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ABSTRACT

This paper examines the relationship between industry and university research, focusing on developments in the United States from the 1950s through the 1980s. It found that while industry spent less than 2 percent of its research funds on academic research in 1965, it spent almost 5 percent on academic research in 1989. It also found that in the first half of the 1980s, industry substantially increased its investment in research, and that rise largely accounted for the rise in industry support for university research. In the second half of the decade, growth in industry research was modest in absolute terms, flat to negative in real terms, even though spending on university research continued to increase markedly. The paper maintains that university involvement in commercial relationships with industry have proliferated during the 1980s, especially in such areas as research parks and patent development, and that such relationships often come into conflict with university missions and goals. (MDM)

Industry and University Research: The Revolution of the 1980s

Roger L. Geiger

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Research in industry and research in universities belong to two separate and autonomous traditions. Research began to be embraced as a distinct mission of American universities in the last quarter of the 19th century. Systematic research in industry began with the foundation of permanent industrial laboratories in the first decade of this century. After the first World War, these two traditions began to interact with regularity. Industry was primarily concerned with universities as the source of research personnel. Universities also set up a variety of special institutes or laboratories that did fairly routine services, like testing, for firms. And, companies took increasing interest in the actual results of academic research. During the 1920s, the internal research efforts of firms in certain industries expanded considerably. As they did so, they relied on universities less for routine services, which were now done in-house; but they found greater use for academic research to complement their own internal investigations. By 1940, large chemical and drug firms, in particular, maintained ongoing contacts with university laboratories and supported university research. Thus, the two autonomous traditions developed an important area of overlap.

The 1980s in Historical Perspective

This overlap of the two systems has persisted to the present day. The current situation, with estimated NSF data for 1989, suggests the following:

- The two systems are fairly similar in size;
- Of the funds that industry spends on research, 4.79 percent went to universities;
- Of the research performed in universities, 6.5 percent was funded by industry.

Several other points can be made about this relationship:

First, the subject here is research, both basic and applied – but not development. Industry and universities have some similar interests in research, but not so with development. Consequently, if data for R&D are used, the picture is muddied considerably. So, the data used here have been adapted to represent just applied and basic research.

Second, this relationship is somewhat larger than it would initially appear. Some university research that is funded from other sources is intended to be useful to industry, and industry spends a larger amount to secure access to academic research than the numbers appearing on university research budgets.

Third, this whole subject is usually discussed from the standpoint of the university, but this is looking at the relationship backwards. Industry is the buyer, essentially, and universities the seller. Both sides of these transactions are important, but the relationship is largely driven by the discretionary purchases of industrial firms. Nevertheless, important changes have occurred on both sides. The revolution of the 1980s has consisted of a significant increase in industrial demand for research. On the university side, the changes might be characterized as "cashing in on academic research."

These developments can be illustrated by examining the long-term trends in this relationship. Table 1 provides data on the expansion of research supported by industry. The total expenditures, expressed in constant dollars, nearly quintupled in a third of a century, but the rate of change was uneven. Industry spending on research accelerated in the late 1950s, but actually declined in real terms during the first half of the 1970s. The first half of the 1980s registered the largest increment of the entire period.

Does this mean that industry has been growing more reliant on scientific research? Possibly. When measured against GNP, industrial expenditures for research show an interesting pattern. This ratio was remarkably stable from 1960 to 1980, but then jumped to a significantly higher level during the early 1980s, and has apparently maintained that new level since then. In other words, after having been fairly stable for 20 years, industry-supported research grew twice as fast as GNP during these years. The next question, then, is what was its relationship to university research?

Table 1. Industry spending for basic and applied research.

Year	National totals (millions, 1982 $)	% of GNP
1955	2,850	0.19
1960	5,061	0.30
1965	6,263	0.30
1970	7,262	0.29
1975	7,180	0.26
1980	9,322	0.29
1985	13,127	0.35
1989 (est.)	14,094	0.34

Table 2. Industry support for basic and applied research.

