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Ayresian Technology, Schumpeterian Innovation, and the Bayh-Dole Act

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Abstract: A main implication of C.E. Ayres tool-combination principle is that the goal of technical progress is best served by a non-proprietary, open science public policy. Joseph Schumpeter claimed that new combinations are consequential *only* when they have been successfully commercialized. The capacity to privatize knowledge is, moreover, a powerful stimulus to innovation. This paper reexamines the Ayresian and Schumpeterian positions using evidence from the Bayh Dole experiment. The Bayh Dole Act, which gave universities title to inventions resulting from federally-sponsored research, created a laboratory wherein the trade-offs between diminution of the appropriable knowledge fund (due to patenting) and incentives to commercialization can be appraised.

Keywords: Bayh-Dole, technology transfer, anticommons

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The communism of the scientific ethos is incompatible with the definition of technology as 'private property' in a capitalistic economy.

Robert Merton (1973, 275)

The difficulty in developing an institutional structure advantageous to the progress of technology can be traced (in part) to the need to reconcile two important, but potentially conflicting, objectives. On the one hand, the collaborative and cumulative nature of the scientific enterprise militates in favor of a policy that preserves the public good properties of knowledge. Clarence Ayres (1944) argued that meaningful inventions arise from the use of tools (calculus, electron microscopes, gene splicers, or particle accelerators, for example) by skilled practitioners. The Ayresian view suggests

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that institutional restrictions on the use of tools — in the form of patents or exclusive licenses, for example — are likely to hinder technological development.

Joseph Schumpeter ([1934] 1961, 88) held that discoveries are "economically irrelevant [if not] carried into practice." Innovation (the dynamic aspect of entrepreneurship) means tendering new ideas or combinations to the process of market selection. A cardinal virtue of capitalism is that, by distributing spectacular awards to a minority of successful innovators, it brings forth a swell of risk-taking, entrepreneurial effort. The proprietary control of new knowledge (or its objectification in new products or processes) is a demonstrable factor in the appearance of some great economic fortunes.[1] Most economists consider strong intellectual property rights essential to maintaining an incentive system propitious to private innovation.

The purpose of this article is to examine the fallout of the Bayh-Dole Act of 1980 (which gave universities the right to retain title and grant exclusive licenses for the use of patents on inventions resulting from federally-funded research) through the Ayresian and Schumpeterian lenses. The argument is made that, while Bayh-Dole appears on the surface to have been successful in sparking entrepreneurial activity (particularly in the biomedical area), the legislation is also implicated in the removal of important research tools from the public domain.

The Bayh-Dole Act

The Patent and Trademark Amendments of 1980 (also known as Bayh-Dole) established a mandate for federal grantees and contractors to assume the role of active agents in the privatization and commercialization of inventions resulting from publicly-funded research.[2] The primary justification for the new regime — one which has allowed universities and private firms to gain proprietary control over a great number of federally-funded technologies — was an allegedly poor return on public investment in research and development. The law was passed in a lame duck session of Congress amid concerns about import penetration and the loss of U.S. competitiveness. A 1979 report of the Comptroller General's Office cited the fact that less than 5 percent of 28,000 taxpayer-funded discoveries had been commercialized as evidence of the need for a reformed licensing policy — specifically a need to lift the ban on the awarding of exclusive licenses of government-owned patents (see Leaf 2005).

Bayh-Dole opened the way for universities to pursue their own research pots of gold, and many responded by hiring technology transfer specialists to promote and manage the commercialization of federally-funded research. Technology transfer officers solicit "disclosures" (a document in which faculty members reveal and describe their research output) from university scientists, appraise the market or licensing potential of disclosed faculty research, provide technical assistance in filing patent applications and creating startups, negotiate terms of patent licensing agreements with private entities, and maintain vigilance against infringement of their institution's intellectual property rights. Some universities (Stanford and Case

Western Reserve, for example) also arrange or directly provide financing for startups or technology incubator firms formed by faculty members.

Based on measures such as the number of successful patent applications, the fraction of patented inventions licensed to firms, the number of startup companies created to commercialize federally-funded research, lucrative faculty consultancies, or total revenues garnered by universities from licensing agreements, Bayh-Dole is a spectacular success. So why has the Act generated a hailstorm of criticism?

