NORTH-HOLLAND

Journal of Policy Modeling
25 (2003) 435–444

Journal of Policy Modeling

Innovations and growth: two common misaprehensions☆

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Keywords: Innovation; Imitation; Growth

1. Two misunderstandings—their character and importance

Innovation and its relation to growth is a subject that does not invite easy generalizations, among many reasons because invention, by definition is an output that must be markedly heterogeneous. Yet illuminating generalizations are possible. This paper will focus on two such observations, both offering fundamental insights on the nature of the pertinent processes. Each is known to some specialists in the field, as will be documented below, but both appear to fly in the face of common beliefs. The first is the observation that possessors of intellectual property characteristically have much to gain, not only by sharing them passively yet voluntarily even with direct competitors, but by actively devoting effort and resources to getting others to use them, on suitable terms, of course. This can demonstrably be profitable, and not only in theory. It is widely done in practice via licensing, trading and other means, and the activity, that began no later than the early 19th century, is evidently expanding. These conclusions clearly clash with the common impression that the possessors of such intellectual property have every incentive to hoard it and to do what they can to deny its use to others. That does happen, of course, but such instances conceal an important part of the pertinent story.

☆ Much of the discussion is based on the analysis of my recent book, *The Free-Market Innovation Machine* (2002). However, it also draws heavily upon Rosenberg (2000), Lamoreaux and Sokoloff (1996), and Arora, Fosfuri, and Gambardella (2001).

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0161-8938/03/$ – see front matter © 2003 Society for Policy Modeling.
doi:10.1016/S0161-8938(03)00038-3

The second generalization deals with the role of what Rosenberg describes as "mere imitation," as contrasted with the innovation itself. As he has documented and explained, what Schumpeter described as the act of imitation of the work of the original inventor is characteristically also an inventive act in itself, entailing adaptation, improvement and discovery of new uses. More than that, the subsequent modification of the original invention, typically carried out via routinized procedures, often contributes far more to output and productivity than was directly yielded by the original breakthough invention. Indeed, I have argued that contribution of the two stages together—that of "original invention" and "mere imitation" are super-additive, their whole yield exceeding the sum of the yields of the parts. Moreover, the competitive process in the oligopoly industries of the free-market economies, drives inventive activity toward such a two-stage division of labor, with breakthroughs still often contributed by the unaffiliated inventors, and firms taking over and bureaucratizing the subsequent task of development—the D in R&D, the innovative mere imitation. Here too, the facts depart from common perception, which appears to focus on the contribution of the lone inventor of romance, driven by inspiration, and struggling in attic and garage to solve the problems that beset transformation of the inspired idea into a workable product. Many will doubtless be surprised by the observation that the *direct* contribution to productivity and growth of the mere imitation often far exceeds that of the original breakthrough.

The two observations just described are not significant only because they will probably be surprising to some. They are significant also because they must play a key role in an analysis that seeks to account for the unique and spectacular growth accomplishments of the free-market economies. For example, if hoarding of intellectual property were universal, the economy would be driven to focus on the production of partially obsolete products. Thus, suppose firms A and B are manufacturers of cellular telephones, and A's labs discover a way to make the sound clearer, while in B a way is found to reduce the weight of the telephone materially. If A and B both hoard successfully, consumers would be forced to choose between an overweight apparatus and one in which messages do not come through clearly. Sharing patents provides the public with a better product. It can also speed the growth of productivity in every participating firm in a perfectly analogous manner, and offer many other benefits. Moreover, the markets have devised ways to internalize to a considerable degree the associated externalities that arise when the efforts of one firm serve to benefit another, as we will see, thereby preserving the incentive for investment in innovation, while at the same time speeding the elimination of obsolete products and processes.

The second of our two focal observations is also of great importance for understanding of the growth and innovation processes. In the market economy, product and process improvement has become a primary weapon of the competitive battles among oligopoly firms in the high-tech industries. Because success in the process has become a requirement for survival in these fields, the firms have struggled to minimize the risks inherent in the innovation process. One of the key steps they have taken is to incorporate the process into their internal and routine activities.

Real expenditure on R&D by these firms has been growing steadily, driven by relentless competitive pressures. But these firms have understandably tended to focus on applied research, on the D in the R&D. Because it turns out that this portion of an economy's innovation process can contribute so much to productivity and growth, it becomes a key ingredient of any explanation of the growth accomplishments of the free market, and to investigation of the avenues available for their encouragement.

