompanying inflation and other financial disturbances could pose a lasting obstacle to innovation and productivity growth – a lesson for the contemporary scene and season. Schumpeter was widely admired for his brilliance and long neglected for his originality. His innovative theories were not easily accommodated within the dominant neoclassical model.

When interest in economic growth finally revived after World War II, economists studied Schumpeter again. They were attracted especially by the theses of his later work, *Capitalism, Socialism, and Democracy* (1942). Here he enlarged on his earlier ideas about the role of profits. He now argued that innovation rested not only on the lure of high but competitive profits; often it also conferred monopoly power and its concomitant monopoly profits. All these he viewed as necessary, therefore useful, inducements and rewards – an acceptable price for the benefits of innovation and growth. Moreover, these prizes were transient, being diluted and eventually eliminated by the imitative inroads and further innovations of rival entrepreneurs. Some degree of monopoly power, therefore, was a regular feature of a progressive economy – constantly limited, but also constantly renewed by the innovative activity of entrepreneurs.

Schumpeter now also abandoned the sharp distinction that his early writings had drawn between invention, the product of activities outside the economic system, and innovation, which was regarded as business investment of a bold and risky sort. Recognizing that large and long-lived corporations had displaced the individual entrepreneur, he suggested that both the search for new technology and its commercial exploitation had become "routine" aspects of business activity. Economists' present models of technological progress incorporate versions of the same ideas; but that revival of Schumpeterian economics remained for the future. While their attention was directed

elsewhere, economists' views about economic growth remained unformed. Guided by neoclassical theory, they treated technological advance as independent of economic incentives and saw only capital accumulation as a source of productivity growth responsive to economic causes.

III. The postwar revival of interest in growth and the response of economics

That was how matters stood as World War II came to an end. Interest, however, quickly shifted. Growth became a primary goal of national policy and consequently an absorbing subject of study by economists. There were considerations of national security and rivalry, of the conquest of poverty, and of advances toward prosperity, and there were pressures for growth to achieve other urgent social objectives.

People, including politicians, realized that the outcome of the war had been determined by GNP. More than ever before, nations viewed their security and power as resting on an economic base. To ensure their independence and safety, they concluded they must grow; if ahead, stay ahead; if behind, catch up.

Europeans became aware that they had lost ground to the United States in levels of living not only during the war but since 1913 and even earlier. They correctly felt that their levels of scientific and general education, their experience with modern commerce, industry, and finance, and their political institutions should be able to support a much higher relative status.

Similarly, the newly independent countries, the former colonies, saw economic growth not only as the means of rising from poverty but as a necessary condition for consolidating their new political regimes.

On another level, the rivalry between the USSR and the United States made each country anxious to prove that its system was capable of producing ever higher material conditions and was therefore worthy of emulation, friendship, or even alliance.

Internal political forces also pressed for growth. The enlargement of the democratic suffrage in the industrialized countries, a stronger egalitarian sentiment, and people's heightened appreciation of the risks and costs of advanced capitalist life drove countries to develop systems of protection and benefit – the welfare state. It was quickly appreciated that it would be easier to pay for these systems from rising incomes than from redistributive taxes. The political tensions and social conflict inherent in redistribution would be mitigated by growth.

Economists responded to the challenges of new public problems and political interest by opening threee large branches of research. One was the study of secular development in those countries that were already far advanced on the path of industrialization and were capable of operating at or near the frontiers of modern technology. Another was the study of development in poor countries still emerging from a preindustrial condition, the countries in which the basic institutions and capabilities for exploiting contemporary technology remained to be established. A third concerned the communist countries, where a new set of institutions based on the state ownership of resources and a system of central planning and control had been established. This essay deals with the first of these, growth in the presently industrialized countries whose economies depend mainly on private enterprise and market guidance.

The growth studies fell into two divisions. The first was principally historical and descriptive. Its aim and, indeed, its solid accomplishment was to establish the observable characteristics of growth on the basis of a wide survey of experience over long periods and across a considerable number of countries. Simon Kuznets's work is the great exemplar of such studies, although in some respects Colin Clark was his precursor.

Kuznets's great achievement was the foundation of the modern national product and national income accounts. He worked out their conceptual bases, made the early estimates for the United States, and extended the U.S. national product series back to 1870. He encouraged the compilation of long-term statistical data to supplement the national product figures and assembled many of them himself – population and other vital statistics, labor force, wealth, and many others. He stimulated and supported similar efforts in other countries. The empirical generalizations that he and his collaborators and followers established comprise many of the broad facts towards an explanation of which much analytical work is directed. A list of such generalizations, incomplete but illustrative, includes the following:

The rise of aggregate and per capita growth rates associated with the onset of "modern economic growth."

The demographic transitions from rising to declining rates of population growth in the course of industrialization.

The gradual spread of modern growth from Britain to the United States, Europe, the countries of European settlement, and Japan.

The secular acceleration of productivity growth; in particular the pronounced acceleration following World War II and the retardation of the last 15 years.

The qualified tendency to convergence in the productivity growth rates and levels of industrialized countries.

The many structural changes associated with growth, notably the shifts in output and employment from agriculture to manufacturing and then to the services and government and from rural to urban location.

The rise of government as an economic agent in production, investment, and income distribution and as a regulator of private activity.

The tendency towards retardation in the output and productivity growth of particular commodities and industries, combined with constant or even rising growth rates of the per capita output and productivity of all industries combined; the associated shift in the importance of industries from older to younger.

These and other empirical generalizations are the necessary framework within which efforts to understand historical changes and national differences in growth rates must proceed. Since theories of economic growth must have implications consistent with these observations, they are the indispensable background for analytical work. This analytical work is the second division of the subject, and it is the concern of the rest of this paper.

IV. The proximate sources of growth

The descriptive efforts of Colin Clark, Simon Kuznets, and the other pioneers in the measurement of national income and product and of associated data on labor force and capital stock were not aimless excursions into the statistical cosmos. They were guided by the conception of a production function, which is to say by the idea that output is a function of the inputs of labor, accumulated capital, and land and of the productivity of these factor inputs. This idea had been part of the outlook of the classical economists, and, as we have seen, it was the organizing theme of Mill's *Principles*. The same fundamental notion was taken over by the neoclassical economists and became a central feature of their static models of price and income distribution. It was therefore as natural for economists, when they returned to the study of growth, as it had been for Mill himself to think that the "increase of production . . . is a result of the increase of the [inputs] themselves, or of their productiveness." But how much was due to the increase of each of the inputs and how much to that of their productiveness? That was an obvious first question. "Growth accounting" was the attempt to answer it.

The discovery of the Residual

Calculations that decomposed the growth of output into the contributions of labor input and labor productivity had been made for many years.[2] They left open the question, how much of the rise of labor productivity was attributable to the increase of capital per worker. A series of studies published over just a few years returned a surprising answer and revealed a great gap in economists' understanding. The studies that first caught the attention and roused the interest of economists were by the present writer (1956), John Kendrick (1956, 1961) and Robert Solow (1957).[3]

The calculations proceeded from the assumption that the wages of labor and the returns to capital also represented the additional product from increments of these factor inputs. This assumption permitted the deduction that the growth rate of output could be decomposed into a portion contributed by "total factor input," which was the joint contribution of labor and capital (including land), and a portion contributed by "total factor productivity." The first was the sum of the growth rates of the factor inputs, each weighted by the share of its earnings in national income. The second was the difference between the growth rate of output and that of total factor input. Since it had long been known, however, that the growth of output per capita was due almost entirely to that of labor productivity, not to that of labor input per head, it was the decomposition of labor productivity growth that was the most interesting matter. But the same assumption, that earnings = marginal productivity, led to the conclusion that the growth rate of labor productivity could be resolved into a portion contributed by the growth rate of the capital–labor ratio weighted by capital's income share and a portion contributed by total factor productivity.

Although the several early investigators used somewhat different data and studied somewhat different periods, they reached identical qualitative conclusions. Only a small fraction of U.S. per capita growth over many decades could be attributed to total input growth per capita. Only a small fraction of labor productivity growth could be attributed to growth of capital per worker or per man hour. An overwhelmingly large fraction (approximately 90 percent) was due to the advance of total factor productivity, that is, to something whose contents were as yet unidentified and unmeasured.

Perhaps because Solow, whose paper (1957) best revealed the underlying theory of the calculations, called the unknown factor "technical change" and showed that, in his theoretical scheme, it corresponded to shifts in an aggregate production function, many economists at first came to speak of the unknown element as "technological progress." Still more, they tended to view the progress so represented as having its source in the advance of knowledge. None of the early growth accountants, however, viewed the matter in this light, and all

explained carefully that the very large unmeasured component must include the contributions of many elements besides new knowledge. Of these the more important were the following:

1. Growth of "human capital" by investment of resources in longer schooling, on-the-job training, nutrition and health care, and research and development. The accumulation of human capital would tend to raise the effectiveness of labor hours, just as tangible capital would, and other matters, such as the age and sex composition of the labor force and the intensity of work, would also affect the productivity of labor.
2. Economies of scale. Since the division of labor is limited by the extent of the market, productivity gains become possible when aggregate output increases, even if the stock of knowledge itself remains unchanged. Productivity, therefore, may rise when output grows for whatever reason, not only technological progress proper, but also labor force growth or the accumulation of capital or the discovery of new resources.
3. Better resource allocation – that is, the shift of workers or capital of standard quality from employments in which their earnings and presumably their productivity are relatively low to others in which they are higher.

Errors and biases in the data must also be part of total factor productivity growth as this is actually measured, because its value in the accounts is no more than the difference between the measured growth rate of output and that of total factor input. Because of its unmeasured, heterogeneous content, the present writer characterized this difference as "some sort of measure of our ignorance about the causes of economic growth" (1956, p. 11). In the end, all this came to be well understood, and the mysterious element of total factor productivity growth was dubbed simply the *Residual*.

The development of growth accounting

The dominant importance of the inscrutable Residual was an irresistible challenge, and economists set themselves to reduce it by devising ways to measure its contents. Edward Denison's work is representative of growth accounts for the United States, but others, especially John Kendrick and Dale Jorgenson, have made impressive contributions. And there have been many similar studies by these and other scholars that provide accounts for European countries, Japan, Canada, and others.[4]

Table 1.1, drawn from Denison's latest publication (1985), illustrates the results. The column refers to the sources of growth of labor productivity, measured by national income per person employed, during the 31 years from 1948 to 1979. When Denison confines his

Table 1.1. *Sources of growth in labor productivity, Denison's estimates, 1948–79*

	Percentage points per year	Percent of total growth rate
1. National income per person employed	1.81	100
2. Hours per person	−0.41	−23
3. Capital stock per person[a]	0.43	24
4. Total factor input (lines 2 + 3)	0.02	1
5. Total factor productivity (= primitive residual) (line 1–4)	1.79	99
6. Labor quality	0.53[b]	29
a. Efficiency offset	0.05	3
b. Age–sex	−0.16	−9
c. Education	0.41	23
d. Other	0.22	12
7. Adjusted total factor input (lines 4 + 6)	0.55	30
8. Adjusted total factor productivity (line 1–7)	1.26	70
Resource allocation	0.24	13
Scale	0.31	17
Intensity of demand	−0.13	−7
Other	−0.08	−4
Knowledge and n.e.c. (final residual)[c]	0.92	51

[a]Includes land.
[b]Total does not equal sum of components because of rounding.
[c]n.e.c. = not elsewhere classified.
Source: Denison (1985), Table 8.3. Figures are weighted arithmetic averages of growth rates for 1948–73 and 1973–79.

concept of inputs to labor measured in natural units (labor hours) and to capital and land measured by their base-period cost, it appears that total factor input per worker hardly rose at all. The contribution of additional capital per worker was essentially offset by the decline in hours per worker. The growth of total factor productivity – I call it here the Primitive Residual – therefore accounts for virtually the entire growth of labor productivity. This result corresponds to those of the early studies.

Denison, however, did not stop there. He found ways to measure the contributions of those changes in the quality of work that cannot, at least in the first instance, be ascribed to technological progress but represent either greater effort, change in the demographic composition of the labor force, or longer schooling. His "efficiency offset" (to

the reduction in hours) is an allowance, admittedly somewhat arbitrary, for the greater intensity, care, and accuracy of work that has probably accompanied the decline in hours. His allowances for the effects of changes in the demographic and educational composition of the work force are based on evidence of systematic and persistent differences in the earnings of workers classified by age, sex, and length of schooling. The contribution of longer schooling is an especially impressive figure.[5] It says that the rise in the educational level of the average worker added as much to the growth of output per worker as did the accumulation of machinery, structures, and other forms of ordinary capital.

If we follow Denison, the allowance for the rise in labor quality makes a big difference. Now three-tenths of the rise in output per person employed can be attributed to an increase in factor inputs, either more conventional capital per worker or more human capital (education) or greater intensity of work. But seven-tenths of the increase in output per worker is still left unexplained in "adjusted" total factor productivity.

Denison went on. He attempted measurements of the effects of changes in "intensity of demand" on the degree of utilization of employed labor and capital, in the "better allocation" of resources as labor and capital shifted from farming and petty trade to more productive occupations in industry and commerce, and in economies flowing from the enlargement of scale as national income and the size of close-knit metropolitan markets increased. The allowance for economies of scale is again a somewhat arbitrary figure, but the other two sources are calculations from relevant data. In the end, the Final Residual, although substantially reduced, is yet by far the most important source (51 percent) of labor productivity growth in the postwar period.[6] Because Denison judged that he had measured a very large part of the content of total factor productivity growth which does not arise from new applied knowledge and because his Final Residual proved to be nearly constant during the period of generally stable development from 1948 to 1973, he regarded it as a measure of growth due to the "advance of knowledge" incorporated into production.[7]

The aim of the growth accounts is to measure the importance of the proximate sources of growth. If these sources were completely identified and accurately measured, we should still want to understand the deeper causes of the process; we should want to know why schooling was extended as much as it was and why an extra year of schooling made the difference to output that it did; we should want to know why capital per worker grew just as fast or slow as it did, and why the incremental productivity of capital was just as high as it was. The accounts themselves, however, would take us a long way. They would tell us that observed changes in a country's productivity growth were due to certain proximate sources and not to others. They would tell us that the causes of differences between one country's growth rate and that of another had to be sought in certain directions but not in others.

So viewed, the development of growth accounting is a potentially important contribution. It remains subject to serious limitations to which I now turn; but the limitations themselves, as we have come to understand them, point the way to better understanding.

Limitations of the growth accounts

As with any set of measurements, the growth accounts are subject to error. The accuracy of some of the underlying data is in question. There are also problems about proper definitions and concepts. The most important is whether aggregate product should be measured net or gross of capital produced to offset capital depreciated or retired. The answer makes a small difference to the measured growth rate of the capital stock. It makes a very large difference to the weight attributed to the growth of capital input. The net basis is more appropriate in analyses of output growth as a source of economic welfare. Labor and capital, however, must be used to produce replacement capital, so the gross basis is more appropriate for measures of productivity. There are other questions. Should depreciation include obsolescence? Can earnings differentials be treated as unqualifiedly good measures of the effectiveness or "quality" of different classes of labor or capital? How should the income earned by the proprietors of unincorporated firms be divided between labor and capital in determining factor shares? There are problems of principle as well as accuracy of data embedded in these and similar questions.

