Minerva 33: 325–338, 1995.

Immiseration of Industrial Scientists in Corporate Laboratories in the United States

ROLI VARMA AND RICHARD WORTHINGTON

THE ENHANCED FREEDOM of movement enjoyed by capital in a global economy brings new relevance to two questions with a long history in social research: Do structural changes in capitalist economy immiserate professionals? Are professionals a new class, or a working class?

Since the Second World War, many leading corporate laboratories in the United States have emphasised the autonomy of scientists in conducting research from business concerns. However, during the 1980s, corporate laboratories were restructured as management started to perceive autonomy as an obstacle to further development in the global economy. In order to examine the impact of this restructuring, we interviewed 47 scientists working in an industrial setting and found disquieting support for the immiseration of industrial scientists, although those we interviewed continue to hold many of the traditional ideals of professionalism. Our research adds empirical support to critiques of the Mertonian tradition that are increasingly common in science studies. Given global developments in science and production, a better understanding of industrial science and scientists has both theoretical and practical relevance.

The Globalisation of Science and Industry

The globalisation of science and industry in recent decades carries profound implications for science and scientists. Whereas land was a key resource in agricultural economies, and capital was critical during the industrial era, information and innovation are increasingly important in today's global economy. Science plays a central role in production as a source of the new knowledge that feeds this innovation. In the global political economy, the nation state has been both politically and organisationally eclipsed by social units that enjoy significant autonomy from territorially defined political power. Some observers have held that Western imperialism is driven by a global capital accumulation process to which state authorities must adapt.[1] Nonetheless, the principal organisational agent of global accumulation has been the imperial state, which derives its

[1] Wallerstein, Immanuel, *The Capitalist World-Economy* (Cambridge: Cambridge University Press, 1980).

authority from the control of territory. Only in recent decades has an essentially aterritorial entity, the transnational or global corporation, taken concrete organisational form. This signals the shift from an international to a global institutional framework for world production.

A company is international when it exports products through a network of foreign affiliates or procures essential inputs from foreign suppliers, but is controlled from a headquarters that concentrates all functional components in one country. A company is global when functional resources—such as manufacturing, marketing, research and development, accounting and assembly—are distributed around the globe. Senior management are in a single location, but production is dispersed to serve local markets and to take advantage of geographical variations in factor endowments and business environments, for example, labour supply, energy resources or university consultants. The whole of the earth—and even outer space—is a potential production site.

Most observers have focused on the dispersion of manufacturing which results, because the relocation of highly paid jobs from old industrial centres to low-wage production sites in the Third World has generated much social dislocation and controversy in advanced countries. But science, too, has been globalised, with international collaboration increasing rapidly since the early 1970s.[2] Like industrial workers, scientists may feel the pressure of global transformations.

The status of scientists has also been undermined by world-wide demilitarisation and redirections in military research and development. Defence conversion has released highly trained personnel, especially in the former Soviet Union, who may undermine the privileged position of scientists in other countries. Mexican leaders, for example, have recruited Russian scientists to lead basic and applied research teams as part of their strategy to increase their share of an integrated North American market.

This spectre of a scientific labour surplus on an international scale has been abetted by the relocation of industrial research from the core countries. For example, since the mid-1980s, research and development centres have been established in India by companies such as Astra and Pharmacia from Sweden, and Texas Instruments, Hewlett Packard and Digital Equipment Corporation from the United States. Unlike traditional commercial research and development centres set up in the Third World, which adapted foreign technology to local conditions, these facilities perform strategic research and development for their parent companies. Research in the Third World can cost 10 to 20 per cent of what would be required in the home country.[3] Such research probably accounts for less

[2] Schott, Thomas, "The World Scientific Community: Globality and Globalisation", *Minerva*, XXIX (Winter 1991), pp. 440–462.

[3] Sigurdson, John, "Global Companies as Generators and Controllers of Knowledge: The New Challenge for Developing Countries", in Brundenius, C. and Goransson, B. (eds), *New Technologies and Global Restructuring: The Third World at a Crossroads* (London: Taylor Graham, 1991), p. 73.

than 10 per cent of the total world expenditure on industrial research and development and is concentrated in emerging fields—software, biotechnology and materials science—in countries like India and Brazil with a decent educational and scientific infrastructure, or those with a sophisticated manufacturing sector like Singapore and Korea.[4] Nonetheless, these growing scientific capabilities and the increased mobility of capital and production threaten the position of Western scientists.[5]

Finally, the privatisation of knowledge has affected the status of scientists. Proprietary research accounts for an increasing share of global research and development, and the communications networks and data sources which are the lifeblood of scientific research are increasingly commercialised.[6] Under these pressures, the old model of autonomous scientists who make their own judgements about research problems, methods and publication is increasingly anachronistic.

