PROFESSIONAL AUTONOMY VS INDUSTRIAL CONTROL?

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The professional autonomy of scientists to select problems and the means to solve them is considered one of the basic norms of science. As scientists have increasingly joined industry, scholars have argued that industrial scientists experience a clash in values between their professional autonomy and industrial control (Marcson, 1960; Kornhauser, 1962; Hall, 1972; Child and Fulk, 1982; Raelin, 1986; Bacharuch *et al.*, 1991). Scientists are viewed as interested mainly in a contribution to the advancement of science. They guard their autonomy, deferring only to the judgment of their colleagues. Industry pursues research in order to maximize profits and thus exercises control through hierarchical structures.

Unlike industry, an academic environment is seen to be compatible with professional autonomy. Academic scientists are viewed as free to select research problems and advance knowledge. University, as an apolitical institution, allows science to be pursued for the sake of knowledge and thus guarantees professional autonomy (Raelin, 1985). Scientific knowledge is regulated by a body of peers in an objective manner (Chubin and Hackett, 1990). Any outside influence—industrial or governmental—on academic research is viewed as threatening scientific progress.

Studies conducted by Harry Collins, Karin Knorr-Cetina, Bruno Latour, Michael Lynch, Michael Mulkay and Steve Woolgar have shown that scientific knowledge is contingent upon social factors and thus deviates from the traditional ethos of science. Further, there has been a growing partnership among university, industry, and government. None the less, scholars take autonomy in academia for granted and argue whether scientists in industry can maintain professional autonomy.

Drawing from my interviews with industrial scientists and former industrial scientists in the United States,[1] I argue that professional

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autonomy among scientists is compatible with corporate agendas, and that corporations accommodate scientists' agendas somewhat. Scientists possess autonomy in industrial context and they do not experience the value conflicts imagined by many social analysts.

Industry offers a challenging environment for research. Unlike academia, industrial scientists are able to organize interdisciplinary projects, and have access to more resources and time to conduct research. Research in university is influenced by many factors, including the availability of resources that tend to undermine the ideal conception of academic autonomy. Furthermore, academic scientists are directing their research, pure and/or applied, at commercial applications.

I briefly describe the model of professionalism. I show that industrial scientists have internalized the inseparability of scientific and business efforts in industrial settings. I explain the entrepreneurialism of academic scientists to show their project selection parallels of those working in industry. I discuss the division of research into pure and applied science to show that the research is carried out for commercial purposes in both, industry and university. I describe the advantages of scientists working in industrial labs over academia.

SCIENTISTS AS PROFESSIONALS

As research started playing a dominant role in the development of technology and production in the 20th century, social analysts started viewing scientists as a group of professionals. The term 'professional' was defined in numerous ways. When Kerr *et al.* (1977) reviewed the literature on 'professionalism', they found six attributes: expertise from prolonged specialized training in a body of abstract knowledge; autonomy to make choices which concern both means and ends; commitment to the work and the profession; identification with the profession and fellow professionals; ethics to render service without concern for self-interest and without becoming emotionally involved with the client; and collegial maintenance of standards to police the conduct of fellow professionals.

Most new definitions of professionals overlap in the attributes, yet there is a disagreement about which attributes should be used to define professionals. Abbott (1988) argues that the term professional is more an honorific than a technical one. Friedson (1986) argues that the term professional is a folk concept.

The professional model has been successful in separating professionals from non-professionals. But there is little ground for generalizing about professionals as a homogeneous group. Occupations vary in the degree to which they are professionalized. Even members of the same profession vary in their conformity to professional attributes.

Some professions are more diverse in higher education and standards than others. Similarly, professional autonomy depends upon at least two factors: the kind of profession and the place of employment. Not all professionals seek to do their job within their discipline; many take jobs as managers, administrators and deans. Often professionals are committed to both the profession and the organization simultaneously, and do not value peer control and collegial maintenance of standards (Zussman, 1985). Often professional organizations have become unable to enforce altruistic ethics.

Furthermore, the professional model obscures the social and historical conditions under which occupational groups become professionals, including the power struggle involved in the process of professionalism (Larson, 1977). There is no indication of how a profession may change over time, or the key factors that may lead to breakdown of a professional occupation (Abbott, 1988). The professional ideologies are accepted on trust, without any systematic examination of their validity (Derber, 1982). The attributes of a professional are not systematically related to one another. Nothing is lost logically if new attributes are added or existing ones are recombined.