A comparison between the accounts compiled by Denison and Dale Jorgenson appears in Table 1.2. It shows how vulnerable the figures are to differences in concept and modes of estimation. The figures in Table 1.2 are decompositions of total output growth, not of output per worker. I use them to make possible an easy comparison between Denison and Jorgenson because the latter does not provide a decomposition of labor productivity. An accounting of the growth of total output, instead of output per worker, does not in itself alter the growth rate of total factor productivity, but it adds the effect of the growth of the employed labor force both to total input growth and to that of output. So total factor productivity makes a smaller proportionate contribution to total output growth. A comparison of the Denison figures in Table 1.2 with those in Table 1.1 shows how this cuts the

Table 1.2. *Sources of growth in total national output, 1948–79: comparison of estimates by Edward Denison and Dale Jorgenson*

	Percentage points per year		Percent of total growth rate	
	Denison	Jorgenson	Denison	Jorgenson
1. Output[a]	3.49	3.42	100	100
2. Total labor hours	0.93	0.68	27	20
3. Labor quality	0.53	0.37	15	11
4. Capital stock[b]	0.77	1.15	22	34
5. Capital quality	–	0.40	–	12
6. Total labor input (lines 2 + 3)	1.46	1.05	42	31
7. Total capital input (lines 4 + 5)	0.77	1.56	22	46
8. Total factor input (lines 6 + 7)[c]	2.23	2.61	64	76
9. Total factor productivity (line 1–8)[c]	1.26	0.81	36	24

[a]Denison output is net national income; Jorgenson output is gross value added.
[b]Includes land.
[c]Sums of lines do not necessarily equal totals due to rounding.
Sources: Denison (1985), table 8.1. Figures are weighted arithmetic averages of growth rates for 1948–73 and 1973–79. Jorgenson, Gollop and Fraumeni (1987), table 9.5.

adjusted total factor productivity share in half – from 70 percent to 36 percent of output growth.

Jorgenson's estimate of adjusted total factor productivity growth, however, is a third less than Denison's. The major part of the difference arises because Denison measures output by net national income, Jorgenson by gross value added. For Denison, therefore, the share weight attached to the growth of capital is determined by capital's net earnings; for Jorgenson it is earnings gross of the allowance for capital consumption. Mainly for this reason, the weight Jorgenson attaches to capital accumulation is twice Denison's; and the weight he attaches to labor input is correspondingly smaller. Since capital is the faster-growing input, Jorgenson's total factor input makes a larger contribution to output growth than Denison's and leaves less to be attributed to total factor productivity. Jorgenson's capital input makes a larger contribution than Denison's for another reason. Corresponding to the growth of labor quality, Jorgenson estimates the growth of capital "quality." This is, in effect, the difference between the growth of the capital stock when its annual increments are measured by the estimated base-period cost of different asset classes and its growth when the different asset classes are combined by their annual "rental prices," that is, by what they must earn to make the investment worth while. On Jorgenson's gross output basis, rental prices must include depreciation, which is necessarily higher for short-lived than for long-lived assets. And since short-lived equipment was growing faster than long-lived structures in the postwar period, capital "quality" rises and, in Jorgenson's figures, raises the contribution of his total capital input growth to 1.56 percent a year, which is 36 percent larger than the contribution of capital stock proper and twice as large as capital's contribution according to Denison.[8]

The upshot is that whereas the early growth accounts centered attention on total factor productivity and presented capital accumulation as a much less important source of output growth, the picture is very different according to Jorgenson. His account elevates capital input to the premier position, more important even than labor input and well-nigh twice as important as adjusted total factor productivity. Although Jorgenson does not estimate the "advance of knowledge" itself, that is, Denison's final residual, that would necessarily be still less important in his view.

Differences of concept and method such as those that separate Jorgenson and Denison are not, however, the most serious problems of the growth accounts. The conceptual bases of both these accounts are clearly identified. One can use the figures that fit the purpose – the net national income basis, for example, in studies directed to the growth of economic welfare, the gross product basis to analyze the advance of productivity. Other problems, to which I now turn, are less easily resolved or evaded.

Arbitrary or uncertain estimates

If growth accounting could do no more than generate the huge and undefined Residuals of the primitive early tables, it would be of little value. The Residuals in the later accounts are much smaller, and the effort to decompose "total factor productivity" has taught us much about the statistics we use, about the conceptual problems of measuring the unmeasured parts of human capital accumulation, and about the services of both human and conventional capital. Making and using the accounts has forced economists to think rigorously about the theoretical bases of the production-function approach to an understanding of growth.

On the surface, there has been progress. The advance of knowledge, the final residual, in the Denison account (1948–79) is but half the original primitive residual. The same is true of adjusted productivity in the Jorgenson account. But are the measurements that lead to the reduction reliable? The sad fact is that they are not. They include

arbitrary or uncertain estimates.[9] I use the justly admired Denison account to illustrate the problem.

1. Denison's account includes an allowance for an inverse association between average hours of work and the intensity of effort and care displayed by workers. He reasonably supposes that when average hours decline from very high levels, intensity rises by more than when they decline from lower levels. He proposes a formula to describe the association. But there is little evidence to support it. The proper offset may have been much less or more than his estimate.

2. Denison estimates the contribution of longer schooling as the difference between the growth rate of labor input in natural units (hours worked) and the growth rate of a weighted sum of hours in which hours worked by members of the work force, cross-classified by age, sex, and years of schooling, are weighted by factors proportionate to their average pay. Do the differences in earnings of workers classified by number of school years represent the effect of schooling on pay? They do not, because people who have remained in school for more years are, on the whole, more intelligent, energetic, persistent, and ambitious than those who left school early. They have, on the average, better-educated parents, who are more well-to-do and are better-connected than the parents of less-schooled people. The more highly educated students, on average, have had a better start at home, a better start in their careers, and more help along the way. Denison makes an allowance for these correlates of longer schooling; but the evidence to support the size of the allowance is problematic.

In extreme form, the problem raised by the correlates of education becomes the "screening model" of the role of schooling (Berg 1970). In this model employers use school records, certificates, and diplomas to identify workers with the sorts of personal characteristics (intelligence, energy, etc.) they desire for different kinds of jobs. They pay more to workers with longer schooling because the supply of people with the personal characteristics associated with longer schooling is limited. When the average level of schooling rises, so the screening model alleges, this does little or nothing to raise the capabilities of workers. It means only that employers must raise the schooling standard they associate with given levels of personal talent. Is the present-day secretary with two or four years of college training a better secretary than the high school graduate of fifty years ago? Carried to the limit, the screening model is absurd. The literacy, numeracy, and communication skills acquired in school, to say nothing of technical and scientific training, all count. The screening model, however, serves to remind us how hard it is to measure how much they do count.

There is a still larger problem. In the growth accounts, the value of a year's schooling is its worth to individual employers. But education has a wider significance. It raises the tolerance of consumers for novel products. It makes workers and their families more willing and able to accept the shifts of place and community that growth requires, from country to city and from region to region. It affects the operations of government and, in a democracy, influences its goals. Education, in short, is one of the governors of the social climate of economic activity. The growth accounts, as they now stand, catch none of these diffuse but important effects of education.

3. When the volume of a country's total output expands, there is an additional bonus. The larger output extends the market and opens the way to all the advantages of the division of labor. These advantages are also obtained when advances in transportation and communications and the removal of political barriers make it possible to trade over longer distances and across national boundaries. And markets are also enlarged when people come together in large cities and metropolitan areas.

The contribution of the economies of scale is one source of total factor productivity growth, and Denison proposes a measure for it. The basis for his measure, however, is uncertain. There are few studies of scale economies at a national level. Moreover, it is unlikely that there is a uniform association between scale of market and productivity growth. The productivity bonus from growth of scale is presumably larger in sparsely settled than in densely settled countries. The source of the enlargement of the market also makes a difference. Technological progress raises per capita incomes as well as aggregate output. Population increase may raise aggregate output with little or no change in per capita incomes. The accompanying changes in the composition of demand and output will not be the same; so the scale of effects will differ. And population growth increases congestion in densely settled countries. So does metropolitan concentration, which brings with it a host of other problems. None of these complexities in the measurement of scale effects has yet been seriously tackled.[10]

Denison's estimate of the three sources just discussed were 43 percent of his growth of labor productivity in the postwar period and 84 percent as large as his Final Residual ("knowledge, etc."). Allowing for errors in other, perhaps better-measured, elements leaves one with a disturbing sense of the uncertainty that surrounds the growth accounts and, more particularly, our understanding of how much we may have gained from work, capital, and knowledge.

The uncertainties associated with the Denison estimates attach as well to those of the other accountants. They face the same problems

Denison does when they make measurements of the same elements, and of course the problems remain when they do not.

Interaction among the sources

The most serious weakness of the growth accounts lies still deeper. The aim of the accounts is modest but definite. It is to measure the proximate sources of the rise of output and so to tell us where we must look if we are to find its more basic causes. Whatever the underlying causes may be, growth accounting asserts that they act through the sources identified in the accounts with a force that the accounts measure. Growth accounting in effect holds that if the measured contribution of capital accumulation was 2.0 percentage points per annum, aggregate output growth would have been 1.0 percentage point slower if capital accumulation had been only half as fast as it was. If the apparent contribution of the "advance of knowledge" was 1.0 percentage point per annum, aggregate output growth would have been just 1.0 percentage point slower if there had been no progress in technology at all. Growth accounting, therefore, holds that the sources it measures act independently of one another so that each makes its own contribution. There are good reasons, however, to question that claim. The growth sources feed from one another. The most important interactions are those between technological progress and the accumulation of tangible capital and between technological progress and the build-up of human capital through education and training.[11]

Technology and tangible capital. Causation runs in both directions. It runs from capital accumulation to technical progress in part because some new knowledge is incorporated into production only when newly designed capital equipment is actually emplaced in producing establishments. How much the exploitation of new knowledge depends upon the installation of newly designed equipment is not known. Some progress certainly takes the form of improvement in managerial routines, in the flow of work, and in the motivation of workers. Some requires but minor modifications in existing equipment. But the experience of most observers suggests that much progress is embodied in new capital. When that is the case, a speedup in the rate of growth of the capital stock also permits new knowledge to be incorporated into production at a faster pace. Otherwise stated, the average age of the capital stock falls and both labor and capital become capable of operating at a level closer to the frontier of knowledge itself.[12]

How important for the exploitation of new technology are the observed differences in rates of capital accumulation? If new capital is always invested in the economically most advanced forms, the effect depends, first, on the pace of advance of knowledge and on the age of the existing stock. Together these two factors determine the size of the technological leap that can occur when new capital replaces, or is added to, old. It depends, second, on the degree of speedup or slowdown in the rate of capital accumulation, because that controls the change that occurs in the average age of the capital stock between two intervals of time. Close calculations by Edward Denison suggest that changes in the pace of capital accumulation could not have made much difference in the pace of technological progress in the United States in the postwar period.[13] The rate of advance of knowledge was not fast enough and the changes in the average age of the stock were not large enough to make much difference.

Those findings, however, cannot be extended to other countries in other circumstances. For the United States, it was reasonable to assume that investments by and large embodied the most advanced knowledge of the time when they were made. There the technological leap that could be made by replacing old by new equipment was governed by the pace of advance in knowledge over a period represented by the age of the capital that is retired. For many other countries, however, investments have not always embodied the most advanced practice of the times they were made. Inadequate markets, managements inexperienced in large-scale business, scarcity of capital, poor engineering guidance, and sheer lack of information combined to make their old capital stocks technologically obsolete even for their age. That was the case with much capital in Europe and Japan when the postwar years began. If conditions then come to support investment in new equipment that represents best practice, much larger technological leaps can be made than the chronological age of existing capital might suggest. Then a rapid rate of capital accumulation can push technology forward substantially faster than slower accumulation. The rapid growth rates in Europe and Japan for twenty-five years after the war were, in some part, based on the combined effects of an initial capital stock that was technologically obsolete even for its age, a new capability for making effective use of best-practice technology, *and* speedy embodiment through rapid capital accumulation.[14]

New capital is needed not only to exploit the advance of practical knowledge but also to take advantage of the economies of scale in larger or more specialized firms as the enlargement of markets makes such change profitable. Furthermore, the changes of output composition and location that accompany the growth of aggregate output also

demand new capital. So in these ways, too, the pace of technological progress actually incorporated into production depends on the rate at which new capital can be laid down.

The rate of capital accumulation not only influences the pace at which the advancing knowledge frontier can be exploited, it is also part of the process of acquiring new knowledge. Costs of production fall as experience with novel capital equipment accumulates. And still further, the incentive to conduct research and to develop and produce new products depends on the market for them. When the new products are capital goods, the size of the market is governed by the level of investment. I return to these matters in the next section.

The support that capital accumulation gives to technological progress is matched by the support that technological progress lends to both the growth of capital and the contribution that capital can make to output. The simplest and most important reason is that the prospective earnings of investment depend on the ability of new capital to increase the efficiency of production and to permit better products to be offered to consumers. This is to say, both the volume of new investment and what a unit of capital can contribute to output growth depends on technological progress. The profitability of new investment and therefore its volume also depend on the possibility of using it to shift output to the industries and locations that new technology and the demand it supports require. Since capital has been increasing so much faster than labor, one might have supposed that the returns to capital would have dropped continuously, slowing down the rate of accumulation and reducing the contribution of each new increment to output and labor productivity. That indeed was the expectation and fear of the classical economists. But they did not appreciate how continuing technical progress would permit each year's new investment to take more effective forms. In the experience of the presently industrialized countries, moreover, technological progress has, on the whole, been "capital-using." It has tended to increase the demand for capital compared with that for labor. The return to capital and the pace of capital accumulation have therefore been further supported, and the contribution of capital accumulation to output growth has been sustained.[15]

Technology and education. Interactions of a similar sort make it hard to separate the contributions of technological progress from the accumulation of the human capital. I illustrate the connection by considering the human capital that takes the form of education, which has so prominent a place in the growth accounting tables.

The level of education in a country, provided its content is modern, manifestly supports the pace at which an economy can exploit the possibilities of technical advance. All forms of education count – scientific, technical, and other forms of professional training, as well as simple reading, writing, and arithmetic. Scientific and technical training count for progress at the frontier. And they apply as well when it comes to acquiring and exploiting methods and products already in use elsewhere. Firms striving to "borrow" technology must have the technical competence to recognize it, to appraise its value, and to adapt it to their own conditions and requirements. Other forms of professional education count, too, because the introduction of new methods and products or their transfer to new places involves the organization of new firms or the reorganization or relocation of old ones, the design of new facilities, training of workers, and the solution of many problems of marketing and materials supply. The cost of exploiting and developing new or borrowed technology, therefore, depends on the availability of legal, administrative, managerial, and marketing, as well as engineering, skills. It is dependent on the capabilities of workers of all types to learn new jobs and routines and to respond to opportunities in new places, and also on the willingness of consumers to accept new products and to adapt their patterns of living to the opportunities they open up. Schooling enhances all these capabilities and thus the rate of technological progress itself.[16]

Finally, there is the influence that runs from technology to education. The pace and character of technological progress affects both the rate of rise of education and the contribution of advances in schooling to output growth. In the past, it has supported them strongly; so it may be said that technological progress supports output growth not only directly but also through its influence on the growth rate and, with a lag, the level of education.

The process by which this occurs runs from technological advance to the earnings premiums that reward workers who have more years of schooling more generously than those with fewer. Firms value workers with technical and general education in part because they contribute to their ability to conduct research, to evaluate and adapt the innovations of others, and to learn new functions and routines. And these qualities are more important in a progressive than in a stagnant economy (Nelson and Phelps 1966).

Earnings premiums enter the process in two ways. First, they determine the financial returns to the costly investment that students and their families make when they undertake to extend their education. They act, therefore, to govern the personal decisions that underlie the length of schooling. They are also a powerful influence on public support for the extension of schooling. They influence voters with

children because government support for education reduces the costs that students or their families must meet. They sway voters generally because their vision of the social benefits of education rests partly on their perception of how much the earning power of the working population will rise if young people have longer schooling. In all these ways the size of the earnings premiums associated with schooling help to govern the growth rate of the level of education.

Secondly, the growth accounts treat the premiums themselves as measures of the marginal productivity of increments to the length of education. They tell us how much an additional year in school adds to a worker's productivity and, therefore, how much the growth of schooling contributes to output growth.

In the United States, for which our estimates are strongest (or least weak) it appears that the earnings profile of workers classified by level of education remained approximately constant from the early years of the present century until about 1970. This presents a challenging question. How did it happen that the earnings premiums on schooling – the marginal productivity of education – should have remained stable over so many years when the proportions of people with high school, college, and graduate education were rising so rapidly?[17]

In the face of a large increase in the relative supply of more educated workers, one might suppose that the earnings differentials associated with longer schooling would have declined decisively. They did not. They remained high enough to encourage a rapid extension of the length of education and to translate the rapid rise of education into a large contribution to output growth.