Year	% in universities	% of total university research
1955	3.1	8.1
1960	2.4	6.0
1965	1.8	2.8
1970	2.2	2.5
1975	2.5	3.3
1980	2.8	3.9
1985	3.4	5.7
1989 (est.)	4.8	6.5

Table 2 presents a much more variable picture. Industry spent less than two percent of its research funds on academic research in 1965 and now spends almost 5 percent. Industry accounted for just 2.5 percent of university research in 1970, but now supports 6.5 percent. The most interesting change transpired in the behavior of industry in the late 1980s. Its relative investment in university research rose by 43 percent to an unprecedented level.

The "Revolution of the 1980s" thus seems to have two distinct facets: in the first half of the decade, industry substantially increased its investment in research, and that rise largely accounted for the rise in industry support for university research. In the second half of the decade, growth in industry research was modest in absolute terms, flat to negative in relative terms, but spending on university research increased markedly. Does this mean then that industry is becoming increasingly dependent on *university* research? Not necessarily.

When long-term trends are examined, it is apparent that industry has the option of substituting for an appreciable amount of the university research that it supports. Table 3 shows industry support for external research in universities and nonprofit organizations. (No data exist for industry purchases of research from other for-profit firms.) There is greater stability in these percentages than in those for only university research. In particular, from 1960 to 1980 when total industrial support for research was relatively stable, so was the proportion supported externally. What was highly variable was the division of purchased research between universities and nonprofits. After being fairly even, nonprofits assumed a 58-to-42 advantage by 1970. Since then, universities have gained a dramatic share in this market.

Given the substitutability of university and nonprofit research, it seems doubtful that the rise in industry support of university research represents an

Table 3. Industry-supported research in universities and nonprofits.

Year	% of total spending	% in universities	% in nonprofits
1955	6.6	47	53
1960	4.8	49	51
1965	4.2	44	56
1970	4.4	42	58
1975	5.0	51	49
1980	4.8	58	42
1985	5.5	65	35
1989	7.1	67	33

inexorable change in the scientific underpinnings of American industry. Rather, it more likely reflects the changes that have taken place in university attitudes and practices. Specifically, it seems probable that the unprecedented growth of industrial research on campus is a result of the many steps taken to encourage these relationships.

Gnostic and Commercial Relationships

Ties with industry involve universities in two types of relationships. Support for research is basically concerned with the search for knowledge, and for that reason these ties can be called *Gnostic Relationships*. Attempts on the part of universities to extract profit from links with industry, on the other hand, can be summarized as *Commercial Relationships*. These two large and complex categories are presented for convenience in schematic form:

There can be little doubt that industrial funding of university research produces positive benefits. The university's comparative advantage lies in performing basic research, and it is largely generic knowledge from basic research that industry has sought from universities. Academic research funded by industry is currently 62 percent basic – up from 60 percent at the beginning of the decade. This research overwhelmingly represents relationships between consenting adults: firms support the research because it is of interest to them, and faculty perform it because the subject interests them. This research thus bolsters the overall university research effort in terms of research funding; support, experience, and contracts for graduate students; and contributions to sustaining university infrastructure.

The influence of industry funding is highly localized in the university: 85 percent of the funds go to areas closely linked to the economy – engineering, agriculture, and medicine. Still, ties with industry bring some degree of benefit

Gnostic relationships between universities and industry.

Character

- Purpose of research to gain knowledge
- Knowledge usually generic and public in nature
- Knowledge intended to complement internal R&D of firms
- Relationship usually with large corporations with extensive internal R&D effort

Forms

General	*Specific*
Consultants	Science Advisory Boards
	Personnel exchange
Contracts	Long-term research contracts
	Research consortia
	Industrial affiliates plans
Research centers	Specialized centers
	NSF Cooperative Research Centers
	NSF Engineering Research Centers

Positive effects

- Increased research funding for faculty, grad student support
- Support for infrastructure
- Voluntary support from industry

Negative effects

- Constraints on the free flow of information
- Steering of university research toward programmatic ends

to the university as a whole. Table 4 suggests a definite relationship between industry sponsorship of research and industry gifts to the institution. Note that for most of these dozen leaders, gifts exceed actual funding from industry for research.