The chief complaint about Bayh-Dole is that it has contributed to a *tragedy of the anti-commons* — that is, a situation in which fragmented ownership rights lead to the underutilization of knowledge.[3] Open science is optimal in terms of minimizing research-related transactions costs. Thus use of non-proprietary knowledge entails no allocation of resources for search, negotiation with patent-holders, licensing, or monitoring. The number of patents issued annually to U.S. universities (including medical schools) increased by more than twelve-fold between 1979 and 2006 — far more than the increase in research funding.[4] Moreover, universities are heavily involved in patent litigation.[5] Thus, an unintended consequence of Bayh-Dole is a "patent thicket" through which researchers must navigate. There is evidence to indicate that partly as a result of active enforcement of patent rights the "research exception" on patented material has been substantially weakened.

Bayh-Dole has also propelled a shift of university research cultures from open and collaborative to secretive and proprietary. Scientists are increasingly loath to share information for fear that others will steal commercially valuable ideas.[6] Confidentiality agreements entered into by consulting university scientists have also worked to prevent the sharing of information.

Ayresian Technology

The Ayresian theory of technology is summarized as follows: (1) *All* inventions are combinations of pre-existing tools and thus were "bound to happen" given the extent of society's accumulated knowledge;[7] (2) the "heroic" theory of technological development, which assigns decisive importance to the "skill-faculties" of scientists and inventors, should be displaced in favor of a theory in which tools — that are the product of cumulative development and, as such, transcend individuals and belong to culture — are primary; and (3) as the tool-combination principle of economic progress is approximated by the mathematical law of combinations, a slight increase in society's stock of accumulated knowledge leads to a much larger increase in the total number of potential combinations or inventions.[8]

Skill-faculties are obviously important for the utilization of *existing* tools. However, the progress of technology does not come from skill but rather "the sheer existence and proliferation of tools" (Lower 1987, 1156). Ayres explained that

> Because technology is objectified in physical tools and apparatus, it is always capable of progressive development. Every tool contains — within itself, so to speak — the possibility of being applied in new situations, to different materials and in different ways from its historic use. This process is the universal pattern of inventions and discovery. (Ayres 1953, 282)

The Ayresian view clearly implies that legal restrictions on the proliferation of tools are likely to stifle discovery and invention. The tool-combination principle raises an important question: Are all discoveries created equal with respect to potential for future re-configuration? Intellectual property theorists argue there are important differences between near-the-market, commercially ready inventions and upstream or basic research discoveries "that are primarily valuable as inputs into further research" (Rai and Eisenberg 2003, 291) that should be respected by patent-granting agencies and jurists. It would seem that the public interest would be better served if tools such as transgenetic mice or gene knock-out models "which guide the identification and validation of targets of [recombinant DNA] therapeutic interventions" (Gelijns and Their 2002, 74) were kept ineligible for privatization. But the Bayh-Dole Act makes no distinction between basic and applied research, an omission that would not have been so consequential if the courts had not contemporaneously expanded the range of discoveries eligible for patent protection. A 1980 Supreme Court decision held that genetically engineered microorganisms were eligible for patent.[9] A key 1995 decision of the Federal Circuit Court of Appeals ruled that the "usefulness" test applied in patent cases involving biomedical research extends beyond "specific benefit [that] exists in currently available form" to "the expectation of future R&D."[10] The changes in the incentive structure of university research as well as case law have catalyzed the "encroachment of the patent system into what was formerly the domain of open science" (Rai and Eisenberg 2003, 291). It should also be noted that the tragedy of the anti-commons invocation is most frequent in the case of biomedical research, where the space separating upstream basic discovery from commercial application is, in comparison with other lines of scientific inquiry, very compressed.

Privatization of Research Tools

Technology transfer officers are evaluated on the basis on their contribution to the institution's patent portfolio and royalty income. There is a clear incentive to commodify *any* discovery that might conceivably generate a future income stream. The quest for saleable intellectual property has predictably moved upstream to basic research. A 2000 survey of 62 technology transfer officers concluded that 88 percent of university-patented technologies required further development and 45 percent amounted to nothing more than a "proof of concept."[11] Another survey reported that some universities were "filing provisional patent applications to retain rights to an invention while exploring whether there was a market" (Henry et al., 2002, 1279).

Columbia University is the perennial leader in licensing income among "nonprofits." It has been estimated that roughly half of Columbia's patents cover research tools. Columbia's cash cow was cotransformation, a process for inserting foreign DNA into a host cell to produce certain proteins, for which it held three patents. Developed by Columbia scientist Richard Axel, cotransformation is considered the basis for a large number of new pharmaceutical products for anemia, hemophilia, multiple sclerosis, and other diseases. Columbia retained a white shoe law firm to extend its Axel patents to 2019 (the first patent was awarded in 1983), but was forced to abandon the effort in the face of a flood of law suits by biotech firms.