The solution of the conundrum lies, again, in technological progress. This acted to increase the demand for workers with longer education in three ways. First, it contributed to a larger rise in income which in turn led to a shift in the composition of consumer wants. Demand turned away from the products of agriculture, where workers typically have little schooling, and toward the production of services and government, including health care services and education itself, in which workers typically need longer schooling. Second, technical progress took a form that caused labor savings to be concentrated in those occupations in which the schooling of workers is typically short. These are the blue-collar occupations in farming, manufacturing, mining, and construction. The technology that produced those gains, moreover, demanded an expansion of employment in managerial, technical, and administrative jobs, in the professions and services auxiliary to blue-collar work, and in communications, distribution, and finance – all occupations in which levels of education are relatively high. And, third, it changed the nature of jobs generally in ways that made schooling more valuable. Concurrently there was a change in the content of education that made it more useful to business and practical pursuits.

The upshot of this extended argument is that growth accounting yields results that have a serious limitation. The accounts purport to measure the independent contributions of the growth sources they identify. But the sources are, in fact, not independent of each other. The accumulation of tangible capital, the expansion of human capital in the form of schooling, and the advance of technology interact. They support one another and make joint rather than separate contributions. The contribution of any one of these sources, as this is measured in the accounts, may be too small because it does not give adequate weight to its effect in generating the contributions of the others. Or it may be too large because it makes no allowance for the effect of the others in supporting its own. The sound instinct that technological progress lies at the core of modern economic growth rests at bottom, not only on its own independent action, such as it is, but also on the support it lends to the accumulation of both tangible and human capital and to the support that they in turn lend to it.

V. The search for deeper causes: technological effort as investment

That the advance of knowledge lies at the core of the modern growth process is more than an inference from the growth accounts. It is a perception enforced by well over a century of common experience. Economists have therefore applied themselves to learning more about the ways that practical knowledge is gained and exploited. A new outlook has developed and spread. It is not yet well defined. In what follows I sketch what I see as its three main features:

Science, technology, and business are distinct, but no longer separate realms. They are closely intertwined, and at some points have fused.

The new knowledge applied to production, in its discovery, in its initial exploitation, and in its spread, is the product and yield of costly and risky investment. With some qualification for the work of academic scientists, such investment responds to incentives and constraints that are, in every general sense, the same as those that control all other investment decisions.

The strength and effectiveness of the technological efforts of business are, in part, controlled by conditions peculiar to individual firms, industries, and technologies. In part, however, they are governed by conditions that are national in scope. These serve to differentiate the growth experience of one country from another and the experience of each country in one era from its experience in another.

I take up the first two features in the present section and reserve the third for the next section.

Science, technology, and business

When economists' attention was focused on matters other than growth, they sometimes spoke as if new knowledge proceeded in a linear progression from pure to applied science, thence to potentially useful inventions, and finally to the exploitation of such inventions in industry and commerce. Engineers were prone to express themselves in a similar way. That, however, was not a seriously held belief among economists. It was simply another way of saying that, for purposes of understanding relative prices, a satisfactory model could treat the state of the arts as a datum, the outcome of a process that was independent of that by which the relative prices of goods are determined. When economic growth and technological progress itself became the subject of serious study, such primitive views were quickly abandoned.

That our knowledge about how to make things and to transport them does not derive from a prior knowledge of scientific laws alone is obvious on the face of the matter. Most, perhaps almost all, of the practical knowledge embodied in the methods of settled agriculture, and even in the advances of the first century following the Industrial Revolution, had become common practice long before the scientific principles on which they rested had been discovered.

Many advances in processes of production and in the tools and materials that they employ are the fruits of experience with their production and consumption. The contemporary and generalized form of this elementary but fundamental fact is contained in the principles of learning-by-doing and learning-by-using. Broadly conceived, these principles can be seen to incorporate many common and plausible ideas about the process of learning that are well supported by the history of technology. Engineers, businessmen, and workers themselves learn to make things more easily and quickly as they study, dissect, and experiment with the production process and the business in which they are engaged. When problems emerge in the conduct of production, engineers and scientists are impelled to find the physical or chemical bases of the trouble, to learn more about the scientific elements of the materials and processes, and to discover solutions. If proper materials are unavailable or costly, they look for substitutes. If alternative materials are plentiful, they are driven to find ways to use them. The commercial and financial sides of business influence the trade-offs that engineers must make between cost and quality. In the same way, firms learn by experience to adapt their products better to the needs of their customers, to the uses to which they are put, and to the conditions under which they must operate.[18] Indeed when a technological innovation is first introduced, more particularly an important new product, its potential range of application to its most valuable and extensive uses remains to be discovered; and the adaptation of the product by redesign and by the development and provision of ancillary and supplementary devices and services is best viewed as a response to experience in use.

Kenneth Arrow, who introduced "learning by doing" to the lexicon of economics, based his thesis on a generalization common among psychologists: "Learning is the product of experience." He drew a second generalization from the many classic learning experiments, that "learning associated with repetition of essentially the same problems is subject to sharply diminishing returns." (Arrow 1962b, p. 155). Arrow argued that the tendency to diminishing returns to experience was offset by the environmental changes that experience itself generates. In effect, he suggested that experience leads to the improved design of capital goods and, therefore, that each successive vintage of capital provides a new set of problems and a new field for exploration and improvement. He therefore proposed that productivity growth is a function of the growth rate of cumulative gross investment, which served as his embodiment of experience. This carried the implication that productivity growth would be constant, other things being equal, if the growth rate of cumulative investment were stable. However, Paul David (1975, Chaps. 2 and 3), in a variant of the argument, contended that experience cumulates with time as well as with the volume of investment.

Arrow's and David's hypotheses may be regarded as generalizations of the early and important empirical studies by Simon Kuznets (1930) and Arthur F. Burns (1934). They had found that the growth rates of output of particular commodities and industries were almost invariably subject to retardation. To this Burns added that there was no evidence of retardation in measures of aggregate output growth. The central, though not the sole, element in their explanations of specific commodity retardation, was the same: The early exploration of a new technology yields relatively rich returns in productivity growth and cost reduction. But as production proceeds and experience cumulates, it becomes progressively harder to achieve equally significant improvements. Barring an occasional dramatic breakthrough, productivity growth slows down and the pace of market expansion falls. Burns and Kuznets found their explanations of stable aggregate output and productivity growth in the emergence of distinctly new products and industries, founded on novel technologies, whose still untapped potentialities furnished fresh fields for exploration and improvement in the course of production, investment, and growing familiarity. Their emphasis on the emergence of new products and industries as a source of renewed vigor proved to be consistent with evidence. Their hypothesis implies, and it is true, that the industrial composition of output is subject to steady alteration. As total output and the level of productivity rise, relatively new products and industries displace the older.

The feedback from industrial and commercial experience to technology is manifestly one source, and likely an important source of new knowledge. It proceeds by multiple channels. It is closely linked to the deliberate and systematic efforts of business firms to discover better things to make and better ways to make them. Indeed, experience by itself does not, as a general rule, directly yield solutions to production or product-line problems immediately applicable in manufacturing and commerce. It is normally one element in the corporate process of research, development, and commercial exploitation that is now the standard method by which the more important changes in applied technology occur. This process itself involves a many-faceted interchange between the research, manufacturing, and commercial arms of firms, and this interchange expresses in a practical way the interdependence of technological advance and business operations (Kline and Rosenberg 1986).

The feedback from business and the market to the advance of knowledge does not stop with the direct effects of industrial experience on methods of production, design of products, and provision of ancillary services. It goes on by still other paths to the development of basic sciences itself and so, by indirection, to far-reaching extensions of fundamental knowledge on which applied scientists and engineers can build.

The influence that business experience and business motives exert on science proceeds, first of all, from the fact that the technology of production and the character of products are, in many spheres, now closely tied to the scientific principles of which they are discernibly applications. Scientific research, therefore, has the potential of making great contributions to people's health and satisfaction and of yielding large financial gains. Thus it is easy to understand that the deployment of scientific talent and laboratory resources should be strongly influenced by the practical prospects so opened. There are several channels of influence.

A major channel is again the experience of industry itself, the problems that arise in production or from the scarcity of materials or from the difficulty of designing reliable, durable, and cheap products. Numerous and significant examples testify to the response of scientific effort and advance to a challenge posed by industry (Rosenberg 1982, Chap. 7). Moreover, when science has met the immediate challenge, it often happens that the principles that offer a solution have much wider application than to the problems for which they were originally intended.

Because technology has drawn closer to science itself, technological advance is now typically sought by methods closely akin to those of scientific research. True, the motivations of the scientists who work in corporate and university laboratories are very different. The former seek advancement by guarding their firms' proprietary interests in their discoveries. The latter seek fame by the earliest and widest diffusion of new results (Dasgupta and David 1987). But the modes of work and even the intellectual products of the two groups have come closer together. Their members are often the graduates of the same university courses. Professors are commonly drawn into commercial research as consultants, and corporate scientists sometimes return to join university faculties. More often they return for short periods of study and research. In a limited way, business firms, seeking early access to the discoveries of university laboratories and to their talented students, have begun to give financial support to academic research. Increasingly, therefore, as the technology of industry has become more explicitly based on scientific principles, the problems and interests of industry have also come to shape the direction and content of academic science.

The conviction that the advance of knowledge applied to production is a process intimately involved with economic activity itself is supported by numerous empirical studies. These are especially persuasive in connection with the diffusion of innovation, and they run to the conclusion that the spread of new methods and products is a response to economic factors, to calculations of profit as influenced by the size of markets and firms (Griliches 1957; David 1975, 1986b). Jacob Schmookler, however, went further and argued that not only the application of inventions but also the pattern of inventive activity itself was governed by the size of the market for its products (Schmookler 1966).

Schmookler's studies aimed to explain the forces that governed the changing rate of invention in an industry over time and the differences in the rate of invention among industries at a given time. He chose patents as his units of invention and found a strong association between patents in the capital equipment of an industry and the industry's level of investment. Schmookler rationalized the association by arguing that, as the proportion of income spent on different classes of goods changes in the course of economic growth, the yield to inventive activity also changes and the direction of inventive activity changes accordingly. In this argument, the level of investment stands as a proxy for the yield to investment activity, which is itself governed by the changing size of the industry's market. Although the technological characteristics of inventions, whether mechanical, chemical, electrical, or biological, will depend on the current state of science, the classes of commodities or services to which inventions are directed are determined by the relative strength of their markets. When Schmookler's results appeared to be confirmed by other studies (Myers and Marquis 1969; Langrish et al. 1972), his views gained wide acceptance. Indeed, the primitive idea that the state of the industrial arts was the outcome of a wholly autonomous process running from science through technology to business appeared to be reversed. It now seemed that the evolution of market demand "called forth" useful new technology by inducing scientists and engineers to bend their efforts to whatever objectives market demand made most profitable.

Read literally, this second position was no more sustainable than the first. For one thing, the relation between the market and invention cuts two ways. A large market increases the potential yield of an invention, and it does appear that demand-side factors regularly trigger inventive effort. Nevertheless, successful inventive efforts also serve to expand markets. One must therefore look at the association between the direction of invention and that of market sales as a cumulative process.

That demand matters is inherent in the fact that business R and D, and its relations to the universities and basic science, is a process now fully incorporated into normal, profit-seeking business life. It does not follow that only demand matters in determining the direction of inventive effort, to say nothing of its results. As Nathan Rosenberg has contended, the twentieth century advances in medical science and in the chemical and biological elements of modern agricultural technology would all have met urgent needs and enjoyed vast markets long ago. That such advances did not appear in response to the latent demands for antibiotics, chemical fertilizers, pesticides, and high-yielding strains of drought-resistant, and insect-resistant crops reflects the inherent complexity of the branches of science on which they depend. Inventive activity could not be directed earlier to such subjects because, before the development of chemical and biological sciences, the difficulty of generating useful inventions made such efforts unprofitable, however wide the potential market.[19]

One is left with a conception of the relations between economic forces and the advance of practical knowledge, which is an amalgam of the two extreme positions. The progress of technology, which is the major source of productivity growth, is itself strongly swayed by the business activity that it stimulates. Its pace and its industrial direction are influenced by the pace of production and investment in the various branches of the economy. It responds to the incentives provided by the potential demand for its fruits, and it is constrained by the difficulties and risks of technological investment and its commercial exploitation. It is driven by the potential competition that rivals may offer, and it is aided and guided by the experience gained in the course of production and use.

The feedback from the economy to the advance of knowledge does not stop at the level of technology but extends to science itself. Technological effort and progress respond to the deployment of resources subject to business decision. The potential response, however, is not uniform in all directions. It is stronger in some, weaker in others, depending on the existing state of science and technology and on the complexities of nature that at times impede further progress. Where the potential response is weak, the costs of progress may be forbiddingly high, and a great market potential will not call forth expenditures or effort, to say nothing of advance itself. We must therefore recognize the existence and importance of "latent knowledge," a state of affairs that is in some degree determined by the cumulative progress of science and its own internal logic. The constraints so imposed can act to retard technological progress and productivity growth more at some times than at others and more in some directions than in others. And, depending on countries' patterns of consumption and on their industrial structure, therefore, it may favor advance in some countries more than in others.

Technological investment from the standpoint of firms and industries

1. The relations between business activity and technological progress imply that, as business firms look at matters, technical advance is the result of investment. The dependence of capital accumulation on technological advance is here reversed. Technological progress is dependent on investment. That is manifestly true when a firm's product lines and production methods lie at the frontier of what is both known and economically efficient. Then further advance requires a costly expenditure of funds in a search for products better adapted to the needs of actual or potential customers or for methods of production that promise lower costs. The search is spurred by

hopes of larger profit from expanding markets or greater efficiency in production or by fears of smaller profits if rivals catch up or move ahead. To maintain or improve their markets and profitability, research and development activities have become routine and, in large firms, are normally carried on in separate departments devoted to the search for commercially profitable knowledge.

The costs of such departments and those costs of manufacturing and commercial departments that are involved in the work of application and development, together with the work of testing, breaking in, and training staff, constitute investment expenditure that is qualitatively identical with investment expenditure in general. Costs are accepted in one period in the expectation of revenues to be obtained in a series of later periods.

Investment in the search for and application of new knowledge, however, has its own special characteristics. The costs of search are highly uncertain. Indeed, it is often not known in advance whether any commercially useful result will be obtained. Since other firms are engaged in similar searches, or may soon be engaged, the potential market promised by technological advance is not likely to be enjoyed alone. Over a period of time, longer or shorter, such markets will in any event have to be shared with imitative, if not innovative, rivals. The profits of new knowledge are therefore subject to commercial obsolescence and decay whose rapidity cannot be predicted in advance. The danger of obsolescence and loss of market spurs the effort to make still further advances, but the danger of very rapid obsolescence discourages the effort by diluting its prospective returns. Investment in knowledge, therefore, carries peculiar and heavy risks, which may discourage private investment unduly (Arrow 1962a), and it has other special characteristics that create problems for public policy to which I shall return.

2. In the older literature, a sharp distinction was made between innovation and imitation. The first required an expensive effort to acquire and apply new knowledge and subjected firms to the uncertainties and risks just described. The second, however, required only choices among products and techniques already in use, and, apart from the expense of choosing, imitation could proceed immediately to production and sale. The distinction was vastly overdrawn. Technology – even that which has in some form been developed and commercially exploited – is not a public good to be freely and easily adopted by all comers. In many instances, though not in all, prospective users must maintain a degree of professional competence simply to be aware of existing alternative possibilities and to appraise them. Next, the innovative knowledge is generally the well-guarded property of

the innovating firm. It may be patented property demanding a license fee for use. But even a license, if it can be obtained, is not a transfer of the innovator's know-how, which is the knowledge that is not obtainable from patent disclosure and not even from the blueprints and instructions that may accompany a license. Much of it lies in the experience of engineers and management to be acquired partly by transfer of personnel, but largely by an investment in study, testing, and production in the acquiring firm itself. R and D that breaks new paths doubtless eases the way for firms that follow. Yet followers as well as leaders must engage in technological investment programs.[20] The programs of followers resemble those of leaders all the more because both are mixtures in some degree of the search for the new as well as the acquisition and adaptation of the old. And all firms are constrained by their own prior history and experience. This has caused them to focus their efforts and has therefore left them, to some extent, restricted in the directions in which they are able to conduct research effectively and in their ability to exploit the results gained by others. Here we have another, but less clearly beneficial, aspect of the dependence of learning on experience. Experience lends an impulse to technological effort, but it may also circumscribe the area of search, to the neglect of alternative lines of advance (David 1975, Chap. 1).