2. Markets in technology: preliminary observations

The fact is that voluntary dissemination of technology by its proprietors does occur and has been going on for well over a century, is substantial in scale and appears to have been growing since its early beginnings. The basic reason, of course, is that it can be a very profitable activity.

Before getting to the imperfectly known facts about the magnitude of the activity, the types of industry involved and the reasons why it pays firms to undertake it, a number of preliminary observations will provide the foundations for that discussion.

1. First, it is important to recognize that a piece of intellectual property is, in essence, just another input into one or many production processes, but one that has a single monopoly proprietor. It is, in this abstract sense, no different from an electric power transmission facility belonging to an electric utility, to which other generating firms in the geographic area would like access. And the owner of a patent, like the owner of the transmission capacity, will find it profitable to let others use it, at a suitable price. In particular, provision of access will be profitable if the license fee is sufficient to make up for any foregone monopoly profit the proprietor would have been able to earn by retaining the input for its exclusive use.
2. Because firms differ in their abilities and in the activities at which they are relatively efficient, some firms will be better at innovative activity while others will be superior in the use of inventions as inputs to final-product supply. This can lead to specialization in which inventor firms profit by licensing or selling their inventions to other firms that are more effective users.
3. Because of the public-good attribute of information, it may cost the proprietor of intellectual property virtually nothing to license the property to others. If so, any revenue from the sale of access to an innovation, unlike the sale of a manufactured item, will constitute a pure addition to the licensor's profit. That is not to say that access is generally costless to the licensee. On the contrary, it may require expensive retraining of staff, acquisition of new equipment, and even some degree of reorganization, all of which have been shown often to be very costly. But these are not costs that need to be borne by the licensor.

4. As is well known, firms can acquire the essence of intellectual property by industrial espionage, reverse engineering and can use the information to create substitutes sufficiently differentiated from the original to immunize the imitator from legal countermeasures. Indeed, once an invention is patented, the pertinent technical information becomes public, facilitating such "hostile replications." However, what I have called "friendly transmission," in which use of the invention is permitted by mutual consent on mutually acceptable terms, can normally be carried out far more rapidly and at far lower cost because the owner of the intellectual property will then facilitate the transfer with information, training of the licensee's personnel, etc. This often makes it worth while for a company that wants to use such an invention to agree to pay for access rather than undertaking a hostile acquisition.
5. In an industry in which technical change is frequent and substantial, delay in putting out a new product or use of a new process may mean that these will be obsolete before they or their products reach the market. That is yet another powerful reason inducing firms to acquire access by the much more rapid friendly means. But it also implies that by licensing, the owner of the invention may give up little of the competitive advantage that derives from being the first to put the invention to use. If, as the evidence suggests, it often requires something on the order of a year before the licensee can get the licensed invention up and running, the licensor then has a year without competition in its use of the invention.
6. Patents play a crucial role in encouraging the dissemination of technology. Rather than always serving to deny use of technology to others, its primary role is often to ensure that the inventor can obtain satisfactory compensation for its use by others. In this way, patents serve in helping to internalize the externalities of innovation, simultaneously encouraging investment in innovative activity *and rapid dissemination of the novel products of that activity.* Apparently, the patent laws were explicitly designed to stimulate both invention and dissemination.

3. Markets in technology in practice: the role of patents

There exists a valuable literature on markets in technology going back at least to the work of Katz and Shapiro (1985), Teece (1986, 1998), Von Hippel (1988), and others, as well as my own work (1993). It discusses the various forms these markets can take, their rationale and their magnitude in reality (for references see Arora et al., 2001, pp. 2–6 and the bibliography). In several articles, Lamoreux and Sokoloff have provided striking evidence about the early beginnings of markets in technology and their subsequent growth. By painstaking study of patent records and related materials they have been able to document the pertinent transactions. They report that "... such exchange began to take off by the middle of the 19th century" (1996, p. 126876). New information channels and intermediaries began to appear at this early date, with a specialized patent agents and lawyers advertising their availability as finders of buyers of patents on a commission basis. "Their numbers began to mushroom in the 1840s, first in the vicinity of Washington and then in other urban centers . . . ." (*loc. Cit.*) Particularly with a secular increase in the percentage of inventions contributed by individuals who specialized in the activity, rather than by part-time inventors, " . . . trade in patent rights increased in all regions (of the US) through 1910 (the date at which the statistical analysis terminates), nearly doubling overall (from 1870 to 1871) by this measure" (p. 12689). The authors conclude that " . . . the growth of intensely competitive national product markets, coupled with the existence of the patent system, created a powerful incentive for firms to become more active participants in the market for technology" (p. 12691).