None the less, according to many scholars scientists conform closely to the attributes of professionals and therefore experience value conflicts in an industrial environment. Earlier Marcson (1960) and Kornhauser (1962) argued: the goal of management is to make profit, while the goal of scientists is to contribute to knowledge; management tends to be structured hierarchically, while scientists prefer to keep ultimate control over their members in the colleague group; and scientists need more autonomy than granted by management.

However, many scholars felt that conflicts between scientists and industry have been overplayed. Cotgrove and Box (1970), for instance, argued that industrial scientists do not experience conflicts because industry does not attract 'more committed scientists' who are dedicated to the advancement of knowledge.

Eventually, scholars drifted away from the issue of value conflicts. But conflict between scientists and industry attracted renewed attention in the 1970s and 1980s when Marxists suggested that professionals were well on the road to proletarianization (Oppenheimer, 1972; Derber, 1982). Proletarianization predicted that eventually the power and autonomy of professionals would wither away as professions become embedded in industry.

The mainstream scholars have revived the theory that professional autonomy causes a conflict among industrial scientists. Bacharuch *et al.*(1991) distinguish between professional and administrative ethos. According to them, professionals desire autonomy and participation in determining both the ends and means of work activities, autonomous discretion to manage uncertainty, peer-evaluation, and only minimal supervision. Administrators, on the other hand, maintain close supervision, exercise control to manage uncertainty, break down tasks, and seek loyalty.

AUTONOMY VERSUS CONTROL

Autonomy is defined as the ability to initiate and conclude action, to control the content, manner and speed with which a task is done (Meiksins and Watson, 1989). Bailyn (1985) has distinguished 'strategic autonomy' (the freedom to set one's own research agenda) from 'operational autonomy' (the freedom, once the problem has been set, to attack it by means determined by oneself). Scientists are expected to exercise varying degrees of both types of autonomy on a routine, daily basis in the course of performing their work. The US National Labor Relations Act differentiates professional employees from other employees on grounds of autonomy.

Since Michael Polanyi argued for the absolute autonomy of scientists to conduct research and Talcott Parsons advocated for the university to guarantee it, scholars have argued that scientists lose their autonomy in industry and thus experience a value conflict. Raelin (1986), for instance, argues that professionals wish to make their own decisions without external pressure from those outside the profession, including their managers. This right of autonomy, however, clashes with management's expectations regarding the proper role of the employee.

In the absence of autonomy, scientists are likely to quit the job, take frequent leaves, do inferior work, or have a low commitment to the employing company. Scholars, therefore, suggest strategies to overcome the problems of autonomy—such as the dual ladder, transition to management, managing ends and not means, and professional participation.

Some studies, however, have found that industrial scientists rarely desire 'absolute autonomy'. In a study of centralized labs in the US and UK, only a small number of scientists desired the freedom to set their own research projects; most favored the freedom in the means to carry on the research (Bailyn, 1985). Scientists at the Lawrence Livermore Lab were satisfied with the amount of freedom they had in setting research goals (Sutton, 1984). Likewise, my interviews with scientists show that professional autonomy and industrial organizations, to some extent, are mutually reinforcing rather than antagonistic.

☐ *Project generation*

In corporate laboratories, most projects are generated by scientists themselves, some are jointly initiated by scientists and managers, and only a few are decided by managers. Scientists generate ideas, write proposals, recruit colleagues, and get managers interested in supporting those projects. Usually, managers generate projects for junior scientists when they join the laboratory. However, as time goes by, junior scientists are expected to develop their own projects. In one scientist's words: 'Scientists come up with projects and get management interested in supporting those projects. It is a sort of bottom-up approach'.

Industrial scientists possess 'strategic autonomy', since they have control over the choice of research projects. No one comes and tells them what to work on; instead, they make their own choices about what they will do. Yet their strategic autonomy is not pure; their research choices fall within the general goals of their company. Scientists have to learn if their research interests coincide with the company.

Since corporations seek to make profits and be responsive to shareholders by increasing the value of their shares, corporate research is conducted to enhance profit-making. Prestige, recognition, and good-will created by research are secondary for a corporation. Scientists' project generation is influenced by the industrial context, and it is not purely internal to them. Even extreme speculative ideas are influenced by industrial interests. There is a constant interaction between a scientific mode of thinking and corporate objectives.