3. The fact that technical advance rests on technological investment helps us understand some of the observable patterns of expenditure on research and development. In particular, one can see why such investment is associated with the scale of firms' general business activities. There are scale factors that affect both the cost and the yield of technological search.

On the side of cost, the effectiveness of technological effort in many fields has become scale-dependent. Supported by venture capital, the lone inventor or the pair of inventive partners still have an important place. In many spheres, however, large and very expensive facilities and the cooperation of many specialists or even specialized departments is needed. Such large-scale efforts can be carried on only by large firms or by the government. There has been a tendency, therefore, for R and D to become concentrated in large firms and this tendency has become stronger as technology has become more complicated and more closely entwined with its scientific base.

On the side of yield, the revenues from innovation depend on the possibilities of maintaining the advantages of an early start, that is, of developing a large market for a new or cheaper product and of holding it for a long time in the face of the imitative efforts and investments of rivals (Nelson 1987; Pavitt 1987). The nature of the knowledge itself and the laws of property in knowledge affect the speed with which rivals can acquire and exploit the new technology. But the ability of an innovative firm to develop and hold a market also depends on the prior possession of a large market position that confers on it public trust, access to channels of distribution, servicing capability, and in some instances the ability to provide ancillary products or services that complement the innovative product itself and make it more valuable to potential users. Scale, therefore, confers advantages, not only in production and distribution, but also in the conduct of R and D and in the protection and exploration of its fruits. The acquisition and protection of market share has, therefore, come to be a critical consideration in the competitive strategies of firms in technologically progressive industries.[21] And when lone inventors or small firms invent, they must often sell their inventions to larger firms to develop and exploit.

When an industry consists of many firms who use essentially the same production process, the industry itself is not normally the source of its own productivity advances. An upstream supplier enjoys two advantages. The supplier can know as much or more about the processes and products of the downstream users as any user firm itself, which suggests another factor governing the focus of research. And the supplier can enjoy a far larger market for its novel products than any single user firm unless, indeed, the latter enters the supply business itself (Nelson 1987). In farming, therefore, R and D is generally carried on by much larger firms in the industries that supply farming with materials or capital goods – that is, by firms in the chemicals industry who make fertilizers, pesticides, and fungicides or by manufacturers of farm machinery. Here the government also plays a large role in a search for better strains of seed and for more efficient methods of farm management. Such considerations run across the whole spectrum of industry, commerce, and finance and influence the way in which investment for knowledge is undertaken by the producers of commodities and services themselves, by the firms who supply materials and capital goods, or by governmental agencies.[22]

The paramount consideration in the location of technological investment is presumably the presence of latent, commercially applicable knowledge. This is hard to confirm persuasively because the existence of latent knowledge is revealed only by its discovery and that occurs only when some effort has been made to uncover it. Early successes, however, have convinced businessmen in chemicals and pharmaceuticals, electronics, computer software, and aerospace that research on the borders between science and technology, as well as in the relevant technologies of production, will explore rich, still untapped fields of knowledge, and a great share of all research expenditure therefore takes place in those industries.

The demonstrable presence of technological opportunities acts to create a competitive environment that incites technological investment. It offers new firms a chance to carve out lucrative markets to the peril of old firms. And it impels existing firms to make large investments in new products and process research and its application in an effort to enlarge or, at least, to protect the markets they have. The threat posed by the obsolescence of existing products and methods leaves them little choice. In a less technologically competitive atmosphere, established firms may well prefer to extend the market life of existing commitments to products, tools, methods, and distribution channels, and they would correspondingly limit their investment in research, retooling, retraining, and market development. But the threat posed by the possible advance of rivals prods firms generally to increase their efforts and to accept the costs and risks of keeping up and moving ahead. Technological progress is then speeded by both the more intense effort and the experience it yields.

The relation between opportunity and effort is another example of the many feedbacks that the process of technological advance presents. Opportunity impels investment and supports the technological rivalry that drives technological effort to high levels. The opportunity that search and innovation offer, however, are not a datum known in advance. It is, as said, a nebulous quantity that is revealed only by investment itself. It is therefore a condition influenced by the complex of factors that governs the state of competition in an industry. The structure of markets and industries and the attitudes of their leaders may act to restrain rivalry. Where the firms in the industry have settled into established market niches, the possibilities of technological advance may be neglected, and only the intrusion of new rivals, if and when it occurs, may rouse older firms from their somnolent state and inject new vigor into the search for improvement.[23]

4. All investment, indeed all productive activity of whatever sort, has a social marginal product that may be different from its private marginal product. When investment is directed to knowledge, however, there is reason to think that the social product may exceed the private by a large margin. That is because knowledge cannot be forever kept in the exclusive possession of its discoverer. Sooner or later, in the same or modified form, the new knowledge comes to be known to others, who exploit it and take a share of its product and profits. The public has an interest in the full and diffused exploitation and use of knowledge. But the private return on, and therefore the private incentive to invest in, the search for better products and processes is confined to that part of a discovery's potential yield that its finder can appropriate and hold. In general, therefore, there is a stronger social interest in technological investment than private individuals and

firms can have. Subject to important limitations, empirical studies suggest that the private return to *successful* innovations (N.B.: *not* to the total technological investment of firms) is higher than that to investment in general, which is consistent with the heavy risk that technical investment involves. But they also suggest that the *social* rate of return to innovation may be much higher.[24]

5. The fact that technological progress, whether by way of innovation or imitation, involves technological investment in general implies that the conditions that support and encourage investment also support technical advance. These conditions include those that apply to investment generally and those that are specific to investment in knowledge.

One may well believe, therefore, that technological investment, like other investment, is encouraged by macroeconomic conditions, including fiscal and monetary policies, that support intensive use of existing capital, high current profits, and easy access to finance at low cost. Given high levels of capital use, such investment will also be supported by a strong propensity to save, which helps keep long-term interest rates low. A fiscal policy consistent with budgetary surplus at high levels of employment is part of a strong propensity to save. Technological investment is also supported by a highly developed and efficient system of financial intermediation and more particularly by specialized financial facilities that can appraise, accept, and spread the risks of supplying venture capital. Tax provisions that favor investment in technology work in the same direction, and such subsidies are justified to the extent that the social benefit of technological investment exceeds its private return.

A plentiful supply of scientific and technical personnel serves to reduce the costs of research and development and, therefore, to raise the rate of return to technical effort. An adaptable labor force, relatively ready to accept new routines of work, train for new occupations, and move to new locations, helps to reduce the costs of exploiting innovations and to increase their yields. All these purposes are served by education at various levels from primary schooling to advanced scientific training. Again, the excess of the social benefit over private return of technical effort joins many other reasons that justify public support for a broad general education and for the development of strong scientific capabilities.

The social interest in technological investment is furthered by a well-devised system of property rights in new knowledge. Here there is need to balance the potential private rewards of innovation, which are the incentive for private investment, against the social interest in spreading knowledge and encouraging its widespread and rapid commercial application. The first element calls for protecting the private investor in an exclusive right to exploit the new knowledge he has gained. The second calls for limiting that exclusive privilege to permit diffusion and to support the competitive investments of rivals. Our patent system and our limited legal protection against the theft of trade secrets are attempts to achieve a proper balance; but the workings of our system under contemporary conditions needs study and appraisal.

Finally, there is need for direct government subsidy of, or participation in, both basic and applied research. That is because there are areas of the search for knowledge where the outcome is valuable – sometimes very valuable – but the prospective private returns are small. That is the case when the costs and risks are great or the time frame is very long, or when the possibilities of commercial application are diffuse and hard to define, or when the results, so far as they can be seen, would be hard to appropriate privately. Much scientific work falls in this category, because even the most exotic and detached fields of study support a generalized capability for scientific investigation that may one day make possible further progress in the material conditions of life. In the absence of support from governments or philanthropic foundations, scientific investigations would exist almost entirely as the joint product, along with their teaching duties, of university scientists. Moreover, industrial laboratories, with their commitments to the more direct application and proprietary exploitation of research, compete for the services of scientists. When the commercial potentialities of investigation appear to be very rich, science may suffer an undue drain of talent to industry, with costs to the training of the next generation of both technologists and scientists and with loss of potential scientific knowledge from which future technology might spring. There is therefore a nice balance to be preserved between support for science and that for the technological investments of private business.[25]

The argument of this section runs to the conclusion that investment in research and its commercial exploitation tends to be too low unless subsidized or otherwise supported by the public or unless supplemented by government research. The conclusion needs qualification. If the fruits of invention are protected by patents or secrecy for significant intervals, competitors are driven to invent around the protected innovation while denied the use of what might be the best technique. If the rewards of science go to the investigator who establishes priority, many will work independently for the same prize. The result may be duplication of effort and possibly duplication under unfavorable conditions. There is a danger of over- rather than underinvestment.

Yet, in the uncertainty that obscures early effort to explore new fields, it would be quite unwise to concentrate all effort on a single approach to a still cloudy goal. It would be wrong to suppress competitive effort, but the private incentives that produce it qualify the need to spur research by subsidy (Dasgupta and Stiglitz 1980a, 1980b; Dasgupta and David 1987).

In addition, although the general argument justifies subsidy, this is not to say that existing levels of support are too low. There are massive government expenditures in all industrial countries to support education at all levels, which is an indirect subsidy for science, technology, and innovative investment. In the United States and most other industrialized countries, there are direct subsidies for scientific investigation and a variety of supports for industrial research. And governments themselves engage in research and promote the diffusion of its fruits.

With government support for education and research in the background, the institutions of the industrialized countries of the West have proven to be an effective support for technological progress.[26] They have rested on the solid integration of technical skills with the commercial departments of industry and on close relations between industrial and academic research. Given the relatively open competition of industrial firms within and across national boundaries, the system of patent laws and property in knowledge has worked much as intended.

Although effective, the institutional system manifestly suffers from defects that make it less than ideal. It balances the private protection of inventions against the social interest in their widespread use in ways that we do not yet sufficiently understand. It is moving towards novel arrangements between business and universities that raise difficult questions about the balance of open science with proprietary technology. There is persistent debate about the volume of government support for research, about its instrumentalities, and about its allocation between education at its various levels and more direct aid to academic and commercial R and D. So the processes by which knowledge is produced, spread, and exploited need continuing hard study.

VI. The search for deeper causes: national and historical determinants

Simon Kuznets proposed that the proper unit of study of economic growth is the nation. He had in mind the fact that a large proportion of economic activity takes the form of exchange within national boundaries and that "strategic decisions" bearing on growth are taken by national governments and apply to activity within their own jurisdictions. There are other powerful considerations that support Kuznets's view, and some are suggested below.

The broad facts about national rates of productivity growth in the modern era that call for explanation are these:

1. The notable difference between the very slow rate of advance that preceded the Industrial Revolution and the more rapid pace characteristic of industrialized nations since that time.
2. The secular shifts in the average pace of advance by the industrialized countries of the "West" since 1870, when data for a considerable number of countries became available. The major shifts are the acceleration of labor productivity growth from about 1.6 or 1.7 percent per annum in the eight decades from 1870 to 1950 to about 4.5 percent in the quarter-century after World War II and the subsequent retardation to a rate of about 2.5 percent.[27]
3. The strikingly different record of the United States, marked by a moderate acceleration from about 2 percent from 1870 to 1913 to about 2.4 percent during the six decades from 1913 to 1973 and the relapse since that time to about 1.2 percent.[28] The United States, therefore, enjoyed no great postwar acceleration; but unlike most other industrialized countries, its subsequent slowdown has brought its rate of advance well below its prewar rate.
4. A tendency in cross-country comparisons among industrialized countries for productivity growth rates to vary inversely with relative levels of productivity and, therefore, for national productivity levels to converge. The strength of this tendency varied over time. It operated somewhat weakly before the postwar era, very strongly from 1950 to 1973, and more weakly since.[29]
5. The tendency to convergence was not uniform across countries. There were many shifts in ranks and the notable transfer of leadership from the UK to the United States near the turn of the century, followed by the great decline in the standing of the UK.
6. The tendency to convergence did not, for a long time, include a uniform general tendency for other industrialized countries to catch up to the United States. Although the productivity levels of other industrial countries were converging among themselves, the United States pulled further and further ahead of the average of other countries from 1870 to 1913. But there has been a strong general tendency to catch up to the United States since World War II.

The earlier discussion of the relations between technological advance and business investment had a particular bearing on differences among firms and industries in their technical efforts and results. These factors also underlie intertemporal and international differences in productivity growth. Insofar as a country's firms or industries display general differences from those of other countries or other times in respect to the factors governing investment in technological search or in the yield of investment, we have a clue to differences in productivity growth rates among countries and over time. To move from interfirm and interindustry differences to those that separate nations and periods, however, requires some further consideration. One must find a place, moreover, for factors other than the characteristics of firms and industries that bear on international differences and intertemporal changes in growth rates. It is convenient to employ a somewhat different framework of discussion than we have used so far. One structure that helps depict the broad outlines of the subject and that also displays its difficulties is to classify its parts under two headings:

The *potential* for productivity growth; and
The factors governing the *realization* of potential.

Potential

Potential has to do with the opportunity that exists during a period to raise productivity. In principle, one should consider every source of productivity growth. To retain the focus needed in a single essay, I take up only technological advance itself. The interdependence among sources, nevertheless, emerges because other elements of productivity growth appear either as conditions influencing the potential for technical progress or as factors governing the pace of realization of potential.

The potential for technological progress differs among countries, according to the degree to which their industries, or at least some firms in their industries, already employ the best practice that the current state of knowledge in the engineering sciences and in management permits. During the period of largely unchallenged U.S. technological leadership in the fifties and sixties, it could well be said: "it seems unlikely that in the US economy . . . the rate at which advances [in knowledge] were incorporated [into practice] departed much from the worldwide rate of new advance" (Denison and Chung 1976, p. 79). For such a country and in such conditions, the potential for progress is controlled by the scientific, engineering, and administrative possibilities that limit the pace at which effort devoted to search can further extend the frontiers of practical knowledge. This is the factor referred to earlier as "latent knowledge." This implies that countries whose industries stand generally at the forefront of technological practice may sometimes enjoy periods of rapid advance because the states of science, technology, and administration make the next steps easy and far-reaching. And they may sometimes suffer periods of slow growth when the path of advance is difficult.

Countries whose firms and industries are not up to worldwide best practice are in a different position. Subject to other considerations, they too enjoy an opportunity to make investments in capital that embodies the currently emerging technological frontier; but because, by contrast with the firms of a technological leader, their existing capital was technologically obsolete even when it was first built, the technological advance open to them is larger. They have a chance to close a technological gap inherited from the past. The chance to borrow existing technology added to that of searching at the frontier for new knowledge means that, for equal investment in R and D, the productivity rewards of followers will be greater than that of leaders. Other things being equal, the lower the productivity level at which a country works at any given time, the larger the leap it can make.

This difference between the technological potentials of leaders and followers is the central idea behind the "catch-up hypothesis" that accounts for the tendency of productivity levels in industrialized countries to converge.[30] And an enlarged technological potential based on a larger gap between existing and best practice, together with other factors, helps account for the postwar acceleration of productivity growth in the industrialized countries of the West.[31] The arguments just put forward are, however, unduly simple, even simple-minded. They skip over very important qualifications. There is more, and less, to the potential for productivity growth than is contained in the notions of latent knowledge and technological gap.