Changes in the Structure of the Corporate Laboratory

These global trends have generated substantial changes in the way industrial laboratories are organised and their strategic role in the corporation. One measure of these changes is corporate expenditure on research and development. While research and development has traditionally been viewed as a key to technical innovation, growth in industrial expenditure has slowed down since the mid-1980s: in inflation adjusted US dollars, from an average annual growth rate of 7.4 per cent in the period from 1979 to 1984, to 3 per cent between 1984 and 1989. In 1989, industrial expenditure declined for the first time in 14 years. Since then, it has continued to decline, in constant dollars, from $93,333 million in 1989 to $90,711 million in 1993.[7]

Decline in the expenditure on industrial research and development has coincided with corporate restructuring by many leading manufacturing companies in the United States—such activities as leveraged buy-outs, mergers and acquisitions, hostile and friendly takeovers, and transactions aimed at delivering higher value to shareholders.[8] Since the 1980s, American companies have concentrated on corporate earnings and cash generation. Brian M. Rushton, vice-president of research and development at Air Products and Chemicals, claims that the pursuit of the current quarter

4 Reddy, Prasade A.A., "Emerging Patterns of Internationalisation of Corporate RD: Opportunities for Developing Countries?", in *ibid.*

5 Sigurdson, J., "Global Companies", *op. cit.*, p. 73.

6 Noam, Eli, "Private Networks and Public Objectives", *ASPEN Institute Quarterly* (Winter 1992), pp. 106–136.

7 National Science Foundation, *Science and Engineering Indicators* (Washington, DC: US Government Printing Office, 1993), pp. 90, 333.

8 See Adams, W. and Brock, J., *The Bigness Complex: Industry, Labor and Government in American Economy* (New York: Pantheon, 1987); Academy Industry Program, *Corporate Restructuring and Industrial Research and Development* (Washington, DC: National Academy Press, 1990).

"earnings per share" has become more frenzied in recent years.[9] Financial restructuring substitutes debt for equity and forces management to allocate more funds to servicing debt than to activities such as research.[10] A company's stock price usually rises after a "buy-back" because, with fewer shares in circulation, its earnings-per-share ratio is likely to improve. Summarising a widely held view, C. Gordon Bell, vice-president for research and development of Ardent Computer Corporation, has commented that "American companies don't like to build things—they like to make deals. Our large organisations have become purchasing agents". [11]

Many corporate leaders now believe that centralised laboratories do not help their business, and their concerns seem to be warranted. Few corporate laboratory projects evidently produce profit. An economist who studied the research and development programmes of three companies found that while 60 per cent were technically successful and 30 per cent were commercialised, only 12 per cent earned a profit.[12] *Financial World* reported that "only about 5% of [research and development] spending yields successful new products".[13] A case study, at the Palo Alto Research Center of the Xerox company, documents the failure to translate promising research results on computerised office systems into profitable products.[14]

Consequently, since the mid-1980s many firms have developed a new strategy for research, which we call the linkage model. Formerly, corporate laboratories were organised under what we call the autonomous model (Table).[15]

The new model restructures the laboratory to link research directly to business divisions. Of two corporate laboratories we studied, one has adopted the linkage model and the other has retained the autonomous model, but the latter initiated changes towards the linkage model within a year of the completion of our research. Four out of six corporate laboratories of 16 former industrial scientists had undergone major organisational changes since the mid-1980s. This restructuring of corporate laboratories has received little scholarly attention.

Autonomous and Linkage Models of Research Compared

After the Second World War, corporate laboratories enjoyed much autonomy from the business divisions of industrial firms. Scientists proposed

9 Rushton, Brian M., "Two Decades of Change in RD Management", *Research Technology Management*, XXXIII, No. 5 (1990), pp. 6–8.

10 Miller, Robert R., "Do Mergers and Acquisitions Hurt RD?", in *ibid.*, No. 10, pp. 11–15.

11 Port, Otis, "Back to Basics", *Business Week*, Special Issue (1989), p. 15.

12 Mansfield, Edwin, "How Economists See the RD", *Research Management*, XXV, No. 4, (1982), pp. 23–29.

13 "Rise and Fall of Industrial Research", *Financial World*, 25 June, 1991, p. 68.