Scientists choose a particular area because the company has some divisions which are working on that area or because the company has a general interest in the area. When it comes to choosing a specific project, they are influenced by the product which the company is making and the particular problems the company has in making such products. Such practical dimensions guide scientists to decide what sort of projects to generate. As one said: 'I look for technological solutions for the company to be more effective'.

Furthermore, corporate labs have a reward system which gives high priority to the relevance of scientific work for the company's goals. Also, the salary and other compensations encourage scientists to choose research problems of interest to their laboratory. As one said: 'the average scientist is motivated by results and the recognition that he will get from those results within his group and within the organization'.

Project generation within industrial goals per se leads to little conflict because scientists do not wish to work on projects which are outside industrial context. One former industrial scientist questioned: 'How can a scientist say that I come here, close my door, and do what ever I like? If he does, then he is very lonely'. Scientists are raised in corporate America and there is little ambiguity in the function of research in industry. They join industry with the understanding that their research must be performed within the framework of business interests of the company.

☐ *Supervision*

Scientists' strategic autonomy is indirectly constrained by managerial supervision. In corporate laboratories, resources invested in research must be expended judiciously, and it is the job of the management to ensure that corporate interests are always at the forefront in determining how the resources are allocated and money is spent. Projects generated by scientists are rarely self-justified; instead, they are approved by managers. Ultimately, it is managers who determine which projects are to be supported and which are not. They also bring in the cost and money factors more than scientific merits in project selection.

However, the process of getting managers' approval for a project is rather informal. Often, scientists 'toss' their ideas to immediate managers on the phone, via e-mail, in the hall, or in the dining room. Once managers show some interest, then scientists send a small report to them. If the work has to be approved by the upper management, scientists make a formal presentation to them.

Scientists face some difficulties in justifying projects to different layers of managers because the justification for proposals is more technical at the lower level of management than at the higher level. But many do not find it difficult to gain management's support, especially if their previous projects have succeeded. Scientists' track record and expertise are major consideration in project evaluation. One scientist explained: 'Last year, I was interested in something but I did not get funding for that. I got chopped down in the chain. I made some comments to one of our higher managers about it, and I got the funding. Now of course, I have to do something about it'.

Scientists accept the necessity for some degree of managerial authority, provided that managers are coordinating research projects in an efficient manner. They believe that management should indicate where they should direct their research efforts. As one said, 'I do not want someone to come back and tell me that it was the wrong problem to solve even though results are very impressive. So, I am much more keeping a big picture'. In fact, they pointed out several limitations in the technical advice provided by their managers. Most showed an interest in articulated managerial leadership.

Corporate laboratories have a hierarchy, which is based on the authority of expertise. Scientists' research work is defined by their credentials and training, and is not dictated by managers (Friedson, 1986). The kind of research scientists do is esoteric, complex, and discretionary in character (Abbott, 1988). It requires theoretical knowledge, skills and judgment that ordinary people do not possess (Brint, 1994). Managers are unable to control because scientists are deemed to have mastery over complex knowledge. Managers, therefore, leave authority over the research projects to the scientists themselves. Managers exercise only indirect control, by approving the scientists' research.

☐ *Publications*

A related aspect of the choice of research projects is the disposition of the research results. Scientists should be able to make their results known to the scientific community. Industrial research typically emphasizes filing patents rather than publishing results in journals or presenting conference papers. Industry does not allow publication if it considers the information to be proprietary (Raelin, 1986). Proprietary knowledge is protected by patents and trade secrecy.

Scientists indicated that the publication policy of their laboratories has been flexible. 'They prefer to get benefits from research instead of publications ... they do not encourage publications but they do not stop us from publishing either'. Scientists who consider publications to be a criterion of professional achievement have to take their own initiative. Further, their papers have to go through managers and sometimes their company's lawyers before they are submitted outside.

My interviewees had excellent publication records. Four had published over 100 articles, 12 over 50, 14 over 25, and the rest around ten articles. Many held distinguished awards, including a Nobel Prize. This suggests that the open publication policy is not merely a token. Perhaps it is because I interviewed scientists who have been working on un-classified projects.

Industrial labs remain under security restrictions. However, communication between industrial and other scientists has become open because of the increase in the number of research sites such as universities, think-tanks, and consultancies (Gibbons *et al.*, 1994). Industrial scientists are increasingly communicating with scientists in other research sites in a variety of ways—electronically, organizationally, socially, and informally.