One consideration is that knowledge does not advance equally fast on every front. New technologies are not neutral in the demands they make for land, other natural resources, tangible capital, and human skills. Nor are they neutral in their dependence on large-scale operations for efficient exploitation. We need to know much more about the biases of technological advance in different times than we do. The U.S. spurt into productivity leadership in the last third of the nineteenth century and its ability to hold and even increase that lead during more than a hundred years thereafter appear to have been based on a congruence between the resource endowments and scale of the U.S. economy and the most fruitful directions of technological advance in the past century. The potentials of latent knowledge lay in the directions of unskilled labor-saving and resource- and capital-using methods and scale-intensive technology. Relative shortage of unskilled labor, plentiful supplies of resources and capital, and a large market tolerant of uniformity were U.S. economic characteristics.[32] At the same time, insofar as technological progress stemmed more from the United States than other countries, the best-practice techniques were given forms well-adapted to U.S. needs. Other countries were then able to borrow U.S. technology more or less easily depending on how closely their own resource endowments and the size of their markets resembled those of the United States. Countries with very different resource characteristics would have had an especially challenging task to adapt U.S. practice to their own conditions and would have had to develop foreign markets to supplement their own much smaller scale.

Now that the technological leadership in important industries is passing to other countries, it will be for the United States to face similar problems in adapting technologies pioneered elsewhere to its own different circumstances. At the same time there is no reason to suppose that the directions imposed by latent knowledge on the character of technological advance are now and will be in the future what they were in the past. They may distribute the relative advantages of progress to different countries in a different pattern.

There are more important restrictions, however, on a country's ability to exploit the potential of science and best-practice technology than are imposed by its natural endowment and market size. These are the limits set by what others and I call *social capability*.[33] The elements of social capability have a bearing both on the use that a country can make of advanced technology and also on its capacity to acquire it in the first place. I regard a country's ability to make use of technology as one constituent of its potential for productivity growth, so I consider it here. I take up its capacity to acquire new technology in connection with the factors governing the rate of realization of potential.

I identify social capability in part with the technical competence of a country's people and suggest that, at least among Western countries, this may be indicated by levels of general education and by the share of the population with training in technical subjects. Complicated and delicate machinery cannot be used to good advantage if managers lack technical knowledge or if workers lack some acquaintance with rudimentary mathematics.

If advanced technology demands operation on a large scale, it will not be used effectively if managers have little experience with the organization and administration of large firms. Large-scale production, moreover, works well only in conjunction with a variety of ancillary services – merchandising and distribution, finance, law, accounting, statistics, personnel administration. These services may be organized within producing firms or they may be sought outside, but the specialized personnel and experience are needed in one way or another. Financial services include those devoted to the mobilization of capital, which is a function of the development of a country's banking system and capital market; these in turn depend on the experience of people with investment in financial assets. In short, technology applied to production demands an overlay of business services, commerce, and finance. This is part of the message conveyed by the Clark–Kuznets observations about the connection between growth and the composition of output and employment.

The effective use of advanced technology also demands an extensive and expensive infrastructure of capital devoted to power, transportation, and communication. In the past at any rate, it has required the assemblage of people in large cities and therefore the organization of the government services that make urban life possible.

The elements of social capability constrain a country in its choice of technology. But technological opportunity also presses for relief from the social constraints.[34] Inadequate levels of education are raised; experience with large-scale business is gained as it is attempted; ancillary services respond to demand; governmental institutions are modified. Such changes, however, occur only with the lapse of time. Some move only with the succession of generations. It takes many years to raise the general level of education of the labor force by as much as that of its new entrants. Change is retarded also by the resistance of vested interests, and by the customary relations among firms and between workers and employers. As this resistance is overcome and their social capability rises, countries can exploit their technological potential more fully.[35]

In these respects, the United States had a fortunate beginning. Its domestic economy had grown up free of the traditional restrictions imposed by guilds, local ordinances, and mercantilist barriers on trade and occupation. The Puritan taste and tradition that spread from the Northeast to the West gave an early impetus to education in these regions. The country's republican and democratic institutions made wealth the dominant mark of distinction and directed talent to business. In all these ways, European countries were at a disadvantage and their social capabilities developed more slowly. These considerations have a bearing on the surge of the United States to technological leadership and on its ability to maintain a productivity lead for so many decades even over the socially and politically advanced countries across the Atlantic. The institutional constraints imposed by the past lend force also to Mancur Olson's suggestion that it required defeat in war, that is in World War II, and the accompanying political convulsions to clear the way in Europe and Japan for new men, firms, modes of operation, and state policies better fitted to the technological potential of the time (Olson 1982).[36]

If the only elements of potential were the latent knowledge beyond current best practice and the technological gap between followers and leaders, there would be a clear tendency for the productivity growth rates of followers to be higher than those of leaders; but the former would tend to slow down as their productivity levels converged on those further ahead. If, however, the process of catching up itself causes social capabilities to rise, the expected convergence may be erratic. Some countries may then advance faster than their initial levels of productivity would suggest. The self-limiting character of the catch-up process becomes problematic, and initially laggard countries may not only overtake but surpass an earlier leader.

One may summarize the position with respect to potential as follows. Insofar as the potential for productivity growth depends on technological opportunity it is governed by latent knowledge and by the gaps between existing and newly emerging best practice. Taken by themselves, their larger gaps give follower countries a relatively strong potential. They tend to enjoy relatively rapid productivity growth rates in a catch-up process that is self-limiting as nations' productivity levels converge. The technological opportunities of different nations, however, vary according to the congruence between their resource endowments and market scales on the one side and the characteristics of technology on the other. They differ also because of the varied limitations of nations' social capabilities. The opportunity for rapid growth afforded by technological backwardness may be offset by social backwardness. Social capability, however, responds in time to technological opportunity and changes also for other reasons, and this puts in question the self-limiting aspect of the catch-up process.

Realization

The potentiality determined by latent knowledge, technological backwardness, and the congruence between technology, resource endowment, and market scale may be regarded as governing a country's rate of advance in the very long run. This implies, of course, that the elements of social capability adapt to economic opportunity over long periods of time. The pace at which a country's potentiality is actually realized, however, depends on still other conditions.

A first and obvious matter has to do with the conditions that govern the rates of investment in the search for new technology and for the acquisition and adaptation of old techniques still not fully exploited – and with the yields of such efforts. Earlier discussion bears on this subject, and I now take up its implications for international differences and for changes over time. There are considerations that concern the efforts of both private and public sectors within countries and that affect the diffusion of knowledge within and between nations.

The capability of private and public agencies alike to engage in technological investment at any time is largely an inheritance from the past. This is so for the supplies of scientific, engineering, and technical personnel. Their numbers cannot be increased rapidly but are determined by past decisions regarding support for higher education and the nature and emphasis of university curricula and by past incentives that directed young people into scientific and technical courses. At a still more remote level, they depend on facilities for general education and on the family and social influences that join in preparing students for such training.

Education developed rapidly in the United States during the last century, first at the elementary level and, in the second half of the century, at advanced levels. In a democratic country where wealth was the principal mark of distinction, it responded readily to a sense that education could be the foundation for both individual and national prosperity.

In the same vein, there was an early beginning of university research directed towards agricultural and industrial technology. This, indeed, was the declared mission of the land grant universities, which were intended to be institutions of higher learning especially concerned with the agricultural and mechanical arts. Schools of engineering and of agriculture, which supported research laboratories in these subjects, flourished for decades in the United States on a scale unknown in Europe. During the same period, industrial research laboratories began to be established and to multiply. There were 139 such laboratories founded before 1900 (Rosenberg 1985; Mowery 1981).

America's early lead in organized efforts to apply scientific knowledge and methods to technical problems was given a great impulse by the scale of the U.S. market and the associated development of very large firms. Large-scale operations put a great premium on uniformity of materials and on exact knowledge and control of their characteristics. The large-scale distribution of foods demanded reliable methods of preservation and therefore more exact knowledge of the chemistry of decomposition. The concentration of slaughtering and meatpacking in a small number of very large firms enormously increased the mass of waste materials and drove the industry to transform them into useful by-products. These were possibilities that were opened by scale but depended on systematic analysis to determine the exact chemical composition of the wastes. They serve to illustrate the general character of the process.

By contrast with the United States, the expansion of secondary and higher education in Europe on the whole took place more slowly. With certain notable exceptions in Germany, so did the provision of university and business laboratories directed to applied science and industrial technology. The result was that the United States gained an early advantage in industrial research[37] that it was able to keep for a long time and that contributed to that country's long-sustained lead in overall productivity. The size of the U.S. lead in provision for education and in industrial research was being slowly reduced all through the present century, and it was cut still more speedily in the years after World War II.

Apart from the channels and volume of support, there is the question of the orientation of scientific studies. During much of the nineteenth and early twentieth centuries, European scientists appeared to lead in theoretical work and fundamental science, whereas the United States seemed to be especially effective in using basic knowledge to advance technology. Since the 1930s and still more since World War II, to the accompaniment of a great expansion of public support, U.S. scientists – and more generally scientists working in the United States – have assumed the leading role in pure science without, however, abandoning their older cultivation of applied science. And it is now the Japanese of whom it is said that, although they are not leaders in pure science, they are especially capable in the technological exploitation of scientific knowledge. All this, however, is almost certainly in the course of change. As the postwar convergence of average productivity levels proceeded, Japan and the various countries of Western Europe assumed the technological lead in certain branches of technology. These will presumably become more numerous. Japan and Europe, moreover, are now able to devote larger resources to scientific research, and it is altogether likely that they will come to share widely in the leadership of science which the United States enjoyed in the years following World War II. It would then be natural if a certain degree of transitory specialization should emerge and if particular countries should, for varying periods, prove to be the leading centers of training and research in specific branches of science.

National differences in effort and achievement in pure science, however, have not in themselves been an important source of national differences in technological progress – at least not hitherto. The ethos and practice of science has ensured that knowledge, wherever it has been gained, has been promptly and widely disseminated and open to those capable of using it.[38] What has counted for individual countries has been their capability, technical and commercial, for exploiting the advances of science. What has counted for the industrial world as a whole has been the worldwide volume of such work, which has been much larger in the postwar period than ever before, and the interaction between scientific effort and practical needs, which has been more intense than ever before. Both changes contributed to the rapid pace of postwar productivity growth and, doubtless, are continuing to support the advance of technology.

Government support for research, of course, is not confined to research in universities; nor is it confined to the support of basic science. It extends to the search for more direct and immediate technological applications and involves a variety of instruments ranging across government laboratories, the organization and partial support of corporate research consortia, and research contracts with business corporations.

In the United States, much more than elsewhere outside the USSR, government support is skewed towards research for military purposes. Indeed, government expenditure for military research in the United States is disproportionate even to the large share of national product that goes for defense itself. The net effect of this disproportionate allocation is probably a reduction of support for work of civilian significance. The loss, however, may be smaller than it seems, because the proceeds of defense research contracts serve to some extent to support general university activities, because there is some civilian fallout from military research, and because the perceived urgency of research for military purposes has served to make the total volume of government support larger than it otherwise would be.

I recite these fairly well-known matters to reinforce a general point: The pace at which nations can exploit either latent scientific knowledge or technological gaps depends on a variety of institutional considerations, and among these are the established practices that govern the relations of government, universities, and business in the conduct of scientific work.

To complete this discussion of the facilities that govern the pace of technological search and its effectiveness, I add some remarks about factors that bear on the diffusion of knowledge both within and among countries. In the course of the postwar period, there was a great proliferation of technical and professional associations and publications. The channels for national, and still more for international, trade and investment were enlarged, and the increased flows of goods and capital, accompanied by faster and cheaper movements of people and messages, carried technical as well as commercial information from region to region and country to country. Whereas foreign investment before World War I had more largely taken the form of

investment in securities, direct investment became more important after World War II. The foreign activities of leading U.S. corporations involving joint ventures, multinational corporate operations, and extensive cross-national agreements for technology transfer became a notable feature of postwar business. In all these ways, the pace at which working knowledge moved from place to place in a practical and effective way was speeded up. This helped to raise the rate at which the technological potential of the postwar period was realized and contributed to the progress made in Europe and Japan in catching up to the United States.

Furthermore, beyond the facilities and practices that are more or less directly connected with technological investment, there are the factors that control the speed with which the economies of nations can adjust to the structural changes required by productivity growth. The enlargement of total output and of per capita incomes does not, needless to say, take the form of a proportionate expansion of each component of consumption and production. The composition of consumption tends to shift away from the relatively unprocessed products of agriculture, at first towards the more highly processed products of manufactures and then towards services. The nature of technological progress, including specialization and division of labor, is such as to save labor in the fabrication of goods themselves but at the cost of a great expansion of the auxiliary services of administration, finance, transport, communications, distribution, and many other ancillary functions. The urbanization of production and population required by modern technology and organization demands an expansion of governmental services, first at a local level, but later in national governments. The human capital requirements of modern technology imply a continuing expansion of the resources devoted to education and adult training. In many spheres of industry and commerce, technological advance demands an increase in the scale of operations of firms and industries and comparable enlargement of markets. In other spheres, technology permits operations on a smaller scale. Consumption trends and technology itself, therefore, combine in a demand for radical changes in the sectoral structure of production, in its geographical distribution, in the occupational composition of the work force, and in the organization of industry and commerce.

The pace at which technological potential can be exploited depends on the speed with which the structural changes implied by productivity growth can be carried through. What conditions control that speed? Here, again, we know much less than we need to. However, there are reasons for thinking that relatively favorable conditions existed in the United States from the beginnings of industrialization and that in the postwar period they became much more favorable in Europe and Japan than they had been before World War II and to an even greater extent more favorable than before World War I.

In the United States, the occupational and geographical mobility of the labor force was supported by rapid population growth, which made the new classes of workers each year large compared with the classes of older, settled workers. The annual arrival of great numbers of immigrants added a special increment of relatively unattached workers. The westward expansion of the country prevented the growth of firm regional roots. The rapid movement from the Atlantic to the Pacific made for more homogeneous styles of life throughout the country than was the case in Europe. And these same conditions also helped form this nation's great domestic markets, which in turn made it easier to accommodate the technologies demanding large-scale production.

After World War II, structural mobility was supported in both Europe and Japan by large reserves of labor on the farms, reserves made still larger in the postwar years by rapid advances in labor productivity. By contrast with conditions before World War I, the redundant European farm populations were denied the chance to come to the United States. They moved to fill the domestic needs for urban employment in their own countries. Eager for growth, moreover, the West European and North European countries opened their borders to immigration from the Mediterranean, which was added to that into West Germany from East Germany and the territories lost to Poland. In all these countries, and still more in the United States, the entry of women into the labor force was another source from which jobs of new sorts in new places could be filled. And the liberalization of international trade together with the creation of the Common Market and of the European Free Trade Association eased the way to large-scale production even for firms in the smaller countries.

When the attempted pace of growth involves changes greater than the mobility of a country's labor force and population can absorb, bottlenecks develop, the skill standards of jobs are diluted, wages rise faster than productivity, and product prices rise. Inflationary tendencies unsettle business and finance, and the balance of international payments weakens. The resulting disjunction between the demand for monetary growth to support inflation and the supply of money that the international position of a country can support imposes a period of recession or retardation. But when and where conditions of mobility are favorable, rapid growth can be sustained for longer periods. Thus the conditions of resource mobility help to govern the pace

at which technological change can be realized and they contribute to the uneven path that growth normally takes.[39]

Finally, there are the macroeconomic conditions that govern business investment decisions in general. These may be especially important for the risky, long-term decisions that control expenditures for research and the much larger expenditures needed to bring the results of research into actual production. These conditions involve a wide variety of matters. They include the fiscal and monetary institutions and policies of national governments and also the institutions and policies that influence international economic stability. The liquidity position and, more generally, the asset–liability structure of business is important. So are the activities of governments in providing the infrastructure of communications, transportation, and power on which the investments of private business can be built. Finally, there is the impact of extraordinary events, of which wars and their aftermaths and OPEC oil shocks are dramatic examples.

From the viewpoint of growth history, the essential point is that favorable or unfavorable macroeconomic conjunctures can persist over several decades – long enough, therefore, to make a difference to that long-term experience of nations with which economic growth is concerned. It is apparent, for example, that the years from 1914 to 1945 or 1950 saw a generally disastrous conjuncture of macroeconomic conditions that depressed investment and productivity growth rates for over three decades. By contrast, the next quarter-century enjoyed a most favorable conjuncture of institutions, policies, and circumstances, which gave way again to the much less favorable conditions that have ruled during the last fifteen years and that still persist.

