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The Economics of Inventive Activity over Fifty Years

Kenneth J. Arrow

It is gratifying that a conference participated in fifty years ago is remembered as sufficiently influential and useful to be acknowledged as inspiring a new conference on the same subject. It is only natural that two of the survivors be trotted out to make the link and continuity more visible.

I will make a few remarks to emphasize the continuity and the change from today's viewpoint. Some seemingly promising leads have been followed up, some not. Some problems, empirical and conceptual, still persist. Other new ideas have appeared. Of course, the technical capacities of economists in all fields, including inventive activity, have changed, itself a reflection of inventive activity. The information and communication technology has changed econometric methodology from difficult to simple and made access to data far easier. Any economist will have to assume that lowering costs will lead to better and more abundant output.

Let me start with a universally valid remark. *Any* theory that purports to explain novelty, whether it deal with invention, innovation, or the emergence of new species of biota, is intrinsically difficult and paradoxical. How can you have a theory of the unexpected? If you can understand what novelties will emerge, they would not be novelties.

Biologists do not attempt to predict the specific characteristics of a species that will emerge in the future. Indeed, the theory of evolution through selection, especially in the form of the "modern synthesis," where mutations occur at random and favorable ones are selected for, virtually implies the impossibility of forecasting the novel elements in future new species. To be sure, there are known constraints. New species must have a lot in common with existing ones. If there is some successor to *Homo sapiens,* it will prob-

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ably be bipedal. But it is precisely the way the new species (or the innovation) differs from the present that is of interest, and that is what is difficult to predict.

Biologists differ among themselves as to the extent to which the broad outlines of evolution could be predictable. The late Stephen Jay Gould argued that if evolution started all over again, the outcomes (the leaves on the evolutionary tree) could be totally different; others (e.g., Christian de Duve) argue that the movement toward greater complexity and greater intelligence would have emerged in any case, though the specific species embodying them might have been different in many ways. This issue has an exact parallel in varying views as to the importance of "path-dependence" in the history of adopted technologies.

A basic theme in both the previous conference (NBER 1962) and the current conference is the definition of the field; what are we studying under the heading of "inventive activity"? This concern is explicit in Simon Kuznets's lead essay in the 1962 volume (Kuznets 1962). He distinguishes between *invention,* a new combination of existing knowledge to create something useful (in some sense), and *discovery,* the development of new knowledge. He distinguishes both from, "the host of improvements in technique that are . . . the result of low-level and rather *obvious* attentiveness or know-how"; an invention, on the other hand, "must be the product of a mental effort above the average" (Kuznets [1962], 21; emphasis in original).

Before reverting to Kuznets's primary distinction, let us consider some implications of the distinction of both from routine improvements. Indeed, this leads to a basic question that the great pioneer in national income accounting might have pondered over: what is the relation between inventions, in Kuznets's (and most others') usage, and growth in total factor productivity (the Solow residual). This question was raised at the 1962 conference by Zvi Griliches (1962). I can do no better than to quote his remark (Griliches 1962, 347). "[I]nventions may be the wrong unit of measurement. What we are really interested in is the stock of useful knowledge or information and the factors that determine its rate of growth. Inventions may represent only one aspect of this process and be a misleading quantum at that. . . . [T]heir fluctuations may not be well correlated with changes in the over-all rate of growth."

Enos's (1962) paper cast some interesting light. He enumerated the basic significant steps in the improvement of petroleum refining to derive from crude oil its useful products (such as gasoline and kerosene), and the many types of "cracking." But he notes that the improvements in productivity between one major innovation and the next are at least as large as the improvements immediately due to each innovation (Enos [1962], table 5, 318, and discussion on 319). This illustrates the well-known phenomenon of progress curves found in airframes and other durable goods and a sequel to every major innovation, down to Moore's Law for integrated chips.

