[The Principle of Acceleration: A Non-Dialectical Theory of Progress]: Comment
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Comment

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Possessing little knowledge or competence in either demography or economics, I am in no position to comment on the central portion of Professor Dovring's paper. Fortunately, I feel no call to do so, for I very much doubt that it can be faulted. No refinement of data or analysis is likely to set aside his basic conclusions. If the time intervals analyzed are made long enough to eliminate local fluctuations, accelerated rather than linear growth, whether of population or productive capacity, has characterized man's life on earth since at least the conquest of fire. Only historical myopia can account for the view that an increasing tempo of change dates only from the Industrial Revolution, that our current condition is, with respect to the *existence* of acceleration, essentially new.

Agreement on these central points does not, however, prevent my being uneasy about certain aspects of the way in which Dovring develops his argument and about certain of that argument's implications. In the first place, if I understand his paper correctly, it is of little concern to Dovring whether the acceleration of which he speaks is continuous or occurs suddenly at separated points in time. A rapid 'break in trend' of national product per worker during 1920 is, for him, evidence of acceleration even though the curve is linear on either side of the break. The data which demonstrate the long-term acceleration of population growth can be fitted equally well by a smooth curve with a steadily increasing slope or by a succession of straight lines each with a slope greater than that of the one before. To the demographer, I gather, the difference is not presently a significant topic for discussion.

The historian, however, may well think the difference all-important, for it bears on the significance of historical events as determinants of the future. If Dovring is saying, for example, that the Industrial Revolution is only one relatively recent episode in a series that has from time to time produced permanent increases in, say, the rate of population growth then I think the historian can have no quarrel. But if he is implying, as I think his readers may suppose, that eighteenth-century innovations in agriculture, technology, and economic organization were not prominently associated with a rapid and pronounced change in the rate of population growth—that there was no revolution or that it made no difference—then the historian may well wish to demur. It is perfectly possible to combine a sense that after the Industrial Revolution 'the world was never the same again' with the recognition that rapid alterations in the rate of change had occurred often before in human history. I enter a plea for the historical integrity of the Industrial Revolution and of its revolutionary predecessors and successors.

A more general malaise is generated for me by Dovring's account of 'the accelerators'. 'Acceleration of progress, or increased leverage on nature, depends', he suggests, 'on more and more generalized ideas, allowing a more and more systematic grasp of reality'. Brainpower, he continues, has probably been constant since remote prehistory, but its successful application 'requires a degree of continuity as well as a measure of accumulated material resources at each stage'. It is the increase of intellectual power due to an increase in continuity and resources—both illustrated by Dovring's discussion of the effects of the invention and spread of printing—which has, he supposes, accelerated man's control of nature since very distant times.

In a number of important respects, this account of the reasons for acceleration fits very well to the development of science. But technology, as Dovring clearly recognizes, has been a different enterprise over most of historic time. It is far from clear that what accounts for one can be transferred to the other. Dovring's example displays part of the difficulty, a failure to conform with historic fact. The printing press, which was vital to the emergence of modern science, appeared at the end rather than the start of the series of great innovations which helped to prepare the modern world. Francis Bacon enumerated a triumvirate of great medieval inventions—the compass, gunpowder, and printing—as a crucial source of the special character of his own time. All three had, in fact, been preceded by still other immensely consequential innovations, particularly in agriculture and power technology. Though it remains controversial, a strong case can be made that the first great period of innovation in European technology ended with the printing press. The sixteenth and seventeenth centuries, for all their prominence in the development of science and in the improvement of intellectual communication and material resources were, relative to the high Middle Ages, somewhat backward in technological change. Here, at least, Dovring's account helps us understand scientific development without at all illuminating the evolution of technology. Its next great advances occurred in the later eighteenth century and must be understood in another way.

Even the suggestion that science and technology are independent may be too weak, for there is at least a bit of evidence to indicate that the social conditions which promote science are antithetic to technology and vice versa. Societies in which one of these enterprises has flourished have usually been weak in the other. Compare Rome with Greece in antiquity, the Middle Ages with early modern times, or France with England at the end of the eighteenth century. Or think of the relative strengths of science and technology in the United States from its origin until World War I. Germany in the second half of the nineteenth century provides the only clear example I know of simultaneous eminence in both science and technology. Perhaps the U.S. and U.S.S.R. in the twentieth century should be added to the list, but we lack the perspective relevant to judgment.