The discussion of the elements of productivity potential and realization can take us some distance towards an understanding of certain leading features of the growth experience of the industrialized countries. The wars and the disturbed state of politics, finance, and business from 1914 until after the end of World War II produced a hiatus in European and Japanese growth relative to that of the United States. It left these countries at the end of World War II with greatly enlarged technological gaps. Because their social capabilities were strong and had continued to rise, however, their potential for productivity growth was especially powerful when the postwar period began. And that, together with the great improvement in conditions supporting the realization of potential, were the bases for the postwar growth boom, for the strong convergence of the productivity levels of these countries, and for their rise relative to the United States. Finally, a deterioration of the conditions supporting realization (the breakdown of postwar international monetary arrangements, the oil shocks, the unusual combination of inflation and recession, and the retreat from free trade) and a weaker potential, reflecting the presumptive narrowing of technological gaps, were contributors to the general productivity slowdown of the last dozen or more years.[40]

This outline of the elements of potential and realization, although quite broad and general in its range of application, is still limited in certain ways. It suggests that social capability rises in a linear fashion, becoming steadily more able to cope with the opportunities presented by technological potential. That is not necessarily so. Countries' physical, organizational, and doctrinal adaptations to the opportunities and requirements of older technological paths may limit their ability to exploit newer directions of technological progress. Considerations of this sort may have restricted British growth after 1870. Similar ideas are being revived now to account for the marked retardation in U.S. growth in recent years. U.S. firms were pioneers in the techniques of mass production, and the huge U.S. corporations were successful adaptations to the opportunities of scale-intensive technological progress. When superlarge conglomerate corporations appeared, they were regarded by many as effective ways to economize scarce talents in management and in the mobilization and allocation of finance. U.S. managerial doctrine absorbed these ideas and they have guided managerial practice. Now that technology appears to permit cheap production of more varied lines of goods more closely fashioned to meet the tastes and needs of smaller groups of industrial and commercial users, as well as ultimate consumers, observers question whether the immense U.S. corporation and its established managerial doctrine are effective instruments for exploiting the newer possibilities. If this is a difficulty, how serious is it, and how long will it take U.S. organization and practice to change?

The complexity of such questions appears as soon as one considers the fact that not every U.S. company is superlarge; nor are all Japanese or European firms much smaller than U.S. firms. And, of course, every firm, large or small, satisfies a large portion of its needs by purchases from others rather than by internal supply. Contemporary theory views the size, organization, and policy of firms as determined by the relative costs of supply from internal and external sources. In the evolutionary test imposed by market competition, the responsiveness of external suppliers to the needs of a purchasing firm is weighed against the cost of obtaining equal responsiveness from the firm's own staff. The outcome depends on the peculiarities of a given firm's own operations, which may limit the ability of a supplier to satisfy

that firm's special needs, and also on the economies of scale and scope, the costs of communication and decision within the firm, and the difficulties of eliciting dedicated effort directed to its purposes, rather than to the possibly divergent interests of individual employees (Matthews 1986; Williamson 1985).

Technical innovations, such as computers, presumably propel industrial organization in different countries in the same direction. In contrast, a national ethos that controls people's honesty and sense of interpersonal obligation may produce national differences in company size and in their styles of organization and operation. Empirical work that may reveal how these considerations may share responsibility for change over time and for differences among countries has not yet gone very far. The theory itself does not yet incorporate the financial influences that may impede or facilitate institutional reorganization, a question urgently raised by the recent wave of mergers, takeovers, divestitures and so forth, in the United States. Reorganization in the direction of an increased capability for the effective exploitation of technological potential may, indeed, be in progress. How consistently it is moving and how fast relative to some undefined model of efficient organization is still a mystery.

VII. Longer thoughts about long-term growth

Considerations bearing on the size and organization of firms do not bring into view the full range of issues raised by the nature and evolution of economic institutions. There are more extensive, but also perhaps more elusive, questions to consider. Some passages from Simon Kuznets provide a start.

> The epochal innovation that distinguishes the modern economic epoch is the extended application of science to problems of economic production. (1966, p. 9)
>
> The application of science meant a proper climate of human opinion in which both the pursuit and use of science could be fostered; and thus when we say that the modern epoch is distinguished by the application of science to problems of economic production and human welfare, we imply that it is distinguished by a climate of human opinion, by some dominant views on the relation of man to the universe that fosters science and its application. (Ibid., p. 12)
>
> The broad views associated with the modern economic epoch can be suggested by three terms: secularism, egalitarianism, and nationalism. (Ibid., p. 12)

Kuznets took secularism to mean "concentration on life on earth, with a scale of priorities that assigns a high rank to economic attainment." This stands in contrast with a view that earthly life is but a brief prelude to an otherworldly eternity. Secularism "makes man paramount and life on earth his main concern" (Ibid., p. 13).

He viewed egalitarianism as the denial of inborn differences among human beings except as they reveal themselves in activities regarded as valuable by others. Egalitarianism, therefore, recognizes no mythological, hereditary, or religious distinctions among people, but it tolerates and justifies large and unequal rewards if they are thought to be received by the economically efficient and used by their recipients "as capable stewards for society as a whole." Egalitarianism, as Kuznets saw it, protects individuals in the free pursuit of their highest economic potential and sanctions rewards proportionate to their productivity. It caused a "shift in the bases of social prestige and political power" and induced "a much larger flow of talent and energy into economic rather than other pursuits" (Ibid., p. 14).

Kuznets saw nationalism as a severe constraint on egalitarianism because it accords equal treatment only to those accepted as members of the national community. But it was also the foundation of the nation-state, an effective unit of power capable of taking and executing strategic decisions and providing services supportive of growth.

In Kuznets's argument, science-based technology and the three broad views needed for its successful cultivation and exploitation appear as distinctive features of the modern economic epoch. As such, they serve, in his view, to distinguish that epoch, for those countries that have entered it, from earlier epochs. So regarded, they are an important conception. However, it is a very generalized conception. It refers to an outlook on life and the world that may need to be accepted in some sufficient degree by all societies that aspire to modern growth. As we shall see, however, there are exceptions even to that minimal requirement. And even where it is met, it is an outlook that people in different societies may entertain in many degrees and in many variants. Notions about what constitutes the good life, the expectations and aspirations proper to different social classes, the bases of distinctions among them, and the standards of decent behavior were hardly the same in, say, Britain, the United States, and Japan when each entered the process of modern economic growth.

Moreover, even if we suppose that Kuznets's "broad views" are characteristic in some adequate degree of people in all countries that experience modern growth, yet it is apparent that this generalized outlook is embodied in political institutions and forms of economic organization that differ sharply among industrialized countries. The differences spread across countries in a wide range, from those that organize activity largely through private enterprises connected by trade in free markets, to the highly centralized, hierarchical systems of planning and command, as in the USSR.

Finally, neither the broad views that people hold about the ends of life, about the rights and obligations of people, and about the relations among classes, nor the political and economic institutions in which these views are embodied are grand constants. They evolve in the course of economic growth in response to influences generated by growth itself, as well as in response to other influences. I can do little more than indicate the directions in which these difficult and subtle issues take us. I do this, first, in the course of brief comments on the class divisions, personal aims, and standards of conduct in the United States, Britain, and Japan.

Classes, goals, and standards of behavior

To Europeans of the early and middle nineteenth century, the United States appeared to be a historical exception. It differed from Europe in respect to all three of Kuznets's broad views. It was more intensely secular in Kuznets's sense of being concentrated on earthly life and assigning a high priority to economic attainment. Because land was plentiful and cheap, ordinary people could aspire to a decent competence. Because the country was growing in population and trade, so were productivity and average incomes; so people could aspire to still greater prosperity. The Puritan strain in religion interposed no obstacle to the pursuit of wealth, and an intense egalitarian ethos lent powerful social support. The older European class distinctions based on birth and class had hardly survived the New World's wider dispersion of property and economic opportunity. People judged each other more largely on merit and, lacking other marks of merit, wealth had become the main badge of distinction and of class. Because the paths of wealth were relatively open, class lines were easily crossed; so the pursuit of social distinction joined more commonplace influences to heighten the priority assigned to economic attainment.

The U.S. nationalism of the nineteenth century also had its peculiarities. With the adoption of the Constitution and the subsequent growth of wealth, the United States became an effective nation-state, well able to make the strategic decisions that were among the foundations of its development. The singularity of U.S. nationalism was that it did not deny the benefits of residence and citizenship to foreigners. New arrivals faced difficulties of language and of adaptation to new ways and a new environment. These, however, were usually surmounted in the space of a generation or two, and the United States of the nineteenth and early twentieth centuries was a successful experiment in the assimilation of many nationalities and cultures. The country therefore benefited from growth in numbers of people through immigration and from the variety of talents that immigrants brought.

In such an egalitarian society, relations among people were founded on agreement and contract to a degree less qualified than elsewhere by custom and ancient usage. At the same time, the conditions of a relatively stable rural and small-town society combined with religious sanctions to enforce the faithful observance of agreement. To give less than full pay or full measure, to do less than an honest day's work, were even more matters of local shame than of legal default.

Fluidity of class lines softened class hostility and eased the relations between employers and employed. The individualistic presumption that relations among people should be matters of personal agreement weakened any feeling of governmental obligation of support of the poor and kept public regulation of economic activity within narrow limits. The goal of increased income, however, fostered an early concern for schooling, and a sense that the common interest in education exceeded the private encouraged support for schools from public funds. The U.S. system of public education was founded early and expanded relatively quickly.

The monstrous aberration in U.S. egalitarianism was black slavery and the persistence of discrimination that followed legal emancipation. Racial barriers and disabilities endure to this day and, besides other evils, deny to economic life the full talents of considerable portions of the population.

Britain, by constrast with the United States, entered its era of modern growth with a more substantial inheritance of caste and class. This separated the nobility and gentry from peasants and workers. Between these two classes, a middle class of businessmen and professionals had established themselves. Class lines were not rigid boundaries; they could be crossed with the help of wealth. However, Britain was less egalitarian than the United States, and wealth alone counted for less. Distinctions based on birth, education, and occupation persisted, and they had persistent effects.

One such effect is in the relations between workers and employers, which was, and still is, afflicted with a degree of hostility strange to most Americans. The employment contract in the United States shares some of the overtones of other commercial transactions. Many workers who take a job see that one day they may be on the other side of such a contract. In the past, that was often so. In Britain, however, employment is an enduring relation between people of different class. They feel their interests to be in opposition and workers, conscious of class, disdain to change sides; they prefer to stand and fight. Industrial conflict is therefore endemic, and the sense of permanence in worker status has the effect of inhibiting innovations that threaten jobs or even a shift of functions and occupations.

A second effect of the persistence of class distinction in the UK was the drain of talent from business, more particularly from manufacturing and trade. Members of the middle class were ambitious that their sons might be gentlemen, and that meant a proper occupation. So a manufacturer's son, if he was clever enough, was pointed to the law or, still better, to the civil service or, if not quite so clever, to the City or perhaps to the army.

Education, however, came first, and a proper education was one fit for a gentleman. In England, that meant, until comparatively recently, a classical education. It was imparted, following preparatory classes, first in public schools, whose students were the children of gentlemen or of aspiring gentlemen. And it was continued in the ancient universities which were hardly less class-bound.

All this gave the education of the British, more particularly the English, elite a peculiar, premodern bias, both in its subject matter and in the class divisions it helped to perpetuate. Class feeling also left its mark on British mass education. The upper class who controlled British politics in the nineteenth century were slow to be persuaded that mass education was needed and that state support was justified. The Church of England resisted state schools that would be nondenominational. Moreover, when a state system was at last established, British working-class feeling gave less than ardent support for its extension. Many workers resisted the view that schooling, at any rate schooling beyond the elementary grades, would be an advantage to their own class-bound children. The net result was that, although Britain had been the leader in nineteenth century industrialization, the school system expanded more slowly there than in the United States and more slowly also than in some continental countries (for example, Prussia) that were comparative latecomers to modern growth.[41] There is at least a strong suspicion that the biased character and slow growth of British education made some contribution to the relative decline of British productivity growth during the present century.

Kuznets's trilogy of secularism, egalitarianism, and nationalism is again a convenient way of describing the outlook and attitudes of the Japanese. In these respects Japan has been and is very different from the United States and Britain; and the differences help us see why Japan was able to accomplish her immensely rapid transformation from a backward, feudal society to a modern industrial power.

As regards secularism, the interest of Japanese people in the things of this life and the importance attached to economic success were and are very high, certainly comparable with the feelings of Americans. There was, however, this difference. From the beginning of Japan's modern era, the private interest in economic attainment was accompanied and, indeed, spurred and led by a powerful political interest. When Japan abandoned its older feudal regime, the imperial circles and lower samurai who were the driving force behind reform saw economic modernization as essential for the maintenance of national independence and power. A potent political motive, therefore, was a central element in Japanese secularism. That Japanese modernization was a state-planned and state-controlled enterprise was a consequence of this difference in the Japanese outlook (Norman 1940; Ohkawa and Rosovsky 1973, Chap. 1). To this there were added other great differences in the spheres of egalitarianism and nationalism.

Kuznets's egalitarianism, as we have seen, has the function of establishing merit, more particularly merit in productive activity, as the basis of material reward and social prestige. It opens the way to talent and sanctions rewards for its accomplishments, therefore providing an incentive for its exercise. The feudal Japan, from which modern Japan began to emerge little over a century ago, was not egalitarian in this sense. It assigned people roles in which each had a proper station clearly marked out by sex, age, and membership in a feudal caste – noble, warrior, peasant, artisan, tradesman. People's proper stations defined their rights and their strict obligations. The fundamental unit was the immediate family within which authority and obligations were defined by sex and age. Families and their members owed duty and obedience to their feudal superiors in a line stretching upward to shogun and Emperor. The obligation defined by station demanded the strict fulfillment of duties, failing which the shame and guilt that attached to the person and family were intense, and punishment, whether inflicted by authority or by oneself, was severe. Although caste lines were not utterly rigid (a rich merchant might ally his family with the lower samurai), the scope for exercise of talent outside one's normal sphere was restricted.[42]

The reforms following the Meiji restoration went some distance to inject an element of Western egalitarianism into Japanese society. The legal privileges and restrictions of the several castes, which controlled occupation, dress, and consumption, were abolished. The larger-scale firms that very gradually replaced the family farms and shops of premodern Japan enlarged the scope for talent. But much of the older feeling of proper station, and of the reciprocal obligations so defined, remained. In some ways they were extended. The loyalties and obligations that ruled within families proved to be transferable to the relations of employers and employed and to the relations among the

larger assemblages of people in the huge firms of a modern economy. They seem to lie behind the loyalty that many observers say that Japanese workers and managers bear to their firms. They act as sanctions for the faithful execution of tasks and the single-minded attachment of executives and workers to the success of their companies (Benedict 1946;1974; Abegglen and Stalk 1985, Chap. 8).

A sense of hierarchy and of deference to those whose proper station is higher is also characteristic of Japan in the political sphere. Following the abolition of the feudal castes, the older sense of obligation and submission to authority was transferred directly to the Emperor and to the bureaucracy, who were his appointed officers. There was therefore an effective concentration of authority in the state. It enabled the group around the Emperor to carry through a series of social and economic reforms that were not widely popular. It enabled the state to establish the basic modern industries (and to transfer them to the private ownership of a restricted group), to arrange for the cooperation of foreign experts and for the technical and business training of Japanese both at home and abroad, to reform mass education, and to found modern universities. The special position of the Emperor and his bureaucracy, resting as it did on the Japanese sense of hierarchy and duty, satisfied one of the functions of nationalism as Kuznets saw it. It made the state, in superlative degree, an effective agent of economic modernization (Norman 1940).

The other characteristic of Kuznets's nationalism, its exclusive aspect, was also present in Japan in an intense degree. The Japanese were and are an ethnically homogeneous society. The sense of both kinship and exclusivity was doubtless reinforced by the centuries of isolation that preceded the Meiji restoration. In Kuznets's view nationalism works to restrict the significance of egalitarianism by limiting access to the benefits of economic opportunity to members of the nation. In this respect, the United States, a nation of immigrants, has been a generally open society. Britain, with a stronger sense of national identity, was still able to accept a long regime of freedom in the movements of people, goods, and capital. Japan's position, however, was extreme. Its intense nationalism was a natural and powerful support for development based on formal and informal protectionist policies and on the virtually exclusive participation of its own citizens. The counterpart of this nationalistic policy of development was the power of the state to make the decisions required for modernization and to enlist the cooperation of its population.