On the negative side, there has been widespread concern about inhibitions on the free flow of information. Universities learned to live with classified research long ago. Perhaps the lesson there was that secrecy where necessary should be openly identified. Similarly, in cases where industry has insisted upon the right to delay publication of findings, procedures agreeable to both sides

Commercial relationships of universities.

Character

- One step removed from search for knowledge
- Largely oriented toward small firms and start-up companies
- Importance of "propinquity effects"

Forms

General	*Specific*
Patenting	Internal patenting offices
	Offices of technology transfer
	Patenting foundations
Real estate development	Research parks
	Business incubators
Equity interests	Venture capital funds
	Equity stakes in development-stage firms

Positive effects

- Technology transfer and economic development
- Stimulating gnostic research relationships
- Making a profit for the university

Negative effects

- Incompatibility with disinterested pursuit of knowledge
- Absence of comparative advantage
- Perverse incentives of "Economics of Opportunism"
- Possibility of financial loss

Costs versus benefits

- The balance of costs and benefits is decidedly different for gnostic relationships and commercial relationships.

have been negotiated. Worse situations seem to arise where patentable discoveries are the expected outcome of academic research. Scientists become reluctant to share ideas that might prove commercially relevant at a later date. Numerous accounts testify to the chilling effect that this has had in biotechnology.

Table 4. Universities with largest industry support for research, 1986–87 ($ in millions).

University	Industrial research support	% of total research	Industrial voluntary support	% of total vol. support
MIT	35	13.3	49.7	49
Georgia Tech	24	20	9.6	39.5
Penn State	20	12	18.1	37
U. of Washington	18.6	10	29.4	38
Cornell	17	7	33.7	22.5
Carnegie Mellon	16	19	18.4	56
U. of Michigan	14.4	6.4	13.3	21.7
UCLA	14.4	7.6	23.1	39.5
Texas A&M	13.4	6	21.6	41.5
Washington U.	12	12	10.6	9.6
N. Carolina St.	12	12	12.6	54
U. of Arizona	11.6	8.4	12.8	34
TOTAL U.S. Higher Ed.	764.1	6.4	1819	21.4

A somewhat similar pattern exists with regard to fostering research. Steering is a ubiquitous threat in a system that depends upon external funding for academic research. To date, however, there has been no perceptible drift away from basic research – just the opposite. But a more subtle problem apparently exists where there is administrative pressure to favor potentially patent-producing lines of research over academic questions. In both cases, however, the dangers stem not from gnostic relationships per se, but from the intrusion of commercial interests.

The motivations for universities to become involved in commercial relationships are usually presented in straightforward terms, but in fact they contain a series of trade-offs that are seldom acknowledged: while the potential for profits exists, these ventures contain risk and hence the possibility of loss as well; while they may augment the dollar volume of research performed, such research may be oriented toward "technological deliverables," and hence contribute little to the core academic purposes of the institution; and while these activities may further economic development, they also draw universities into activities where they have few or no comparative advantages. It thus becomes difficult to judge university participation in these nonacademic activities by any

one criterion, and virtually hopeless when, as is usually the case, the criteria are confounded.

Due to the nature of universities, it is quite a complicated matter to determine whether they make a profit or endure a loss from commercial relationships. When these activities are considered, it is the great successes that spring to mind – the Stanford Research Park, WARF, or the high-tech firms that have prospered in Silicon Valley or around Route 128 in Boston. These are misleading examples; they represent universities or individuals capitalizing upon unusual circumstances. Universities, it has been frequently pointed out, have no comparative advantage when it comes to ordinary real estate development, patenting, or founding companies. But they do possess another kind of advantage, that of having privileged access to extraordinary opportunities that emerge as secondary outcomes of their normal activities. These great success stories, in fact, largely spring from these serendipitous opportunities.

In large measure, the behavior of universities in the commercial realm has exhibited an *economics of opportunism*. Universities have positioned themselves to take advantage of the infrequent discovery or development in their midst that has significant commercial potential. The crucial distinction has been that, whereas before about 1980, much of this activity was not systematic; during the 1980s, it has been institutionalized to a significant extent. This has been the revolution of the 1980s on the university's side of the relationship.