Some argue that Bayh-Dole merely certified what a few prestigious universities were doing already.[12] Stanford and UC-San Francisco obtained a waiver to patent the Cohen-Boyer technique for gene splicing (the basic tool for recombinant DNA technology) in 1980 and commenced licensing gene splicing technology to biotech firms. These institutions received approximately $200 million in royalty income over the life of the patent (it expired in 1979). No one is disputing that the Cohen-Boyer discovery was essential to the appearance and explosive growth of the biotechnology industry. At the same time, there is every reason to believe that substantially the same thing would have happened had gene splicing technology remained in the public domain. In fact, it is quite likely the scale of biotechnology research would have been greater than it actually was if startups or university researchers were not required to pay royalties for the use of the Cohen-Boyer process. Furthermore, the proprietary status of the technology probably narrowed the scope of its use to research areas with the highest commercial potential.

Another example of the displacement of a broadly enabling research tool from the knowledge commons involves the University of Wisconsin. Its National Institutes of Health (NIH)-sponsored researchers discovered a technique for deriving embryonic stem cells from rhesus monkeys and macaques. The Wisconsin technology transfer unit subsequently obtained a patent covering *all* primate (including human) embryonic (pluripotent) stem cell lines. Pluripotent stem cells are considered "true" stem cells because they are capable of producing any differentiated cell in the body. The NIH would seem to have an interest in limiting rent-seeking behavior by grantees in the case of basic research tools such as stem cells or genetic sequences. The "exceptional circumstances" clause of the Bayh-Dole Act nominally gives the NIH (and other funding agencies) the power to protect the public domain. The process is complex, however, and declarations of exceptional circumstances by granting agencies can be challenged in court or overturned by the Secretary of Commerce (the Department of Commerce has primary responsibility administering the Bayh-Dole law).[12]

Schumpeterian Defense?

The "carrying out of new combinations" (Schumpeter [1934] 1961, 67) by entrepreneurs roils the stasis of economic life and is, according to Schumpeter, the key factor driving the secular growth of output.

> It is therefore quite wrong . . . to say . . . that capitalist enterprise was one, and technological progress was a second, distinct factor in the observed development of output; they were essentially one and the same thing, or as we may also put it, the former was the propelling force of the latter. (Schumpeter 1942, 110)

A Schumpeterian defense of Bayh-Dole might be constructed around two elements: (1) incentives to knowledge transfer; and (2) incentives to allocate resources for the commercialization of new knowledge. With respect to (1) above, the separation of federally-funded research (federal money accounts for two-thirds of total research support at U.S. universities, hospitals, and research institutions) from commercial development obviously requires that there be mechanisms of knowledge transfer — that is, if research outputs are to become "relevant." Technology transfer via licensing is an alternative to conventional forms of knowledge dissemination such as publications and working papers, seminars and presentations, consulting, and the training of graduate students who eventually take jobs in the private sector. Licensing and patent litigation by nonprofits clearly raise the costs of technology transfer (see Mazzoleni 2005). The proponents of Bayh-Dole face a difficult task in explaining precisely how licensing is superior to other modes of knowledge transfer — as they should be required to do, given the inefficiencies involved. It strains credulity to suggest that non-rivalrous tool combinations such as cotransformation or gene-splicing would not have achieved such wide diffusion if the parties involved in their development lacked the proper economic incentives to transfer technology. Something like the opposite is probably closer to the truth. That is, the increased reliance on licensing pursuant to Bayh-Dole has likely resulted in a reduced scale of knowledge transfer (and tool combination) in comparison with what an "open science" regime might have delivered.

The multiplication of biotechnology startups around research universities would not have occurred without Bayh-Dole. Does it follow that the legislation was the key to the growth of the biotechnology industry? Not necessarily. The act requires grant recipients to give licensing preference to small business (500 employees or less). If the "entrepreneurial activity" effects of Bayh-Dole are measured by the number of new firms spawned by federally-funded research, the post-1981 regime is a great success. However, many biotech startups do not innovate in the Schumpeterian sense.

Cook *et al.* (2006) divide the "knowledge value chain" in the life sciences into three segments: *exploration* or basic research; *examination* (clinical trials), and; *exploitation* "that enables discoveries to be transformed into commercial products with market demand" (116). The value-added contributed by biotech incubators derives primarily from examination. Large-scale firms enjoy many advantages (existing production capacity and distribution channels, lines of credit, marketing expertise, for example) over startups with regard to exploitation. Given that examination is a crucial link in the knowledge value chain, it seems the most effective defense for Bayh-Dole would reside in showing that it helps to correct for an under-allocation of resources to this activity that would be experienced under an open science policy. The patenting of pre-market science by universities and their startups is on one level "preemptive" — meaning its aim is to capture the rents that otherwise might accrue to units nearer the market. The relocation of property rights upstream in the knowledge value chain has, by causing the vertical separation of product development from commercialization, weakened incentives to the latter.