These comments on the outlook and climate of opinion that govern relations among people, between employers and employed, between people and the state, and between one national community and others are enough to suggest their importance. They influence technological progress and growth through their bearing on the scope for the use of talent and the direction it takes, on the spread and content of education, on the costs of innovation and structural change, and doubtless on much more. They also suggest that no single variant or combination of attitudes is consistent with growth. The differences between the United States, Britain, and Japan tell us that there are complexities and subtleties in the content and meaning of secularism, egalitarianism, and nationalism. These have promoted or hindered growth in each country, but the differences in social climate that we can connect with Kuznets's trilogy are not to be measured along some uniform scale. Attitudes and values have many dimensions and work along multiple axes. Egalitarianism, in the Kuznets sense, means scope for talent; together with secularism, it means energy and talent directed to economic achievement. But hierarchical authority and deference to superior station, which may appear to be the antithesis of egalitarianism, may support cooperative activity and the power of the state to make and carry through strategic decisions. Together with secularism and bolstered by nationalism, it may also mean energy directed to modernization and growth.

Besides attesting to the importance of social climate and to its complications, these remarks also testify to our ignorance about it. For lack of a theory of social climate and its consequences, economists have not known how to study the subject. And for lack of interest in the problem of growth, except perhaps as it concerns the less developed countries,[43] the other social sciences have also neglected it. When economists construct models of growth, they have been implicitly based on the assumption that social climate is a constant. In comparisons over time, it is assumed not to change; in comparisons among countries, it is assumed to be the same. When such an assumption is too implausible to maintain, as it would be in comparisons between industrialized and underdeveloped countries, studies keep the two sets of countries in different boxes, as this paper itself has done. So there are separate branches of growth studies, one for industrialized countries, another for less-developed countries.

From laissez-faire to the mixed economy

Our pronounced ignorance about the content of climates of opinion and how they operate to promote or thwart technological progress and growth is compounded by the fact that individual attitudes and social outlooks change in the course of growth itself. The secular and egalitarian outlook that, in various degrees, characterized the countries of Western Europe and North America in the middle nineteenth century had a dominantly individualistic coloration. It made families and their members responsible for their own fortunes and left governments with comparatively few responsibilities and functions. For these countries, but not for Japan, the transformation that matters is that from the relatively individualistic outlook and relatively laissez-faire policies of the nineteenth century to the mixed economies and welfare states of the present time. It is a change that is itself best viewed as part of technological development and modern economic growth as they proceeded in the Western political and cultural context. The change arises from people's latent desires, revealed by higher levels of income or aroused by the education and technology on which income growth itself was based; from the structural changes that are implied by growth, the costs and conflicts of the process, and the new organizations of population, production, and family life needed to sustain advanced levels of technology; from the inherent instability of growing economies organized mainly by private enterprise; and from the generally democratic or, as Kuznets said, the egalitarian, character of Western political systems. Economists and other observers and critics emphasize different aspects of these background causes, but all are involved.

1. The rise of income has released or aroused demands that impart a new content to the secularism and egalitarianism on which Kuznets contended that modern economic growth rests. Secularism continues to mean a "concentration on life on earth," but its scale of priorities no longer assigns the same "high rank to economic attainment" – not if that is identified simply with productivity, that is, the measured outputs of marketed goods and services and the time and effort spent in producing them. Rather, our concerns have come to emphasize other interests that are not included in measured productivity and that must be pursued in one way or another through the agency and activity of government.

One such concern is safety. The science that has given us novel and wonderfully serviceable products has also made us aware that products, materials, and occupations may carry dangers, immediate or remote. Unable, however, to make reliable judgments themselves about specific products or jobs, people press strongly for government regulation of both consumer products and services and of conditions of work.

The rise of income has also revealed a latent demand for protection against the most compelling incidents and hazards of life, for care in sickness and for maintenance in old age. This desire is all the stronger because the advance of technology has enlarged the scope of what medical care offers and because the extension of life has increased the span of years in retirement. These enlarged demands do not imply a diversion of resources to unmeasured output, except insofar as improvements in the effectiveness of medical care is a particular dramatic example of the qualitative improvement that national product fails to measure. But the demands have been the occasion for using the government as the tax-paid provider of at least a portion of health care, as the organizer and provider of health insurance and old-age pensions, and as the redistributor of their costs. Moreover, although the reliance on government in this sphere stems from a number of causes, one is the weakening of the family itself, an important matter to which I will return. This has called for an alternative source of protection in time of trouble and for another way of redistributing the costs of sickness and age between generations.

Next, the rise of incomes, and of the education on which it is partly based, has increased our concern for the environment in which we all live, and it has enabled us to support that concern with funds. This is only partly a matter of our enlarged demand for safety already noticed. It is also a demand for beauty, solitude, recreation, adventure, and solidarity with other living species. The protection of these scarce attributes of nature involves a diversion of resources to unmeasured output; and since the depradations of extended use are the external effects of individual consumption and production, the government becomes our natural protective agent. The concerns that John Stuart Mill voiced so many years ago and the role for government that he sketched became at last a matter of practical politics.[44]

Egalitarianism too has come to mean something different from what Kuznets saw in the outlook underlying modern economic growth. Kuznets thought of it as equal freedom to use one's abilities and to follow one's bent in the pursuit of personal fulfillment – careers open to the talents, with rewards according to one's production. He saw the rise of average income as a source of ease that made the concomitant income inequality tolerable. Matters appear to have taken a different course. In the ease created by higher incomes, the need to tolerate inequalities in order to support the inducement to work, save, and venture came to seem less urgent. The result was our governmental systems of redistributive income transfers, intended not only to add to the capabilities of the less well endowed, but also to increase their incomes directly.

2. The predilection for safety, security, and equality has a wide and compelling field for exercise in the structural changes required by growth and in its inherently unstable character.

Growth based on technological progress means large, often rapid, shifts in the distribution of employment among industries and occupations. It means migration of people from one locality or region to another, from country to country, from countryside to city, and from city to suburb – and back again. The shifts occur partly by attraction, as growing employment openings induce people to change jobs and homes. But they also occur by compulsion, when changes in demand, labor-saving techniques, cheaper sources of supply, or novel products bankrupt or shrink old firms or farms and close down old jobs. The adjustments can sometimes be made slowly and without great pain as young people take up new jobs in new places while jobs in old industries and localities shrink by attrition. But not infrequently the shifts are more rapid and drastic. Then the generalized rewards of growth are paid for by costs imposed on a minority who must pack up and move, abandon old skills, homes, and connections, and try in mid-career to rebuild a damaged life.

Growth, therefore, means cost, conflict, and resistance. Translated to the political sphere, these are a temptation to protectionism, and for a long time this has been a governmental response to the costs of structural change. It still is. Gradually, however, governments began to experiment, not always successfully, with more constructive alternatives, the elements of an "active" labor-market policy. These have gradually built up from employment exchanges and unemployment insurance to programs for retraining, grants to aid relocation, and subsidized work programs.

Insofar as growth involved urbanization, it called forth the first large expansion in the role of government – that is, the expansion of municipal government to provide the services that make possible large concentrations of people. And insofar as modern economic growth separated people from the land and required intergenerational shifts in occupation and location, it weakened the family's capacity to carry out its traditional functions of rearing children, caring for the sick, and maintaining the old, and it impelled governments to provide public substitutes for these services.

3. The inherent instability of economic activity and employment in private enterprise economies in the course of growth has consequences similar to those of structural change. It imposes severe burdens on the victims of business contractions. Its irregularity and unpredictability make it hard for individuals themselves to provide against the risk, whereas the moral hazard involved makes private insurance impracticably expensive. Publicly provided unemployment compensation, therefore, has become a universal feature of Western economies. And when it appeared that governments might be able, by monetary and fiscal policies, to take practical steps to stabilize business, these functions were also assumed. How much has been

accomplished by fiscal and monetary management remains in dispute. It seems clear enough, however, that the very growth in the size of government has had the welcome by-product of making a considerable share of all employment and income less vulnerable to fluctuations in market demand. The system of transfer payments, adopted for other reasons, has similarly reduced the cyclical vulnerability of income flows. And the regulation of securities markets, the insurance of bank deposits, and the standby resources of central banks have rendered financial markets and institutions less susceptible to the panics and crises that were among the most potent sources of past depressions.

4. Governments striving for national growth are driven to assume investment functions, as well as some current service functions, that private enterprise cannot or is not impelled to take on. They were again foreseen and defined nearly 150 years ago by J. S. Mill, himself a great defender of limited government. Their hallmarks are huge size, distant and uncertain returns, externalities that promise larger social than private products, the involvement of governmental authority (e.g., eminent domain), and the creation of natural monopolies. Transport, communications, and water supply systems, education and research, and the public provision of statistical and other information are common and well-understood examples. There are questions about methods – whether regulated private power companies are more efficient instruments than publicly owned enterprises, or whether education vouchers should be used to permit families to make financially unbiased choices between public and private schools. The functions themselves, however, are not in serious dispute.

5. The spirit of individualism that supported the relatively unregulated economies of the nineteenth century with their limited role for government was the outlook of those restricted classes in whom the political power of the time was concentrated. It was less objectionable to people generally because such a large proportion of them still lived on the land in accustomed ways, because the costs associated with industrial occupations in a growing economy were still not widespread, and because the egalitarianism spawned by the French Revolution was still a novel force. All these conditions changed as technological development proceeded and incomes rose. In particular, the new egalitarian spirit, joined with an appreciation of the possibilities and requirements of technologically driven growth, made for an expansion of education. The movement to universal suffrage and the diffusion of political power followed. They formed the political base on which the elements of economic welfare that are not measured by per capita income and that are pursued through government could be built.

This statement, though true enough as far as it goes, is insufficient. It does not deal with the limitations of the political democracy of the West as a means of representing the desires and interests of people at large. There are two problems.

The first is that our system of representative government is an effective but still a very imperfect instrument for expressing the general interest. The reason is well known. It is the political activism and, therefore, power of minorities, who stand to gain from legislation in their special interest. This is matched by the corresponding passivity and political weakness of the generality of people, who are not stirred to resist the diffused and therefore relatively small costs that particular governmental actions impose on individuals. The result is that the various goals that government has been led to pursue, whether justifiable in some general sense or not, tend strongly to be pursued in a biased fashion and often by inappropriate methods. The bias is in favor of the limited groups who, in each case, stand to benefit; the bias is against the general population who, in almost all cases, bear the cost.

In the minds of some critics, this political flaw stands as virtually the sole stimulus or source of the rise of government. In their view, the distortions to which it leads are great enough to make state intervention in general a negative force. Laissez-faire with all its tolerance for market failures would be better, they contend, than the governmental failures that are the unavoidable concomitants of government action. And even those critics who concede that government action in some spheres, by some methods, and in some degree is desirable are clear about the direction that reform should now take. They would reduce the scope of government generally and drastically.

There is a second flaw. We often have only vague ideas about the needs to be met, what government can do to satisfy them, and the costs of trying to do so. Governmental action, therefore, has the character of a series of expensive experiments. Costly mistakes are inevitable, their lessons are hard to learn, and, when learned, are politically difficult to correct.

One is left, therefore, with a sense of great change in the social climate underlying technological progress and economic growth, and of great change in the economic institutions that the new social climate has tolerated and supported. The developed countries of the West now enter a new phase of modern economic growth with new views of what our societies should try to do and of what in the changed circumstances created by past growth, individual effort, and market-organized exchange can do. The much larger role that has been assigned to governments represents our attempts to pursue aspects of economic welfare that are, in one degree or another, beyond the competence of free-market action. They are functions that respond to needs that have been created by growth, or that people have become more sensitive to with the increase of incomes and the expansion of education, or that the diffusion of political power has permitted people to transform from an individual to a collective responsibility. They respond to desires or values that have no counterpart in the goods that form part of the measured national product, which means that measures of future growth, if they remain restricted to the national product accounts so far employed, will not reflect them.

Most, but not all, of the welfare goals now sought through government fall under these headings. They cover the attempts by education and income transfer to make a closer approach to equality of opportunity and income. They include the legislation and regulation that seeks to ensure the safety of consumers and workers and the protection of the common environment. They embrace the provision of capital in the form of infrastructure, education, and the advance of knowledge. They also cover the public assumption of a portion of the costs of growth in the form of compensation for losses suffered due to the obsolescence of jobs, skills, and financial capital and of localities themselves. And they include the new public responsibility for the care of children, the sick, and the old. They include, therefore, the obligations that used to be borne within families but that families are now less able to bear, or that, in view of the alternative afforded by government, they are less willing to bear. One should add, with reference to the care of the aged, that this is also a responsibility that, in view of the alternative afforded by government, older people are less willing to see borne by their families.

All this represents the positive side of the new social outlook and its institutionalization. The new functions assumed by government, however, obviously have their costs in the taxation, transfers, and regulation that alter the rewards, costs, and risks of work, saving, and investment in their many shapes and forms. These have not been successfully measured and presumably there is no common rule that applies to all countries and circumstances.[45] There remains a presumption, however, that they act to inhibit work, saving, investment, and enterprise and that the welfare goals we seek through government must be paid for by some slowdown of measured output growth itself.

This, however, is a tentative judgment and an incomplete one, and it must be qualified carefully. The judgment has to do with the effects of taxation that is raised to support income transfers and to the effects of regulation to promote safety and environmental protection. It is not a judgment about the net effects of taxation to support investments in human and physical capital that have the aim and effect of increasing our productive capabilities. It is a judgment, moreover, that neglects the contribution of transfers to the increase of output itself. Because the growth of output involves the obsolescence of industries and localities, there is a conflict between the interests of those whose jobs, skills, capital, and homes are threatened by change and the interests of the community at large, whose incomes are raised. The various developments that have brought women out of the home and the very movement of people in the course of economic growth have placed strains on the family and limited its ability to carry out its traditional functions. Conflict and resistance are, therefore, part of the growth process. And the transfer system, the public health care system, and other elements of government activity are the means by which we resolve conflicts or moderate the resistance that otherwise would operate to inhibit growth.

The considerations that qualify a judgment about the costs of the new roles assigned to government are matched by very practical considerations that qualify a judgment about its benefits. The private sector, guided by markets, can do more than it is generally thought it can do. And government agencies, without market guidance and exempt from market pressure, can do less. Faulty knowledge leads to faulty decisions about the functions of government, and the same is true about the methods that public agencies use to carry out the functions they are given. Moreover, our decisions about the scope and methods of government action, of what to try to do and how to try to do it, are distorted by the interest-group biases that are inherent in the democratic process. The welfare benefits we seek through government are reduced by faulty knowledge and political distortion.[46]

What lessons does this discussion teach? The sources of economic growth spring at bottom from a social climate, the outlook that expresses people's views about the relation, as Kuznets put it, between "man and the universe" and between one person and another. Kuznets thought that the outlook that supports modern economic growth could be epitomized in his triad – secularism, egalitarianism, and nationalism. It is easy to see, however, that these views have taken different forms in the countries that have entered the modern growth process. Indeed, they do not stretch far enough to capture the full spectrum of attitudes consistent with the advance and application of science. It is hard to see Japanese growth as the expression of an egalitarian spirit, but the Confucian ideals of hierarchy and obligation on which Japanese society is founded proved to be an effective alternative. The social climates characteristic of nations, moreoever, are not stationary matters. The secularism and egalitarianism on which modern economic growth in Europe and North America was based have themselves changed in the course of the past century, very largely in response to conditions that growth itself has created.