14 Smith, Douglas K. and Alexander, Robert C., *Fumbling the Future: How Xerox Invented, Then Ignored, the First Personal Computer* (New York: William Morrow, 1988).

15 Varma, Roli, "Restructuring Corporate RD: From Autonomous to Linkage Model", *Technology Analysis and Strategic Management*, VII, No. 2 (1995), pp. 231–246; and "Managing Industrial Science", doctoral dissertation, Rensselaer Polytechnic Institute, New York, 1993.

and managers selected research projects in areas of general interest to a firm. Managers assumed that scientists should make their own decisions without pressure from non-technical staff. Either scientists related their ideas to the company's broad goals, or the managers determined the general projects and the scientists decided which specific aspects they wanted to work on.

TABLE

Autonomous and Linkage Models of Industrial Laboratories

The Autonomous Model	*The Linkage Model*
Existed since Second World War	Developed in mid-1980s
Corporate laboratory has autonomy	Corporate laboratory depends on firm
Firm's interests a source for research	Customers' needs a source for research
Indirect link between research and business divisions	Direct link between research and business divisions
Research strategies indeterminate	Research strategies well established
Scientists persuade laboratory managers to support projects	Scientists persuade laboratory and business managers to support projects
Stable funds for research	Unstable funds for research
Funds gained from flat tax on business divisions	Funds gained from direct contracts from business divisions
Research focused on generation of knowledge	Research focused on requirements of financial source
Emphasis on research	Emphasis on development
Emphasis on long-term research	Emphasis on short-term research

In the mid-1980s, a new model was adopted by many leading corporate laboratories. Under this model, corporate laboratories no longer enjoy their earlier autonomy; now, they depend on contracts from different business divisions. Managers and scientists must encourage joint projects between scientists and personnel in other functional areas. Research must be closely relevant to the company's short-term interests, and must be capable of succeeding in the marketplace.

Under the autonomous model, corporate laboratories were regarded as a strategic asset and a premium was placed on stability in funding. Many leading companies in the same industry spent approximately the same proportion of money on corporate research, regardless of variations in profitability. Expenditure on corporate research and development was an outcome of a flat tax on the sales or the profits of the company's business divisions. Only a small portion of such expenditure came from direct contracts with the business divisions or the federal government. Under the new linkage model, corporate laboratories have changed their financing structure so that almost two thirds of their funds are now generated by business divisions' contracts, rather than one third as previously.

Formerly, corporate research and development funds were spent at the discretion of technical managers and scientists for projects. Now they have to accommodate business divisions which support research that addresses their immediate needs. Formerly, technical managers supported long-term research, believing that it would yield products and processes of great value to the firm. Corporate laboratories incorporated basic research after the Second World War because government had increased its level of support for research, and industry did not want to depend on the academic sector where basic research was concentrated.[16] Corporate research funds supported work on fast moving technology of generic interest to the firm. Technical managers and scientists anticipated that basic research would lead to new knowledge, provide scientific capital and generate practical applications. Scientists completed the research and turned it over to developers who delivered a finished product to the marketing division.

Under the linkage model, technical managers seek short-term solutions instead of new products and processes. They acquire technology outside the laboratory instead of building their own, reducing risky long-term research, and directing research to incremental improvements. Business divisions which support research present specific problems to scientists; they do not consider the long-range needs of the business. They want the product to be ready within a month, or to increase their earnings. Consequently, development has been the fastest growing activity in corporate laboratories. In 1993, industry performed 86 per cent of total development and funded 61 per cent of it. Of all applied research, industry performed 67 per cent and funded 53 per cent over the same period; the equivalent figures for basic research were 19 per cent and 18 per cent respectively.[17]

Industrial Scientists: Marxist and Mertonian Views

Industrial laboratories have been viewed by social scientists as filled with tensions and conflicts between scientists and managers. Scholars influenced by the Marxist tradition have viewed scientists as members of a working class in conflict with managers representing capitalists' interests.[18] Scholars

[16] Graham, Margaret B., "Industrial Research in the Age of Big Science", *Research on Technological Innovation, Management and Policy*, II, No. I (1985), pp. 47–79.

[17] National Science Foundation, *Science and Engineering Indicators, op cit.*, pp. 94–95, 334–336.