There have been tangible forces that have pushed universities toward parks, patenting, and firm formation, as explained above, but there has also been a kind of bandwagon effect at work. As this has occurred, the comparative advantage of opportunism becomes more tenuous as universities become involved in ongoing commercial activities. Research parks need tenants, patent offices must patent, and incubators ought to incubate. The more that universities engage in such activities, the more their situation resembles that of other market participants. On average, university performance in these areas has not inspired confidence in their competence.

Universities are no neophytes in real estate. By their very existence, major research universities exert a significant effect upon local real estate markets, and they have been inescapably involved in those markets as they grew. Nevertheless, developing research parks has proven to be a long-term commitment with an uncertain payoff. One study reached the judgment that three parks failed ("attracted no industries or substantially fewer than planned") for each clear success. Another estimated that just four of fourteen parks were producing the benefits that had been expected.

Establishing a research park requires a substantial initial investment. Of course, in cases where these funds are provided by a public agency, the university's own commitment is less. With perhaps 40 parks currently under development, prospective tenants have both choice and bargaining power,

which could have the effect of requiring even larger initial investments. Then, too, considering the variety of programs universities wish to sell, a firm desiring propinquity with a given university is by no means constrained to do so through a research park. A considerable length of time is usually required before the cash flow from a park will cover its expenses; another similar period is normal before the park will yield a profit. Although these many recent park projects have not yet had time to prove themselves, it seems unlikely that the majority will be of pecuniary benefit to the sponsoring university or substantially enhance technology transfer.

The economics of opportunism are even more evident in the case of university patenting. Only a very few patents yield substantial amounts of income, while the vast majority produce no income at all. Yet, patenting involves considerable expenditures. Maintaining a one-person patenting office costs over $100,000 per year; each patent application costs from $5,000 to $10,000; and successful patents have to be defended in court.

For these reasons, it has made good sense economically for universities to engage outside patent management organizations. But universities have recently opted instead for internal control over the patent process and the potential income. University foundations have been the preferable mode of doing this, but such a course also presupposes sufficient capital to cover overhead expenses.

The aggressive stance that universities have adopted toward patenting is usually justified in terms of economic development: patenting brings discoveries into the commercial realm by making it possible for firms to appropriate the rewards from their investments in development costs. Individual universities are probably more concerned with their own returns from patenting than these supposed social returns. For the few universities that have significant income from patents, this income is still dwarfed by the other support they receive for research.

Nevertheless, excess patent income (above costs) is particularly valuable because it can be used for discretionary purposes. Thus, universities seem willing to invest in patents largely in the hope of hitting the jackpot. This lure seems to outweigh the less tangible distractions that aggressive patenting brings, particularly the latent conflict with the university's role as a disinterested arbiter of knowledge.

The university's disinterested status is further occluded when it seeks to profit from its opportunities to invest in fledgling companies. But in this area too the university's hand was to some extent forced. The commercialization of biotechnology began in the late 1970s when venture capitalists teamed with university biologists to form the initial companies. Once again, those who first seized the opportunities reaped spectacular gains. These unrepresentative examples inspired university administrators to seek ways to participate in really

large profits by acquiring equity interest, although here too they preferred to conceal self interest under the cloak of economic development. In this case, however, the economics of opportunism are even more problematic: the payoffs are uncertain while the threat to the academic mission is considerable.

The incompatibility of purpose becomes visible in the everyday operations of the university. Faculty who become entrepreneurs, although they tend to be overachievers, can hardly find the time to fulfill all the unremunerated chores of academic citizenship. Moreover, the two roles that they fill require decisions about graduate students, laboratory use, and research funding in which interests inherently conflict. Many faculty entrepreneurs eventually leave the university when their firms become commercially successful. This situation represents a triumph for the university's mission of economic development, but a loss for academic purposes.