The hypothesis that inventions require a distinctive mental effort led to an emphasis in the 1962 volume on the psychological and social characteristics of inventors, reflected in the term "social" in the subtitle of the volume and in the presence of a whole part (part IV) dealing with, "nonmarket factors." No counterpart exists in the current volume. Part IV tried to discuss what kind of people become inventors and how decisions about invention are made in decentralized firms and in government departments. I am afraid that, both originally and on rereading, I felt that the ninety-six pages were a waste of space and effort. Some of the results are incredible; most are uninteresting even if correct. In the current volume, no parallel effort was even made.

Let me return to Kuznets's primary distinction between invention and discovery. Thomas Kuhn, in a comment later in the volume, prefers the terms "technology" and "science" (Kuhn 1962, 451–2), and these have been widely used since (e.g., Dasgupta and David 1994). The distinction, in any vocabulary, is associated with several rather different hypotheses:

1. Kuznets suggested that discoveries made in science provided the knowledge on which inventions or new technology, according to one's preferred terminology, were developed. Kuhn pointed out that this relation only begins to be true after 1860; before that, virtually none of the great inventions were based on scientific knowledge. Even today, many of the great improvements in information and communications technology do not depend on new scientific principles.

2. To the obviously considerable extent that scientific advance does provide the basis for technological improvement, a question arises as to the causes of scientific advance. To Kuznets (and, I think, implicit in the case studies in part III of the 1962 volume), scientific advance is essentially exogenous to technology and to the economy. It plays the role that Solow assigns to technological advance in general, causing but not caused. How sound and how fruitful this hypothesis is remains to be determined. I should note it is very distinct from that held by many, from Karl Marx to the present day, who ascribe the great growth in technology of the last quarter millenium to capitalist institutions and, in particular, the patent system. The latter point of view would imply that science is responsive to the needs of industry. I expand a little on this point later.

3. There are two further aspects of the relation between science and technology (invention and discovery) that have received mention in the 1962 volume and subsequent literature. One is the argument that the motivations of scientists and technologists differ. It is held that technologists are interested essentially in money, while scientists are primarily driven by curiosity or fame. (Actually, some of the 1962 authors suggested that curiosity might be a driving force in technology as well.) Certainly, many of the innovators in information and communications technology created concepts, such as the Internet, from which they benefited relatively little in a financial sense. They

were trying to solve some specific problem. Now, fame is certainly a reward for scientists. As John Milton put it, "Fame is the spur/that last impediment of a noble mind" (from *Lycidas,* lines 70–71). I noticed no concern with this question in the present conference.

I must add the somewhat atypical motivation of one major health discovery (one I learned about as chair of a study group on the introduction of a new antimalarial pharmaceutical) (Institute of Medicine 2004). Currently, the best treatments for falciparum malaria (the deadly form) are combinations of artmesinins, drugs derived from a plant popularly known as sweet wormwood. They were developed on the basis of ancient Chinese medical texts by a group of scientists who published their findings (tested by the best current scientific standards) *anonymously,* giving as author the Chinese Cooperative Research Group on Qinghaosu [sweet wormwood] and Its Derivatives as Antimalarials (1982). Of course, no patents or other intellectual property claims were filed. In short, neither fame nor wealth was implicated as a motive. The spread of open software and the anonymous writing of articles for *Wikipedia* may suggest that this example, if not common, is not entirely unique.

4. Finally, in this list of the problematic relations between science and technology, is the influence of technology on science. Once the point is made, it is entirely obvious that technological improvements have made science easier to perform, as they have improved performance in other human activities. I do not believe this proposition is at all discussed in the current conference, and I found only one brief remark in the 1962 paper of Irving Siegel (1962 448). When someone had the idea of using two lenses to create a telescope, Galileo was empowered to search the skies, to identify the complex surface structure of the Moon, and to determine that Jupiter had several moons. Later, someone put the lenses together in a different way, and Leeuwenhoek was enabled to see that a drop of water contained many very small animals. This audience may be young enough to need reminding that computers and the Internet have transformed economic analysis.