It ought not, I think, occasion surprise that, until the last century or two, the factors which have promoted the development and spread of ideas, and thus of science, have done little or nothing to advance technology. Francis Bacon invoked the great medieval inventions in order to deplore the fact that learning had played no part in their creation. That invocation was part of his call for a new, more useful, more powerful science. Two centuries later, however, the men who wrote on the science of the steam engine were repeating Bacon's lament. Was it not deplorable that these vastly important machines had been invented and improved by untutored craftsmen with little or no understanding of what they were doing? Perhaps we should not trust the scientist's evaluation of the crafts. Perhaps the men responsible for the development and dispersion of innovation in agriculture, metallurgy, and the chemical crafts did possess a developing system of general ideas which guided their work, ideas which were unrecognized by the scientist because they seemed so strange. But if technology possessed such an idea system, it has left no trace in written records or elsewhere. Once discovered, a process in which change may have played an overwhelming role, technological innovations were embodied in artifact and local practice, preserved and transmitted by precept and example. Migration and industrial espionage, not manuscripts or printed books, were the determinants of both the rate and route of diffusion. Though I freely admit exceptions, I think nothing but mythology prevents our realizing quite how little the development of the intellect need have had to do with that of technology during all but the most recent stage of human history. Our difficulty is very like that of the men who found Darwin's theory implausible because such organs as the eye and hand seemed too perfect in their elaboration to have evolved without the intervention of mind, in that case the mind not of man but of God.

It would be absurd to suppose that the history of technological innovation is *nothing but* the story of chance discoveries, improved by trial and error, and transmitted by inspection and precept. But it is worth noting that much of the development of technology could have occurred in this way. The metallurgy of copper almost surely began with the discovery of unexpected malleable residues in primitive cooking fires or, more likely, kilns. Once developed, furnaces for reducing copper provided a new site at which other accidents, previously impossible, could occur. Bronze, iron, and early steel technology may well have arisen successively from such chance innovations in the new environment provided by their predecessors. The domestication of plants and animals is likely to have had similar origins; once begun, very little in the way of 'general ideas' or a 'more systematic grasp of reality' would be required to generate further improvements. Even in the case of deliberately generated innovations, like the flying shuttle, the mule, or the cotton gin, new motives and new loci for innovation appear to be more important than new ideas in the genesis of innovation. Search as he will, the historian finds no new ideas, except perhaps the idea of invention, that helps at all in understanding the time at which innovations of this sort occurred. If general ideas, their development or their communication, had been the missing ingredient, the Industrial Revolution, unlike the Scientific Revolution, would have occurred in antiquity.

Note now that, in spite of its obvious superficiality and incompleteness, a theory which would explain technological evolution as the result of inevitable accidents occurring in a developing environment can by itself account for the fact of acceleration. The chance that someone will have a fruitful accident must increase with the population to whom accidents can happen. Since, in addition, the result of such chance innovations is a productive apparatus that can support a larger population, growth must be at a rate greater than linear. Though I share Dovring's desire for a non-dialectical explanation of progress, I doubt that man's highest intellectual faculties need or can properly be given the central place in a theory directed to that end.

At least, I doubt that they can until technological progress during the last hundred years is considered. Prior to the mid-nineteenth century, increasingly general and systematic ideas about nature played some role in improving existing technology but virtually none in technological innovation. (Even in the improvement of technology, however, the typical case remains that of Kepler and the beer keg. Kepler forged fundamental techniques of the calculus of variation in deriving mathematically the optimum dimensions of beer kegs only to discover that they were already being built to his specifications. Sadi Carnot's contributions to thermodynamics and to the improvement of steam engines provides a nineteenth-century version of the same story.) Beginning, however, with the development of German dye and drug industry in the 1870s and with that of the electric power industry a decade later, the situation changed radically.

Both these industries were based on laboratory derived products; neither could flourish competitively without including on its staff men trained to manipulate the most up-to-date intellectual and instrumental tools of science. No previous industries of major importance had grown from these roots or required these skills, but these two proved to be only the first, and the number still increases. No more than the Industrial Revolution does the resulting transition to a science-based technology mark the beginning of accelerated growth. Acceleration has, as Dovring insists, been a permanent characteristic of the human condition. But the recent marriage of science and technology does, I suspect, mark another decisive change, both qualitative and quantitative, in the nature of acceleration. Fifty years from now the historian may again wish to exclaim, 'The world was never the same again.'