☐ *Research process*

Operational autonomy refers to the technical part of research, to the ability to control the process of research activities, and/or the rhythm and pace of research (Bailyn, 1985; Meiksins and Watson, 1989).

Scientists decide how to conduct research, how much time is needed to finish the work, and whether the given resources are appropriate for the completion of the given project. Managers are not involved in the technical aspect of projects such as which technique is better to follow, whether a particular experiment is the best to conduct the research, and so on. Instead, managers determine why certain types of research projects are terminated from further support, whether scientists get their requested technical assistance or equipment, and the time frame to finish the work.

Scientists' operational autonomy is increasingly constrained by the decline in R&D expenditures and the restructuring of corporate research labs which began in the mid-1980s (Varma, 1995). Many leading corporate laboratories are involved in linking research directly to development, engineering, and manufacturing. They are backing away from growth through new products and processes, and instead are seeking short-term modifications.

For instance, Xerox's PARC Lab now gets detailed contracts from the company's product divisions. The Bell Labs is shifting its focus to information science to address the customers' needs in its businesses. As corporate laboratories are changing from science-driven to market-driven research, scientists have to adjust in order to survive.

With the decline in R&D funds, scientists are working on an increasing number of projects with fewer technicians. As a result, they are often overwhelmed with things to do, but do not have enough time and hands. One scientist said: 'Our lab has been reduced from fifty to thirty-seven. So I have to do everything. Either free some of my time or give me more manpower'.

Research time is also lost with the frequency and agenda of managerial meetings. Scientists feel that 'there are too many meetings and they take too much time'. The budget process that came with the restructuring requires scientists to get funds from business people. Now scientists have to have meetings to get new business interested in their work. As one said: 'I have to devote significant amounts of my time to superficial work like presentation to business managers. It does not have any bearing on research'.

To reduce cost, projects which are considered risky are terminated or put on hold, despite a long history of research in those areas. Scientists working on such projects have to generate different projects or take employment elsewhere. Most former industrial scientists whom I interviewed left the industry because of its shift away from the scientific inquiries in which they were involved. The movement of scientists means re-organization of research groups, and it takes a considerable amount of time to build research projects.

Some corporate labs have introduced a policy of having a report to account for every hour of scientists' research time by filling a time card at the end of every day; previously, they could give a write-up every month or so on their progress. The practice of a time card is imposed upon a company by government to account for government money. Scientists acknowledge that 'even though it was imposed by government, [the company] is happy to have it'. They think 'their professionalism is being taken away from them'.

Industrial scientists are concerned about the changes that are taking place in corporate laboratories and the impact they are having on their careers (Varma and Worthington, 1995). Scientists, however, adjust to these constraints since the situation in their company is not very different from other companies as well as in academia. As one said: 'Where could I go?' Further, they enjoy numerous advantages in continuing their research in industry, as shown later on.

☐ *Academic scientists as entrepreneurs*

In academia, autonomy is generally taken to mean freedom to select research problems. However, project generation in academic institutions is influenced by many factors—from professional priorities to the availability of resources—that tend to undermine the ideal conception of academic autonomy. According to former industrial scientists, 'academic scientists are under all kinds of pressure, financial and peer. There are very few scientists who can work on what they want ... they have to convince someone'.

Academic institutions pay little for research from their regular budget, so academic scientists must increase the amount of money available for their research. They spend much time writing grant proposals and establishing contacts to raise funds from industrial and governmental sources in order to support their research. The ability to acquire funds has become a prerequisite for their careers as researchers as well as getting tenure (Barinaga, 1992). As one former industrial scientist said: 'One of my colleagues is coming up for tenure. He has an excellent publication records. But he has not been able to get any grant. He is concerned ... it is going to be a tough decision'.

Since the early 1980s, university–industry research centers have emerged which are located in top academic institutions such as MIT, Yale, Harvard, Stanford, Georgia Institute of Technology, and University of Washington. Their goal is to develop knowledge in scientific and engineering fields that will help US industry (Freundlich, 1989). Through these centers, industry gains access to cutting-edge research as well as a downstream employment pool. In constant dollars, academic research financed by industry increased by an estimated 265% from 1980 to 1993 (National Science Foundation [NSF], 1993, pp. 121, 134–137).