The social climate of a time and place shape the political and economic institutions that are among the underlying determinants of technological progress and economic growth. Secularism and egalitarianism in their nineteenth century forms were consistent with the generally individualistic spirit of that century's economic and political policy. A change in the content and character of that outlook and the diffusion of political power that growth has brought have given us the mixed economies and welfare states of the contemporary West. They are a far cry from the unequivocal laissez-faire for which modern-day libertarians claim Adam Smith's authority. Yet they are not alien to the spirit of John Stuart Mill, the great individualist who was Smith's mid-nineteenth century exponent. The Western welfare state in its present form is still a relatively new regime. Its content, scope, and mode of operation remain in flux. After some experience with excesses of government, one now sees a notable revival of a more individualistic outlook. Yet the boundaries and methods of the mixed economy are not likely to change much unless our social outlook and the distribution of political power undergo a more radical alteration than is now in sight.

It is clear enough that the new regime expresses a great change in the character of the society in which people choose to live and of the economic satisfactions they seek. One can see that to some degree their goals have been met. We know little as yet about how much the new regime has already cost, and may in the future cost, in terms of the growth of measured national product, that is, of the older welfare goal that has not been abandoned. As befits a mixed economy, we can see that the new institutions and policies have mixed effects. To learn more about the effects of the new political regime, as well as about the effects of the evolving institutions through which the private sector operates, must be an important task of growth studies today.

Notes

1. Neoclassical economists resisted these contentions. They appealed to time-preference, a psychological trait, to defend the persistence of positive interest in a stationary state. They argued that there are an infinitude of possibilities to substitute capital for labor even where technology – the state of practical knowledge – is unchanging. If capital accumulates faster than population, the marginal productivity of capital would decline, but it would do so very very slowly. All this remains in contention. History provides no test.

2. The U.S. Bureau of Labor Statistics made many such estimates, and a notable series of studies were made in the National Bureau of Economic Research beginning in the later twenties and continuing in the thirties and forties.

3. Theirs were not, however, the earliest work of this sort. Priority belongs to Jan Tinbergen (1942), followed by George Stigler (1947), Jacob Schmookler (1952) and Solomon Fabricant (1954).

4. Representative publications are Denison (1974, 1985), Kendrick (1961, 1973) and Jorgenson, Gollop and Fraumeni (1987).

5. "Other" sources of changes in labor quality consist mainly of an allowance to offset the fact that when workers shifted from farming or from self-employment or small family businesses to wage and salary work in nonfarm occupations, their hours of work declined. Denison judged, however, that the effective work done per year was not reduced by such shifts.

6. It is perhaps a noteworthy matter, however, that in measures over a still longer period, from 1929 to 1981, which includes the Great Depression and World War II, Denison's estimate of adjusted total factor productivity growth was a distinctly less important source of the advance of labor productivity (52 percent) than it was in the postwar years themselves. And his Final Residual, the putative "advance of knowledge" accounted for only 22 percent of labor productivity growth.

7. To be quite accurate, the Final Residual also includes the effect of minor sources unmeasured and not classified under other rubrics in his account, as well as errors in the measured elements.

8. The relatively high depreciation rate on fast growing equipment is the main reason for the large contribution of Jorgenson's capital quality. Actually, however, his breakdown of investment reflects not only capital by durability, but also by industry and legal form of organization; correspondingly his rental prices also reflect sectoral differences in net rates of return and taxes, besides depreciation.

9. Compare the discussion in Chapter 4, below.

10. Denison's own discussion of the measurement of the scale effect is sophisticated and subtle (Denison 1974, pp. 71–6). In particular, he recognizes that the effect is likely to become weaker as the scale of output expands, so long as the state of technology is unchanging, and the benefits may be offset by problems of coordination and congestion. But he holds, sensibly enough, that the advance of knowledge opens new opportunities to use resources in more intense and specialized ways and so renews the potential benefits of enlarged scale. Needless to say, however, neither he nor anyone else can yet say how strong these opposing tendencies are.

11. Richard R. Nelson (1964) provides an illuminating discussion, and I make use of it.

12. Robert Solow (1962) devised the basic model. See also Nelson (1964).

13. Edward Denison (1964; 1967, pp. 144–50).

14. See Chapters 6 and 7 in this book.

15. In principle, the growth accounts, which neglect these considerations, are proceeding on the assumption that the elasticity of substitution of capital for labor is just unity and that technological progress is neutral. Repeated studies, however, suggest that the elasticity of capital-labor substitution is less than unity. In the absence of capital-using technological progress, capital's income share and the contribution of given rates of accumulation to output growth would be driven down as the capital stock rises relative to labor. In a different formulation, we depend on technical progress to augment the labor power of workers and so to prevent the ratio of capital to *effective* labor input from rising even as the quantity of capital increases relative to the number of workers.

During much of the nineteenth century, the impact of technological progress on the demand for capital in the United States more than offset the effect of the growth in its supply relative to labor. Capital's share in national product increased. In the present century, the capital-using character of technology has been weaker. Still, the gross earnings share of capital has not retreated much, and the rate of growth of capital's contribution to productivity growth has remained large (Abramovitz and David 1973).

16. One should be aware of an important, if technical, point. The connection traced in the text runs from the *level* of education to the pace of technological progress incorporated into production. The growth accounts, however, recognize, not the level, but rather the growth rate of the education level as a proximate source of output growth. In the framework of the accounts, the level of education itself is one of those underlying causes of increase in output with which the growth accounts do not pretend to deal. Strictly speaking that is true; and the distinction between the level and growth rate of education is clear when growth is measured over relatively short intervals of years. Over short intervals the growth that occurs does not affect the level substantially. When, however, we are concerned with the long periods that are the proper sphere of growth studies, differences in growth rates of schooling can have a significant affect on the level itself. And then it operates to influence the contemporaneous pace of technical progress.

17. One striking indication of this change is the figures for school enrollment. Between 1900 and 1960, the percentage ratio of students enrolled in secondary school to those in elementary school rose from 4.3 to 29.6; that for students in institutions of higher learning to those in elementary school rose from 1.4 to 9.9. Between 1910 and 1960, the average number of school years completed by men 25 years of age and more rose by nearly 50 percent.

18. Stephen J. Kline and Nathan Rosenberg provide a vivid and detailed exposition of the interdependence of technological advance and business experience.

19. Rosenberg (1974). See also David C. Mowery and Rosenberg, in Rosenberg (1982, Chap. 10); Nelson (1979); and Nelson, Peck, and Kalachek (1969, Chap. 2). Nelson, like Rosenberg, argues that knowledge relating to certain technologies is stronger than that to others, that strong knowledge reduces the cost and increases the potential yield of inventive effort, and that differences in background knowledge help explain differences among industries in research effort. He goes on, however, to relate such variation to the differential capacity of firms to translate the benefits of invention into private returns, a matter to which I turn in later pages.

20. Edwin Mansfield studied the costs of imitations and the times required to carry them out for 48 products in four industries. He found that, on average, the ratio of imitation cost to innovation cost was about 0.65, and ratio of imitation to innovation time was about 0.70. For about half the products, however, the cost ratio was either less than 0.4 or more than 0.9; and for about half the products again, the time ratio was either less than 0.4 or *greater than 1.0*. The cost ratio was 1.0 or higher for some one-seventh of the products. Imitation evidently is a costly procedure (Mansfield, Schwartz, and Wagner 1981; Mansfield 1986).

21. A special and important aspect of the relations between scale, innovation, and technological competition arises in the case of a technical system subject to "network externalities." These stem from the system's dependence on the technical compatibility of all its elements and on its capacity to yield larger benefits to each user as the scale of its use increases. The leading contemporary examples of such systems are the increasingly common computer hardware–software systems, local-area computer networks, electronic mail systems, cellular telephone networks, and many others. These, however, are only the latest in a series of great developments with similar characteristics: the railway, telegraph, telephone, radio, and still others. The technical interrelatedness of such systems makes the profits of each component supplier depend on its compatibility with all the others. The system-scale aspect means that the system's utility to consumers, and therefore the demand for its product, increase with the number of its users. The second aspect presses each rival system sponsor to seek the cumulative returns of increasing market share by aggressive competition. The first means that the apparent success of any system drives component suppliers to design to the technical standards of the successful system – which enhances the cumulative benefits of market share, and the competition to achieve it, still more. The cumulative pressures of this dual competitive drive is towards de facto industry monopoly, or at least substantial industrial concentration, and towards universal adoption of the technical standards of the successful system. The first tendency raises obvious problems of market power. And the second raises problems as well, if it occurs either prematurely (that is, before the merits of possible alternatives have been explored) or mistakenly (that is, if the successful system's drive for customers triumphs over a technically superior alternative system). See Kindleberger (1983); David (1986b); and Arthur (1987).

22. Keith Pavitt (1985) has written a compact explanation of the location of R and D activity and its determinants. And Nelson (1988) has an especially useful discussion.

23. Technological rivalry and its interactive relation to industrial competition and technological investment and advance is a relatively new subject. Burton H. Klein (1977) and Nelson and Sidney Winter (1982) have made influential contributions, and my statement reflects the views they have developed at length.

24. Edwin Mansfield et al. (1971). In studies of a wide range of innovations, Mansfield and his associates found that the median private rate of return was 25 percent, whereas the median social rate was 56 percent. This applies, however, only to successful innovations. A truly representative sample might yield different results.

25. Dasgupta and David (1987) discuss this whole range of issues in an illuminating and subtle argument. See also Pavitt (1987).

26. My expression here is an adaptation of both the title and theme of Richard Nelson's essay, "Institutions Supporting Technical Change in Industry", *op. cit.*, 1988.

27. These are average rates of gross domestic product per hour for 16 industrialized countries as presented by Angus Maddison (1982, Table 5.3).

28. The Maddison figure for GDP per man-hour for 1973–84, comparable with his figures for 1870–1973, is just 1.0 percent (Maddison 1987, Table 1). The BLS growth rate for the productivity of all persons in the private business sector rises very little from 1984 to 1986.

29. The facts regarding convergence and an extended discussion are presented in "Catching Up, Forging Ahead, and Falling Behind," Chapter 7, in this volume. I am making no statement about a more general tendency to convergence. The evidence I cite refers to the presently industrialized countries and suffers from a certain sample selection bias, as my own paper just cited states. Indeed, the evidence suggests that the tendency may not extend much beyond the group of presently industrialized countries, although its precise range is still unclear (Baumol 1986, Baumol and Wolff forthcoming). My own paper below proposes an explanation for this limitation. On the matter of sample selection bias in the Baumol paper and my own (this volume, Chapter 7) see J. Bradford DeLong (forthcoming).

30. The growth potential of laggard countries may be strong for reasons other than the chance to replace obsolete capital with best-practice equipment. There is also a chance to adopt advanced management practice. Next, the rate of capital accumulation, including human capital accumulation, is supported by the high returns on using more advanced techniques. Finally, the expansion of manufacturing and distribution permits workers to transfer from low productivity jobs in farming or from self-employment in

petty trade to higher-productivity wage and salary work in industry, commerce, and finance. See Chapter 7 in this volume.

31. Chapters 6 and 7 in this volume present an extended argument and evidence in support of these views.

32. The general question of the congruence between the directions of nineteenth century technological advance and American resources and market scale is also taken up in Chapter 7. My argument is based on Rosenberg, "Why in America" (1981), and Abramovitz and David (1973). See also Chandler (1977). A succession of authors have argued that, by comparison with Britain and continental Europe, not only were U.S. consumers tolerant of uniformity, but also their consumption habits were malleable. U.S. producers were relatively free to design products to make them suitable for low-cost, mass-production methods. The initiative in product design lay more largely in the hands of the producer. This not only made consumer goods industries more open to the economies of scale; it also conduced to uniformity of product and large-scale production in the capital goods industries. See Samuel Hollander (1965); Tibor Scitovsky (1960) and Nathan Rosenberg (1970).

33. The term itself was first proposed by Kazushi Ohkawa and Henry Rosovsky (1973, Chap. 9) in the course of a discussion of institutional development in Japan. Simon Kuznets (1968, Chap. 13) takes up the same subject in its bearing on the "relevance" of the existing stock of unexploited technology to less-advanced countries. Thorstein Veblen (1915) and Alexander Gerschenkron (1952) are both devoted to what I here call "social capability" in relation to "catching up."

34. There is indeed, a line of theoretical speculation that holds that institutional change not only consistently favors efficiency and increasing incomes and wealth but even that institutional adaptation occurs speedily (Posner 1977). Neither contention seems valid, and R.C.O. Matthews (1986) cites numerous instances of state action that operate to frustrate efficiency and growth, of which protectionist measures of every sort are the most familiar. Countries that succeed in industrializing, however, do respond positively to the demands of modern technology, and there may be a general tendency towards such response, if only in the very long run.

35. Veblen was an early exponent of the idea that institutions constrain countries in their exploitation of new technology, but that they adapt to technological opportunities and requirements (1915). Also see Ohkawa (1979). Douglas North (1981) presents a complex, systematic, and somewhat abstract general theory of institutional adaptation and makes some preliminary attempt to illustrate its historical application.

36. Wars and their aftermaths, however, are not uniformly favorable to an advance of social capability. The territorial, political and financial convulsions following World War I were on a scale commensurate with those after World War II, but they did not set off a comparable European growth boom. Indeed, the European response on that occasion was quite unfavorable to growth. Protectionism, not a common market, was then the answer to territorial change. Cartels more than innovation and competition were the instrument for industrial reorganization and the elimination of "excess" capacity. Trade unions became more powerful than they had been both in the market and in politics. The lessons learned from the failures of post-World War I policies were one reason why policies after World War II were more conducive to growth.

37. This was not a lead universally present in all fields of technology. Germany was a pioneer in chemicals and in electrical power production methods and made notable advances in the ferrous metals industry.

38. As already noted, there are recent developments that qualify this condition. Universities have begun to accept industrial, as well as government (defense), support that, in some cases, imposes restrictions on the early publication of results. And both universities and their scientists have increasingly sought patents to control the commercial applications of their discoveries. This in turn has restricted the prompt dissemination of scientific findings.

39. On all these matters bearing on labor supply and the control of inflation, see Chapter 6 in this volume. See also Kindleberger (1967) and Ohkawa and Henry (1973), Chaps. 2 and 5.

40. Chapter 6 in this volume treats these matters at greater length.

41. "Not long after Queen Victoria came to the throne, Prussia was spending 600,000 pounds annually on public education. England in the same year . . . voted 30,000 pounds for education – and 70,000 pounds for building royal stables. That spirit still lingered up to the late sixties" (Garvin 1932, Vol. 1, p. 89).

In the United States, 72 percent of children aged 5 to 17 were enrolled in schools in 1880 (almost all in elementary schools). The British ratio (in government-supported schools) reached 69 percent in 1950. In that year two-thirds of U.S. children between 15 and 18 were enrolled in government-supported secondary schools; the British ratio barely exceeded ten percent (Abramovitz and Eliasberg, 1957, p. 15 and Table 14).

42. See Ruth Benedict (1974, first published 1946). Of course, the United States was far from being free of sex and age discrimination. Yet the restricted roles imposed on women were not so rigidly fixed as in Japan. As to age, there were marked differences. The Japanese revere age and accord it, not only respect, but rights of leadership in family, business, and public life. Old age in the United States imposes disabilities, which opens leading positions earlier to younger people. Which outlook is more functional is not entirely clear, and it may be that each works well in its own setting.

43. One prominent exception is the study by Alex Inkeles and David H. Smith (1974).

44. See above, p. 7. Here, at any rate, was one subject connected with economic growth to which the neoclassical writers attended. The externalities of production and consumption became a staple of the welfare theory of standard economics (Pigon 1932).

45. The effects of an incremental tax burden equal to one percent of net national product are not likely to be the same in a country where the level of taxation exceeds 50 percent of total income as in another where it is no more than 30 percent. Allowing for levels of taxation, effects are likely to differ among countries according to their states of tax morale, general respect for law, and the severity of law enforcement. The forms taken by taxation count as well. And similar considerations apply to the effects of transfers and regulatory measures.

46. Our troubles with the political process stem in part from our own impatience with it. We invest only reluctantly in the expensive task of recruiting and supporting a talented and devoted civil service. We find it hard to tolerate in government the costs of learning by experiment and failure that we find natural in the private sector. We have a penchant for illusory programs if they promise quick and easy solutions to complex and stubborn problems. Since in government as in the private sphere, learning is based on investment and experience, the present partial recoil from government carries the danger of reducing still more our limited capability for communal action.

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