Finally, the university's absence of comparative advantage may be more glaring in this area. Backing development-stage companies is one of the most free-wheeling and risky arenas of capital finance. Unless the university's opportunistic advantage allows it to score a blockbuster success, it is likely to fare poorly among more nimble private investors motivated purely by greed. In the worst case, universities can find themselves throwing good money after bad in order to keep a failing investment afloat.

Toward a Balanced View

Much of the ambiguity that has enshrouded the research and research-related ties between industry and universities derives from the fact that this is such a large and complex arena. I have argued that these relationships consist of two basic types, gnostic and commercial, which correspond with the two faces of the revolution of the 1980s.

The decade as a whole witnessed an unprecedented acceleration of industry-sponsored university research. This growth during the first half of the decade was driven by an increase in total industry-sponsored university research. The growth in the latter half of the decade almost certainly was due to the lagged effects of the numerous university programs and facilities established to encourage interaction with industry.

The preponderance of this research represents gnostic relationships, in which generic knowledge is sought through academic research to complement the internal R&D of (mostly) large, technology-based firms. Industry is the consumer here, and although universities have expended what they have to sell, it is purchases by industry that drive this relationship. Gnostic relationships have been on the whole highly advantageous for universities. Despite possible friction in areas like expectations of patenting and the faculty commitments to centers, universities on balance stand to increase their volume of research, support for infrastructure, and overall gifts to the institution.

Commercial relationships, in which universities have entered the marketplace in order to profit from internal research or to provide services to industry, have also proliferated during the 1980s. This growth has been made possible by a transformation of attitudes and inhibitions affecting university behavior. Universities have been expected to contribute in various guises to economic development; but commercial relationships, in particular, generate conflicts with fundamental academic norms. The incentives for institutional behavior in the 1980s have been preponderantly on the side of broadening commercial relationships; and, critics aside, this trend has not to date threatened academic norms sufficiently to provoke significant backlash. Absent such negative feedback, university behavior will probably continue to drift in this same direction, but to what effect?

The university's role in economic development is largely a byproduct of its primary, and economically most valuable, missions of educating students and extending fundamental knowledge. The case for the importance of the university role in economic development rests on two pillars: that industry has been underinvesting in generic research, and thus could profitably utilize additional research from universities; and second, that discoveries of potential commercial value were being made in universities, but were not reaching the market because of the inefficiency of linking mechanisms.

The first pillar supports gnostic relationships. The sustained expansion of industry-supported research through the mid-1980s would seem to indicate the validity of this case (although the recent leveling might then mean that optimal levels have now been reached). The second pillar implicates commercial relationships. Here, convincing evidence would seem to be lacking that special exertions are required to bring university discoveries to market.

But valid or not, individual institutions still have positive incentives to pursue these relationships. The result is the perverse economics of opportunism, by which universities continue to hope for large payoffs from research parks, patents, or equity in new firms, despite the fact that the more who try, the worse the average return will be.

The expansion of commercial activities is likely to encounter negative feedback at some future point. Either financial disappointments or dissonance with academic norms could force a moderation or encapsulation of these programs on the part of universities. Richard Nelson and Dorothy Nelkin have warned that "there is a lot of winnowing that will go on," as both sponsoring companies and universities discover that some of the current arrangements are uneconomic. To dwell on the inevitable failures, however, is to miss the great strength and resilience that universities possess.

Historically, the American university has reconciled the many and contradictory demands that have been placed upon it by evolving complicated organizational arrangements. The panoply of centers, institutes, and foundations

that mediate university-industry relationships are thus a natural way of accommodating activities that are loosely related to the academic core. Given the flexibility of such arrangements, and also given the political and financial pressures on higher education, there is no reason to expect universities to withdraw from linkages with industry.

James Killian has described the research university as one of the central institutions of American society, and the expansion of ties with business during the 1980s only confirms that role. In a society increasingly dependent on knowledge, the university's incongruous and ambiguous entanglements with nonacademic institutions seem destined to grow, not contract.

Note: An extended version of this chapter with references is scheduled to appear in *Higher Education and Economic Development*, William E. Becker and Darrell Lewis, Eds.