Many academic scientists are responding favorably to new possibilities; some have even gone further to create their own firms. They direct research at fields they feel are favored by funding agencies (Brint, 1994). Research universities have been increasingly developing industrial parks and pilot programs to encourage scientists to develop their ideas and inventions further towards products and processes. It is being accelerated by the availability of federal funds to universities for mission interests of Federal agencies (Slaughter and Rhodes, 1996).

With the increasing global competition, scientific research in academic institutions is intended to be useful to industry, and this imperative is present from the beginning (Gibbons *et al.*, 1994). Academic scientists are, at least partially, involved in research that industry is interested in, i.e. goal-oriented research. Of the former industrial scientists interviewed, all were involved in research with industry. They were either consultants or had a grant for their projects. The earning of money beyond one's academic salary has acquired the status of legitimacy, even necessity.

BASIC VERSUS APPLIED RESEARCH

Since the publication of Vannevar Bush's *Science—The Endless Frontier* in 1945, basic and applied science have been seen as two distinct entities that are mutually exclusive. Basic research in the industrial context is defined as research that advances scientific knowledge but does not have specific commercial objectives, although such investigations may be done in fields of present or potential interest to the reporting company. Applied research in industry means investigations directed at discovery of new scientific knowledge having specific commercial objectives with respect to products, processes, or services (NSF, 1993, p. 94).

It is believed that basic research first generates knowledge, which is then transformed into useful products and processes. Basic research is regarded as having greater intellectual challenge than applied research, as the latter is seen as a derivative of the former. It is claimed that scientists prefer to work on pure basic research because science is pursued for the sake of truth. Raelin (1986) believes that the professionals favor high-quality research rather than low-cost research.

This linear model has been criticized by the social constructionists, especially for its perception of basic and applied science. They describe numerous occasions when applied research led to basic science than vice versa. They show how science is governed by social factors rather than any search for truth. It is not the case that knowledge is developed first and then applied; instead, multidisciplinary groups are involved in problem-solving efforts (Gibbons *et al.*, 1994).

Scientists whom I interviewed worked on goal-oriented research which could be basic, applied, or both. They believed that one cannot alway separate basic from applied research, and their problem-solving projects were advancing the existing scientific knowledge. Even academic scientists were choosing application-oriented projects.

☐ *Goal-oriented science*

Few scientists in industry (or academia) desire to work on basic science for its own sake. Instead, they seek to work on goal-oriented research. In one industrial scientist's words: 'Fundamental research for its own sake is not practiced in industry; instead, fundamental research to get good out of it is practiced'.

Scientists believe that it is an elitist view to demand that science should be pursued for its own sake. As one former industrial scientist said: 'Scientists do not have a God-given right to do whatever they please'. Even scientists who have worked on exploratory projects rarely claim to explore only areas of scientific ignorance without any potential application in their mind. As one industrial scientist said: 'I do fundamental research. But, I like the connection between basic and reality to be necessary to keep thinking focused. ... research is too much work to simply see the results of your work sitting on the shelf and collecting dust'.

Scientists choose their area of research on the basis of their credentials and training. Often the issue is the duration and depth of a research project. It is whether the investigation of specific problems is going to lead to a study of fundamental processes and principles, or it is going to be more of 'controlling and putting out the fires'.

Both basic and applied research have their own challenges which may be slightly different and which stimulate scientists in different ways. Scientists who preferred basic research indicated that applied research is not as intellectually motivating as basic research because it is short term, concerned with solving immediate problems. They think that sometimes the applied research gets into a 'dog and pony show' more than basic research. Scientists who liked to do application-oriented research often did not like to do basic research because they wanted to see the 'products'.

Due to the increasing role of markets and pressures for innovations in American economy, scientists are less likely to desire basic science (Brint, 1994). Many big companies appear to be backing away from basic long-term research. They are seeking mostly short-term solutions, such as to acquire the necessary technology and expertise from sources/vendors outside the company (Varma, 1995). Many basic research projects are thus being terminated. Consequently, industrial scientists are sorting out which of their research interests are application-oriented and which are not.

☐ *Separation of basic from applied research*

Basic and applied research have been differentiated in many respects. Basic research is seen as curiosity-driven, while applied research is viewed as contributing to the development of technologies. Basic research has a high degree of uncertainty, as opposed to a low degree of uncertainty in applied research. Basic research is long term while applied research is not. Basic research is generic and public; applied research is more specific and private. Funds for basic research comes from public where as funds for applied research comes from private organizations (Jansen, 1995).