Today, the sale, licensing and trading of technology has become a large scale activity. Arora et al. (2001) list a sample of "leading deal makers in markets for technology" that includes companies such as Microsoft, IBM, AT&T, Monsanto, Motorola, Bell South, Daimler-Benz, Eli Lilly, Eastman Kodak, Sprint, Philips Electronics, Siemens, General Motors, Honeywell, Boeing, Fiat, Ford, General Electric, Hitachi, Toshiba, Dow Chemical, Johnson & Johnson, and many others. (pp. 34–37) They report the results of a survey of 133 companies by a British consulting firm, indicating that 77% of the companies studied had licensed technology from others while 62% had licensed technology to others. They report that "When compared to internal R&D, however, licensing is a fairly modest activity in terms of budgets involved. The survey estimated that expenditures for licensing technology from others amount to 12, 5, and 10% of the total R&D budgets of North American, European and Japanese respondents, respectively" (pp. 30–31). However, they estimate that "the size of the market for technology" is about US$25 billion in North America alone, which, they note, is about the size of the 1996 gross domestic expenditure on R&D in France and greater than that of the UK. (p. 31)

For a number of firms participation in markets in technology is of critical importance. For example, the sale of access to polypropylene technology has constituted a major activity of the Union Carbide corporation, and IBM has informed me that it has a technology exchange contract with every major manufacturer of every significant computer part throughout the world. I have estimated that in the year 2000 approximately 20% of IBM's total profits derive from the sale of licenses.

The prevalence of the activity has been sufficient for the formation of the Licensing Executives Society that reports a membership of nearly 10,000 from more than 60 countries, and that runs seminars and conferences such as one on "Leveraging Technology for Competitive Advantage." There are many websites offering information and help for licensing and technology transfer. According to the U.S. National Science Board, between 1980 and 1998, American, European, and Japanese firms arranged some 9,000 strategic technology alliances. It is clear that voluntary dissemination is no isolated and unusual phenomenon.

4. Technology sharing and transfer arrangements: why do firms undertake them?

Sharing of information on proprietary technology can take many forms. The most widely recognized are research joint ventures in which several firms finance some R&D activity whose results are to be made available to all the companies that supported it (see, e.g., Katz & Ordover, 1990). Sometimes the sharing is informal, with no contracts and no license fees, each firm helping its rivals to adopt and utilize new techniques with the understanding that the favor will be returned when appropriate. For example, Von Hippel reports that this is the normal approach to technology trading by the U.S. steel mini mills. Often, of course, firms enter into contracts in which one gives the other permission to use its proprietary technology in return for a license fee. Firms also often enter into reciprocal licensing contracts with licenses, in which the participants agree to permit one another to use not only their current technology, but also any future innovations of the sorts specified and for a specified period. The contracts also vary in the ways in which the payment obligations are calculated, in terms of the obligations for updating of information on improvements of the technology and on the amount of training that the licensor will provide to employees of the licensee. Thus, there is no one standardized approach employed in the voluntary business dissemination of technology.

Once one frees oneself of the prejudgment that the self interest of firms will generally lead them to withhold their technological information from others, it is easy to think of reasons why they may want to behave otherwise, though we will see presently that there can be reasons that are not quite so obvious.

The most straightforward reason, and the one most frequently offered to me by businesspersons with whom I have discussed the subject, is the high cost of R&D activity. By entering into some sort of sharing consortium the burden can obviously be divided and reduced for each participant. Given the public-good attribute of the resulting information, it is far less expensive (per user) to provide such information to several firms than only to supply it to one.

A second reason is reduction of risk. In any given year a single firm's R&D division may fail to come up with any significant breakthroughs. The fear by management of firm A that this will happen to it in a year when its rival, B, manages a significant breakthrough is a fear that is replicated in firm B. Since, as already emphasized, product and process improvement are a matter of life and death in the high-tech industries characterized by vigorous oligopolistic competition, technology sharing agreements serve as effective insurance policies, protecting each participant from such catastrophes.