[18] Braverman, Harry, *Labor and Monopoly Capital* (New York: Monthly Review Press, 1974); Derber, Charles, "Proletarianisation of the Professionals", "Managing Professionals", and "Toward a New Theory of Professionals as Workers", in Derber, C. (ed.), *Professionals as Workers: Mental Labor in Advanced Capitalism* (Boston: G.K. Hall, 1982), pp. 13–34, 167–190, 193–208; Gorz, Andre, *Strategy for Labor* (Boston: Beacon Press, 1967); Larson, Magali S., *The Rise of Professionalism* (Berkeley: University of California Press 1977); McKinlay, John B., "Toward the Proletarianisation of Physicians", in Derber, C. (ed.), *Professionals as Workers, op. cit.*, pp. 37–62; Noble, David F., *America by Design: Science, Technology and the Rise of Corporate Capitalism* (New York: Knopf, 1977).

working within the Mertonian framework have viewed scientists as members of a professional class whose values clash with the business objectives of profit and control.[19] Both Marxists and Mertonians see a conflict between scientists and management. Both agree that industrial scientists need autonomy and must be granted operational freedom from the management of the firms for whom they work. Marxists emphasise economic analysis while Mertonians focus on the sociological analysis of scientists in organisations. Mertonians are interested in maintaining the *status quo* whereas Marxists seek to change it. Marxists regard scientists as a part of the working class, while Mertonians see them as a legitimately favoured segment of the workforce.

Proletarianisation of scientists: Social scientists working in the Marxist tradition believe in the proletarianisation of the professional: scientists experience conflicts when they work as salaried employees, subordinated to those who control capital.[20] This theory, held by only a small fraction of social scientists, merits serious consideration because of its explanatory relevance to the conditions of science in a global economy. Scientists do not conduct research by themselves; they work with other scientists under managerial supervision. Scientists and managers occupy different places of control and authority in a corporate laboratory.

According to Marxists, more and more professionals must work for others. Few can be self-employed, because they lack capital. The changing position of professionals in this century parallels that of artisans and craftsmen in the nineteenth century. It has been claimed that from 1900 to 1950, the number of salaried professionals increased tenfold; this trend continued in the next three decades, so that self-employed professionals are now a minority.[21]

In the Marxist view, professionals, like the proletariat, are in conflict with the capitalist class which derives its income and wealth by employing others to work for it. One class lives by owning and hiring and the other lives by working. The professional "like the working class possesses no economic or occupational independence, is employed by capital and its offshoots, possesses no access to the labour process or the means of production outside that employment and must renew its labour for capital incessantly in order to subsist".[22] Professionals are said to be expressing dissatisfaction

[19] Glaser, Barney G., *Organisational Scientists: Their Professional Careers* (New York: Bobbs-Merrill, 1964); Kornhauser, William, *Scientists in Industry: Conflict and Accommodation* (Berkeley: University of California Press, 1962); Marcson, Simon, *The Scientist in American Industry* (New York: Harper Brothers, 1960); Raelin, Joseph A., *The Clash of Cultures: Managers and Professionals* (Boston: Harvard Business School Press, 1986).

[20] Braverman, H., *Labor and Monopoly Capital, op. cit.*; Derber, C., "The Proletarianisation", "Managing Professionals", and "Toward a New Theory", *op. cit.*; Gorz, A., *Strategy for Labor, op. cit.*; Larson, M. S., *The Rise of Professionalism, op. cit.*; McKinlay, J. B., "Toward the Proletarianisation", *op. cit.*

[21] Derber, C., "The Proletarianisation", *op. cit.*, p. 5.

[22] Braverman, H., *Labor and Monopoly Capital, op. cit.*, p. 403.

with almost the entire range of their working conditions, wages, health and safety, job security and work autonomy.[23] The tasks of professionals are found to be fragmented and and their job functions narrowly specialised.[24] Professionals command only "powerless discretion".[25]

Marxists see the increasing number of salaried professionals and their growing discontent as fertile sources of radicalism. Professionals are urged to move towards unionisation, to abandon the ideology of professionalisation, and to identify with clients and the working class.[26] Scientists are urged to "become public intellectuals because science/power enables them to be more than servants of corporations and the state".[27]