Centralized corporate laboratories were created separate from manufacturing units in the early 20th century in order to prepare companies for the future and external technological changes. The main aim of corporate laboratories has been to identify and develop processes, leading edge technologies, and the associated scientific principles relevant to business interests.

In corporate laboratories, there has never been a clear-cut line separating basic research from applied research; instead, basic and applied research are often integrated to work for business interests (Schmitt, 1991). Basic projects are ventures into areas where efforts are dedicated to highly speculative ideas. This does not, however, mean that business considerations are suspended until the basic research is completed. Instead, basic research projects usually carry a technological implication interwoven with their scientific aims as well as business goals.

Research projects are not usually identified as purely basic or purely applied. Instead, there are some projects where the future product or process can be easily identified. In other types of projects, targets are less precisely identified. Finally, there are exploratory projects where new products or processes cannot be identified. In 1993, industry performed and funded 18% of all basic research, performed 67%, and funded 53% of all applied research (NSF, 1993, pp. 94–95). Typically, big companies devote 10% of their R&D budget to exploratory research.

Many scientists are 'not sure where and how one draws the line between basic and applied research', especially in the industrial setting. According to them, by separating basic and applied, one gets into a semantic problem. What some scientists consider as basic research others may apply to solve a problem. Even if there is a project which can be labeled as applied, still some scientists focus on why a particular thing has worked. So there are fundamental questions that arise in the applied work.

The difference between 'what' to study and 'how' to study a given problem are blurred at the practical level. One scientist explained: 'We do a lot of basic research and it is not difficult to see what applications you will see from the basic work. You extend and study those aspects, and that is also a part of your project'. Another said: 'Look around this lab. Can you tell me which scientist is doing basic and which one doing applied? You can't'.

With the emergence of trans-disciplinary research, the distinction between a theoretical core and other areas where theoretical knowledge is translated into applications is increasingly less clear (Gibbons *et al.*, 1994). Research in both sites—industry and academia—is oriented towards contextualized results. Industrial and academic scientists are working in a problem context that tends to soften the distinctions between pure and applied science, and between what is curiosity-oriented and what is mission oriented research.

☐ *Basic research in academia*

The academic sector is the largest site of US basic research, accounting for about 50% of national basic research expenditures. For the past 25 years, however, its share of the total amount spent on applied research has been rising. It is now the second largest performer of applied research, accounting for almost 15% of the total spent in 1990.

Since World War II, academic scientists have depended on mission agencies for the vast majority of their research funds. Though these funds were tagged as support for basic science, it was not clear how distinct these were from funds for applied science (Slaughter and Rhoades, 1996). Basic science in academia was directly shaped by goals of mission agencies (Leslie, 1993).

With the US losing the status of a leading producer of high-tech products in the global economy, the needs of industry have been presented as paramount. Basic science is valued only if it contributes to the creation of products or processes for the US industry. The government agencies are now supporting academic research which is geared to help industry (Slaughter and Rhodes, 1996). The general strategy of industry is to support joint research projects with universities. Industry has increased its share of support to universities from 2.6% in 1970 and 3.9% in 1980 to an estimated 6.9% in 1990 (NSF, 1993, p. 134).

As the boundary between industry and the university has dissolved into partnership agreements, the distinction between basic research in academia and applied research in the industrial laboratories has become further blurred (Jansen, 1995). Basic research in academia is performed in the context of applications. Quality of academic research is not only determined by the contributions made by individuals, but also by marketability and cost-effectiveness (Gibbons *et al.*, 1994).

ACADEMIC VERSUS INDUSTRIAL SETTING

Since Robert Merton identified a *professional ethos* guiding the behavior of scientists, the academic setting has been seen as facilitating professionalism, while the industrial setting is not. There is a prejudice that good research is in academia, while marginal scientists go to industry. Scientists, as they go through training, are taught that 'the apex is the faculty position' (Barinaga, 1992).

It is mainly because academia is devoted to research, experimental practice, and theorizing. The knowledge elite of the professions and its members do both: teach professionals-in-training the latest knowledge and explore new areas (Friedson, 1986). Professions sustain their jurisdiction in the power and prestige of their academic knowledge (Abbott, 1988). Experts acquire a complex body of formal knowledge from higher academic institutions (Brint, 1994).