Final Remarks

The post-1980 expansion of intellectual property rights is informed by an individualistic or heroic conception of scientific progress. An Ayresian analysis concluded that the surge in proprietary claims by universities pursuant to Bayh-Dole has hastened the foreclosure of the knowledge commons and slowed the pace at which new combinations are formed. The effects have been particularly harmful in the case of broadly enabling tools such as pluripotent embryonic stem cells.

Bayh-Dole is difficult to uphold on Schumpeterian grounds as well. The standard argument — patents serve to attract private resources to the development and commercialization of valuable technologies that, absent such protections, would lie dormant — is "more plausible for discoveries that depend on private investment than for discoveries made with public funds" (Rai and Eisenberg 2003, 295). Moreover, it is hard to understand how a system that forces private firms to confront a phalanx of pre-market patent claims can be conducive to innovation.

Notes

1. For example, Microsoft's proprietary control of its Windows application program interfaces (APIs) ("the synapses at which the developer of a software application can connect to invoke pre-fabricated blocks of code in the operating system" (Judge Jackson, United States v. Microsoft 530 U.S. 1301 (2000))) is thought to be a key factor underpinning the "applications barrier to entry" into the Intel-compatible desktop operating software segment because it enables Microsoft to keep independent software developers in the Windows tent and prevent their migration to other platforms.
2. The stated intention of Bayh-Dole is "to use the patent system to promote the utilization of inventions arising from federally-funded research and development . . ." 35 U.S.C. § 200. Pre-Bayh-Dole, federally-funded research could be patented and licensed. However, the federal government retained rights to patents and exclusive licenses (which some argued were vital to attracting the private dollars necessary for successful commercialization of publicly-owned inventions) were forbidden.
3. Another complaint concerns the shift in emphasis from basic research, which provides seed corn for future technological progress, to applied research. Also, research lines that are patentable tend to get first priority. Biological control is the use of living organisms (predators, parasitoids, pathogens, for example) to control pests, insects, weeds or disease. Berkeley entomologist Andy Gutierrez, who worked on a project to save the cassava crop (a staple for 200 million West Africans) explained the difficulty in obtaining funding by noting that "[y]ou can't patent natural organisms and ecological understanding used in biological control" (quoted in Washburn 2005, 7).
4. According to the Association of University Technology Managers (AUTM) *FY 2006 Licensing Survey*, Tables US-3 and US-5.
5. Leaf (2005, 252) writes that "[c]ourt dockets are now clogged with university patent claims. In 2002, North American academic institutions spent over $200 million. . . more than five times the amount spent in 1991."
6. Disputes among scientists (and graduate students) over credit for scientific discoveries have, given the economic stakes, become more problematic. Oxford University has established a Due Diligence team

"whose primary function is establishing ownership of [intellectual property] generated from the university's research activities"(Cook et al., 2008, 10).

7. Ayres (1944, 119) wrote that: "[g]ranted that tools are always tools of men who have the capacity to use tools and therefore the capacity to use them together, combinations are bound to occur."
8. The counting rule for combinations can be used to illustrate. Let

$$C_n^N = \frac{N!}{n!(N-n)!}$$

where N is the number of combinations of N objects taken n at a time. Let N (the number of tools) be equal to 4 and $n = 2$. Solving by the equation above yields C = 6. If the number of tools (N) increases to 5, then the number of possible combinations (C) increases to 10. Ayres gave a mathematical example (see Ayres 1944, 119-120), but pointed out that "[w]e do not know that tool-combinations occur according to the mathematical law of permutations." Illustrations like the one above are useful however. First, they provide an insight into why technological progress in early times was, judged by modern standards, extremely slow. Also, they give a rough idea of the social cost of restrictions on the use of existing tools. For a more in-depth treatment of this problem, see Zambelli (2004). Also see Lower (1987).
9. Diamond v. Chakabarty, 447 U.S. 303, (309), 1980.
10. The former standard comes from Brenner v. Manson, 383 U.S. 519 (1966) and the latter from *In re* Brana, 51 f.3d 1552, 1559 (Fed. Cir. 1995).
11. This comes from Thursby and Thursby (2000, 4).
12. Universities did receive 277 patents in 1979. The number in 2006 was 3,255. The former figure is from Mowery et al. (2001); the latter is from the Association of University Technology managers *FY 2006 U.S. Licensing Survey*.
13. Rai and Eisenberg (2003) found only one instance where the NIH made a declaration of exceptional circumstances.

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