A third reason, is simply straightforward profit. Suppose firm A invents a new widget and expects to make a net profit of X dollars per widget of the new type that it produces. Then if rival firm B offers A a Y dollar license fee ($Y > X$) for each unit of the new widget it is able to sell, A obviously can be better off letting B do so, even if every widget sold by B means one less sale for A. Of course, B will generally be able to afford so high a fee only if it is a more efficient *producer* of widgets than A, even though it may be an inferior inventor. In this way the price mechanism will not only encourage licensing, but will, as usual, encourage efficient specialization, with inventive activity undertaken primarily by the more effective inventor and production of the resulting products undertaken predominantly by the more efficient producer. This sort of unreciprocated licensing does take place in practice, but it seems most frequently to entail the sale of licenses by large firms that are in a position to undertake extensive R&D activity, the licensees being smaller enterprises that cannot afford to carry out such activity and do not possess personnel qualified to do so.

A fourth and less obvious reason for voluntary dissemination also entails trading of technology, but it is undertaken because it protects the firm from entry. To see how this works, consider, for example, an industry with 10 firms of identical size, each with an R&D division with similar staffing and similar funding to those of the others. Each firm in such a consortium will then have available to it not only the discoveries of its own R&D establishment, but those of nine other firms in addition. Now suppose an 11th firm wants to enter the market, but is not invited to join the technology sharing consortium. Having only the products of its own R&D division at its disposal, while the other firms each obtain the outputs of 10 R&D establishments, the entrant can evidently find itself at a severe competitive disadvantage.

This type of arrangements evidently has its pros and cons. It can be shown to stimulate innovative effort (provided that anticompetitive conspiracy is absent). For it helps to internalize the externalities generated by the innovative efforts of each firm. Indeed, if as happens in practice, in such an exchange each firm undertakes compensation equalization payments to any other member of the consortium if the latter's innovations are of market value significantly superior to its own, then the firm has a direct incentive to come to the contract bargaining table with a menu of valuable innovations to offer. It can also be shown that the formation of such a consortium tends to be welfare enhancing (Baumol, 2002, Chap. 7).

Yet there are evidently exceptions. Such consortia can serve as vehicles or as camouflage for anticompetitive behavior. For example, the contract discussions can conceivably serve as a disguise for price fixing by the competitors. Or they can enter into an agreement for mutual restriction of their R&D expenditures, each firm knowing that it can safely limit its innovative efforts if it can rely on its rivals to do the same. Or the contracts can be offered in a discriminatory manner that limit the benefits offered to entrants or denies them access altogether.

It is of some interest that the U.S. Department of Justice and the Federal Trade Commission have recognized the two sides of the issue. Their 2000 *Guidelines for the Licensing of Intellectual Property* very explicitly discuss the procompetitive benefits of licensing as well as the nature of the associated concerns. This is not the place to offer an evaluation of the *Guidelines*. What is significant for us here is that licensing as the prime instrument for technology dissemination has become sufficiently important to merit this sort of attention by the antitrust agencies.

5. The invaluable contribution of "mere imitation"

I turn now to a second misapprehension about the innovation process. As is well known from the extreme but by no means unique example of medieval China, an outburst of invention is not a feature of capitalism alone. What only capitalism has accomplished very effectively in the arena of innovation and growth is systematization and stimulation of practical utilization of its inventions. It is true, that it has also generated a considerable amount of successful activity by independent inventors, induced to do so by the success of predecessors, by the public acclaim they could hope to obtain, by immunity from confiscation of their creations that had often been the lot of their counterparts in earlier economies, and by protective institutions such as patents, contract law, and sanctity of private property.

But beginning in the 19th century another development arose, one that also made major contributions to the innovation process. This was the incorporation of innovative activity into the regular operations of many large enterprises, turning such R&D effort into a bureaucratized process, in which the firm's management decided upon budgets, personnel, operational methods, and even frequently decided for the company's R&D units what they should currently undertake to invent. As already indicated, this was a step driven by the desire to minimize risk in industries where failure to update products and processes could be extremely damaging to the firm and sometimes even fatal.