Yet employment of doctoral scientists has been shifting from the academic to industrial sector in the past two decades. In 1991, approximately one-third of the total 367,400 doctoral scientists were employed by industry (NSF, 1993, p. 76). With the academic world becoming more constrained, doctoral scientists find most opportunities in industry (Barinaga, 1992; Flam, 1992; Holden, 1992). US industry provides jobs for approximately 900,000 scientists. Despite constraints on operational autonomy, scientists enjoy numerous benefits in working for industry rather than for academia.

Research time

Academic scientists have to teach and advise students, unlike industrial scientists. Teaching and advising are time-consuming activities which leave little time for research. Industrial scientists asserted that they can 'engage mostly in research activities and nothing else'. Former industrial scientists felt that 'more time was available to do research in industry'. Scientists preferred to be known as a credible researcher in the scientific community than as a good teacher. The faculty reporting their primary work responsibility as research increased 60% between 1979 and 1991, while teaching rose 15% for the same period (NSF, 1993, p. 146).

☐ *Cross-disciplinary research*

Industry emphasizes group and cross-disciplinary research because it is the most efficient way to work on industrial problems. Through group research, industry is able to compress the duration of a research project. Timing of research has become a competitive weapon in the global economy. Furthermore, the increasing specialization necessitates assembling scientists from different disciplines or specialties within a discipline. This creates an atmosphere qualitatively different from that found in the academia, where disciplines are separated.

Scientists as researchers prefer an interdisciplinary problem orientation rather than an isolated disciplinary academic department. One industrial scientist noted that 'I am able to finish my projects in a very short time. If I was doing the same projects [in university] it would have taken God knows many years'. Former industrial scientists said: 'I collaborated with scientists from all kinds of disciplines. I have not found such group activity in an academic environment. I have some collaborations, but it is not the same. There is much more resistance in academe to breaking traditional disciplinary boundaries'. 'When you work in a interdisciplinary project, you learn a lot from others. You are not sitting alone in your office and brainstorming by yourself'.

Academic scientists tend to resist interdisciplinary collaborations mainly because they perceive disciplines to be their homes. According to former industrial scientists, most prominent academic scientists are more interested in building their own 'empire' than sharing credit with others. They dream of having their own laboratory with technicians, assistants, post-doctorals, and students.

Recently, funding agencies have started to promote cross-disciplinary research by providing funds for big projects and by establishing national centers of excellence in academic institutions. This has resulted in some scientists from different departments and disciplines collaborating on joint projects. Working in an application context has created some pressure on academic scientists to draw upon a diverse array of knowledge resources and to configure them according to the problem in hand (Gibbons *et al.*, 1994).

☐ *Resources*

Industry is the greatest source of research funding, at least in the US. Industrial R&D expenditures have increased after 1968, when industry for the first time became the largest source of funding of industry-performed R&D. Total constant dollar expenditures for industrial R&D increased from approximately $51 million in 1970 to $90 million in 1993.

A closer examination, however, shows that the growth of industrial R&D expenditures has slowed since the mid-1980s. From 1979 to 1984, industrial R&D expenditures in 1987 constant dollars grew from $58 million to $89 million, an average annual increase of 7.4%. This growth rate fell to 3.0% per year during 1984–1989 (NSF, 1993, pp. 90–95, 333).

Funding for academic research, on the other hand, has been increasing. From 1980 to 1993, academic R&D expenditures doubled from approximately $8 million to $16 million in 1987 constant dollars (NSF, 1993. pp. 90–95, 333). None the less, industry remains the largest performer of R&D, with 68% in contrast to 13% in academia.

Industry has equipment which is up-to-date, technicians who know how equipment functions, and experts in repairing equipment. With such resources, industrial scientists can pursue research in more than one direction. In academia, however, research has to be compatible with the existing equipment, which may be outmoded.

Even though academic scientists have students as assistants, students are no substitute for technical assistants available to scientists in industry. As one former industrial scientist said: 'When you explain your project to students, you lose a lot of spontaneity and continuity'. Furthermore, students are an uncertain resource as they graduate and thus leave.

Former industrial scientists were clear that 'If industry likes what you are doing, they are really going to put big bucks in that. They have a lot more money than you can ever imagine ... If you want a better machine, it will be available. It is not a blank check, but you will get reasonably high-quality equipment without breaking your neck'. One felt that moving to university from industry was like becoming a 'poor student'.

☐ *Monetary benefits*

Industry has always been more attractive than academia in one important respect—salary. Monetary benefits are often associated with job satisfaction. Salaries of industrial scientists are typically higher than of their colleagues in academia, although some academics are able to increase their salaries through grants and consultancies.