I have a few more, somewhat miscellaneous, remarks. I have already alluded to one, the role of patents and, more generally, institutions, legal and other, in encouraging and directing both science and technology. Despite a considerable number of individual remarks, neither conference has been much concerned with evaluating this role. As I have already indicated, many authors have ascribed an important role to capitalism in general and the institution of intellectual property in particular in stimulating technological progress. For vigorous defenses, of this point of view, see, for example, Rosenberg and Birdzell (1986) and Baumol (2003).

On the other hand, in informal conversations with presumably knowledgeable lawyers and businessmen, I derive the impression that patent protection is important only for a limited range of products, such as pharmaceuticals. There has also been an intellectual and theoretical case, arguing that the private information held by inventors enables them to reward themselves adequately without the need for patent protection (Hirshleifer 1971; Boldrin and Levine 2008). Is there no way of measuring the significance of the patent system as an incentive for invention, including bringing the new product or process into the market?

Patents indeed appear very frequently in the literature on invention but mostly as a measure of inventive activity rather than for their incentive implications. In turn, this measure has been repeatedly subject to criticism. We are sometimes told that counting the number of patents is meaningless. Most patents are, of course, of no importance; a few are of great importance. Does the total number have some significance for measuring technological progress in some sense? It is true that patent activity has one great advantage as a statistic: it is measurable with high accuracy.

To complete the items on my list of knowledge gaps, there is one more question related to incentives. It is generally accepted that the main source of profits to the innovator are those derived from temporary monopoly. Why is it that royalties are not an equivalent source of revenues? In simple theory, the two should be equivalent. Indeed, if there is heterogeneity in productive efficiency, in the use of the innovation in production, then it should generally be more profitable to the innovator to grant a license to a more efficient producer. This does happen, of course, but I have the impression that licensing is a minor source of revenues.

I conclude with a note about the genesis of the two volumes. A great deal of attention was paid to the role of government procurement of innovation in the first volume, primarily in relation to defense. A high percentage of the papers dealt with this topic. I do not believe there is a single chapter on this subject in the current volume.

References

Baumol, W. J. 2003. *The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism.* Princeton, NJ: Princeton University Press.

Boldrin, M., and D. K. Levine. 2008. *Against Intellectual Property.* New York: Cambridge University Press.

Chinese Cooperative Research Group on Qinghaosu and Its Derivatives as Antimalarials. 1982. "Clinical Studies on the Treatment of Malaria with Qinghaosu and Its Derivatives." *Journal of Traditional Chinese Medicine* 2:45–50.

Dasgupta, P., and P. David. 1994. "Toward a New Economics of Science." *Research Policy* 23:487–521.

Enos, J. L. 1962. "Invention and Innovation in the Petroleum Refining Industry." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 299–321. Princeton, NJ: Princeton University Press.

Griliches, Z. 1962. "Comment on 'The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations, 1920 to 1950,' by Willard F. Mueller." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 346–53. Princeton, NJ: Princeton University Press.

Hirshleifer, J. 1971. "The Private and Social Value of Information and the Reward to Inventive Activity." *American Economic Review* 61:561–74.

Institute of Medicine. 2004. *Saving Lives, Buying Time.* Washington, DC: The National Academies Press.

Kuhn, T. 1962. "Comment on 'Scientific Discovery and the Rate of Invention," by Irving Siegel." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 450–57. Princeton, NJ: Princeton University Press.

Kuznets, S. 1962. "Inventive Activity: Problems of Definition and Measurement." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 19–51. Princeton, NJ: Princeton University Press.

Milton, John. 1983. "Lycidas." In *The Norton Anthology of Poetry*, 3rd ed., edited by A. A. Allison, H. Barrows, C. R. Blake, A. J. Carr, A. M. Eastman, and H. M. English Jr., 276. New York: W. W. Norton.

National Bureau of Economic Research. 1962. *The Rate and Direction of Inventive Activity: Economic and Social Factors.* Princeton, NJ: Princeton University Press.

Rosenberg, N., and L. E. Birdzell. 1986. *How the West Grew Rich.* Chicago: Basic Books.

Siegel, I. H. 1962. "Scientific Discovery and the Rate of Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors,* Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Councils, 441–50. Princeton, NJ: Princeton University Press.