Understandably, the pressures in such an arrangement drove the R&D establishment of the firm to focus on applied rather than basic research, and to give priority to product improvements such as increases in reliability and user friendliness rather than to imaginative breakthroughs. The result was that a very substantial share of such breakthroughs continued to emerge from the workrooms of the unaffiliated inventors (as well as from nonbusiness institutions such as universities and government agencies). Scherer cites as examples alternating current, the radio telephone, the synchronous orbit communications satellite, the turbojet engine, and sound motion pictures, among others. And to these one must surely add the automobile, the airplane, and the electronic computer. It is the evident value of these breakthrough creations that led Schumpeter to imply that their subsequent adoption and adaptation by large business firms constituted "mere imitation." But, following Rosenberg, I will argue next that this is sheer mischaracterization. The bulk of the benefits the economy derives from most of these breakthroughs could not have been obtained without the work of both, the independent inventor and the giant corporations that focused on improvement of the product. Elsewhere I have characterized their combined role as David–Goliath symbiosis, both activities being necessary requirements for the full current value of the output of the innovation process.

Two very noteworthy examples, the airplane and the electronic computer will make the point. On the former, I will simply quote Rosenberg:

> At the beginning of the century the question was whether heavier-than-air flight was even possible. That question remained unresolved until the Wright brothers

> actually did it, when they managed to get airborne for just a few brief seconds at Kitty Hawk, South Carolina in December 1903 . . . . I personally doubt that, if some of us had seen the Wright brothers' airplane leave the ground on its brief flight back in 1903, we would have left the scene with visions of airplanes crossing the Atlantic Ocean in six hours or so carrying 350 people watching movies in at least some reasonable degree of comfort . . . . In fact, almost 70 years elapsed between the Wright brothers and the introduction of the 747. It even took a full third of a century before a much more modest set of improvements in airplane design, structure, and components were incorporated in the DC-3 (1936), the introduction of which marked the beginning of commercial aviation. (2000, pp. 59–61)

Indeed, one can go one step further, and compare the number of passenger miles a Boeing 777 is capable of providing over its lifetime with the corresponding figure for any flying machine produced by the Wright brothers or any of their contemporaries. The ratio is evidently enormous, meaning that *almost all* of the passenger-carrying capability of today's airplane was contributed by the mere imitators, many of them working inside the airplane manufacturing firms or under their sponsorship and direction, who followed the breakthrough of 1903. Of course, that breakthrough was indispensable for the later contributions. But in terms of magnitude of direct product contribution it was surely the later work that beats out the earlier, by far.

The computer story is similar. The ENIAC, created at the University of Pennsylvania in 1945, was the first operational electronic digital computer. Measuring the output capacity of the computer in the standard MIPS (millions of instructions per second), there can be no doubt that a respectable modern notebook is capable of providing a MIPS performance that so enormously exceeds that of the ENIAC as to make the comparison seem ridiculous. But the laptop does not simply do more of the same and do it far faster. Today's machine is reasonably reliable and user friendly. Gone is the need for huge air conditioned rooms to house the computer with is masses of cables, electric bulbs, and other unwieldy accoutrements, its constant breakdowns, and its accessibility to an ordinary mortal provided only at 4 a.m., and then only if that mortal had proper authorization. And yet, much more than that, today's computer is capable of doing many things far from anything dreamed of in 1945. Its graphics, it ability to provide music, doctor photographs, and movie films, and above all, its role as gateway to the internet, are mostly contributions of members of the tribe of mere imitators.

The upshot of all this is that the innovative role of the corporation, though it makes little contribution to basic research and is ill designed to provide the preponderance of breakthroughs, must nevertheless by recognized as a very major contributor to the productivity that stems from the economy's innovation assembly line. Without the routinized R&D activities of these oligopolistic enterprises one can be confident that today's economy would be characterized by productivity considerably lower than that actually achieved, and that the reliability, practicality and user friendliness of the innovative products now at the consumer's disposal would be far more circumscribed.

6. Concluding comment

It follows from all this that much of the economics of innovation is far from obvious. There is a great deal in the arena that is not yet widely recognized, and much that is widely misunderstood. Effort to provide further illumination on the subject is surely well expended, for it will help us to understand more fully the roots and the nature of the mechanism that underlies the hallmark accomplishment of the free-market economy, its unparalleled achievement in terms of applied invention and economic growth.

Acknowledgments

I am grateful to the C.V. Starr Center for Applied Economics for its support of the work underlying this paper.

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