In 1991, the median annual salaries for doctoral scientists and engineers working in industry was $69,000 and $74,400, respectively. In the academic sector, the salary for scientists was $55,200 for doctoral scientists and for engineers $67,800 (NSF, 1993, pp. 78, 320). The difference between doctoral salaries in industry and in academia has become smaller because faculty salaries have risen at a faster pace than those paid to scientists working in industry (Finn, 1991).

Brint (1994) finds that the professions that are mainly located in industry are able to bring up the incomes of those in the profession who are working outside industry. For instance, engineers had a higher salary because in recent years many universities had difficulty recruiting engineering faculty and therefore had to offer salaries competitive with those offered by industry. None the less, some scientists felt that 'salary is low in academe for at least the first ten years'.

■ CONCLUSION

In centralized research laboratories in the United States, research projects result from the understanding that scientific and business efforts are inseparable. Scientists have internalized this basic assumption in proposing their research agendas. Within these limits, they have a major influence over the choice of research projects and how to carry them out.

Derber (1982) has argued that industrial control over strategic autonomy (choice over projects) is greater than operational autonomy (how the research is conducted). My interviews, however, suggest a different conclusion. Scientists enjoy freedom to generate their research projects and publish the results. They experience some industrial control on operational autonomy due to managerial supervision, declining research funds and assistance, and lack of research time. But they accept the reality of some degree of managerial authority in industry.

Unlike industrial scientists, academic scientists have more freedom to establish their own research and how to pursue it; the department chair in a university is not superior to academic scientists. However, academic scientists are increasingly involved in entrepreneurial activities, often with industry; the university has become a source of future profits. Academic scientists have made their own choice to exploit industrial applications of their research. They are diverting their research in response to demands generated outside the university. It is not the case that knowledge-based values have spread into industry as Gibbons *et al.* (1994) suggest; instead, academic scientists have willingly absorbed industrial values.

Since academic research is being conducted in the context of applications, the difference between industrial and university research is shrinking; it is only a matter of degree. Basic science is not easily separable from applied science. Professional autonomy in both sites is constrained by business interests, though more in industry than in academia. This warrants some critical analysis of lost autonomy in academia and its deleterious effects on academic research. Meanwhile it is no surprise that former industrial scientists in academe were envious of their former colleagues for being able to organize interdisciplinary projects, to enjoy more time to do research, and to have access to abundant resources and up-to-date equipment.

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NOTES

1. I interviewed scientists from the centralized corporate laboratories of high-technology manufacturing industries in the United States because they lead in

research and development expenditures and employment. On these criteria, the five leading high technology industries are aircraft and missiles, professional and scientific instruments, electrical equipment, machinery, and chemicals. I interviewed 31 scientists from two centralized corporate laboratories in machinery and chemical companies, and 16 others who had worked in corporate laboratories of machinery, electrical equipment, and professional and scientific instruments, and later joined two academic institutions. The latter worked in more than one organization, thus they were in position to give direct evidence concerning the working conditions of scientists.

I identified companies on the basis of size, expenditures, and research activities. Typical centralized corporate laboratories are independent of any business division and employ over 1000 personnel in a broad range of scientific and engineering disciplines. I identified interviewers by PhD and MS degrees in science and engineering disciplines, employment as research scientists, and self-identification on the basis of degree and work experience. Even though some had their degrees in engineering discipline, they held the title of research scientists and viewed themselves as scientists.

I conducted taped interviews in two stages: from May 1991 to July 1991 with former industrial scientists about their experiences in industry, and from September 1991 to January 1992 with industrial scientists. A pre-testing of the interview was done with two former industrial scientists and four industrial scientists, but they are not included as a part of the sample. Only one scientist declined to participate in interviews on initial contact. Interviews combined structured and unstructured formats and lasted almost 2 h. I used open-ended questions so I could get a detailed description of the whole research process. I avoided questions that would predetermine the form the data would take and limit the options of responses.

I asked general questions such as: What is the process of selecting projects in which you are involved? How do you generate ideas for research? How do you view the connections between your research goals and the company's goals and interests? How would you characterize your research, basic and/or applied? Do you prefer doing one over the other, and why? Does working in an industrial laboratory environment affect your professional autonomy in decisions about research projects and, if so, how? How would you characterize industrial and academic research environment? Do you have a preference one over the other, and why?

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