Scientists as professionals: The dominant model of scientists in society after the Second World War was the Mertonian paradigm, which sees science as the autonomous pursuit of knowledge. Robert K. Merton suggested that four basic norms contribute the "ethos" of science and guide the behaviour of scientists: universalism—contributions are evaluated in a purely impersonal, objective fashion; organised scepticism—scientists scrutinise the findings of other scientists, including those on which they base their work; communality—all empirical knowledge is the property of the scientific community, not of individual scientists; and disinterestedness—science is pursued for the sake of science and not for personal gain.[28]

In this paradigm, scientists have faced a conflict between professional and industrial values. It has been argued that management seeks profits, while scientists want scientific recognition; management operates through a hierarchical executive organisation, while scientists cling to their professional independence, deferring only to collegial judgement.[29] And it has been proposed that: "The inherent conflict between managers and professionals results basically from a clash of cultures: the corporate culture, which captures the commitment of managers, and the professional culture which socialises professionals."[30]

Few observers perceived the conflicts between scientists and management as a real problem. They argued that industrial laboratories would become more like universities in their atmosphere and management practices, "groping their way towards collegial authority".[31] Conflicts between scien

[23] Derber, C., "The Proletarianisation", *op. cit.*, p. 11. Derber is quoting from Quinn, Robert and Staines, G.L. *The 1977 Quality of Employment Survey.*

[24] McKinlay, J. B., "Toward the Proletarianisation", *op. cit.*

[25] Larson, M. S., *The Rise of Professionalism*, *op. cit.*

[26] Cohen, Marcia B. and Wagner, David, "Social Work Professionalism: Reality and Illusion", in Derber, C. (ed.), *Professionals as Workers*, *op. cit.*, pp. 141–164.

[27] Aronowitz, Stanley and DiFazio, William, *The Jobless Future: Science-Technology and the Dogma of Work* (Minneapolis: University of Minnesota Press, 1994), p. 169.

[28] Merton, Robert K., *The Sociology of Science* (Chicago: University of Chicago Press, 1973; first edn, 1942).

[29] Marcson, S., *The Scientist*, *op. cit.*

[30] Raelin, J. A., *The Clash of Cultures*, *op. cit.*, p. 1.

[31] Marcson, S., *The Scientist*, *op. cit.*, p. 150.

tists and management would be accommodated by the progressive differentiation of research functions from other company activities.[32] Industrial scientists would not experience conflicts because industrial firms do not—in contrast to academic institutions—attract "more committed scientists" dedicated to the advancement of knowledge.[33] And many scientists and engineers share in the exercise of authority or feel close to management and part of a graded social hierarchy.[34]

Industrial Scientists at Work

In 1991, out of two million scientists in the United States, 667,000 were employed in the industrial sector. Approximately, 118,000 of them held doctoral degrees and were mostly engaged in research and development.[35] In order to address the question of whether current patterns of change in a global economy immiserate industrial scientists, we interviewed 47 such scientists in the United States. We examined the organisational change in their centralised corporate laboratories and its impact on their working lives and professional careers.

We interviewed scientists of high-technology manufacturing industries with high expenditure on research and development and employment. On these measures, the five leading high-technology industries are aircraft and missiles, professional and scientific instruments, electrical equipment, machinery, and chemicals. We interviewed 31 scientists from one centralised corporate laboratory in machinery and another in a chemical company, and 16 others who had worked in corporate laboratories of machinery, electrical equipment, and professional and scientific instruments, and later joined two academic institutions. These laboratories aim at developing new product lines and processes. In size, expenditure and research activities, they are typical corporate laboratories. They are independent of any business division and employ over 1,000 personnel in a broad range of scientific and engineering disciplines.

Our interviewees were identified 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. They were selected by a snowball sampling method.[36] Some prominent scientists named other successful scientists in their group.[37] We conducted taped interviews from

[32] Kornhauser, W., *Scientists in Industry, op. cit.*

[33] Cotgrove, Stephen and Box, Steven, *Science, Industry and Society* (New York: Barnes Noble, 1970), p. 46.

[34] Prandy, Kenneth, *Professional Employees: A Study of Scientists and Engineers* (London: Faber and Faber, 1965).

[35] NSF, *Science and Engineering Indicators, op. cit.*, pp. 60–69, 301, 308–309.

[36] Chadwick, Bruce A., Bahr, Howard M. and Albrecht, Stan L., *Social Science Research Methods* (New Jersey: Prentice Hall, 1984), p. 66.

[37] Mitroff, I.I., "Norms and Counternorms in a Select Group of the Apollo Moon Scientists: A Case Study of the Ambivalence of Scientists ", *American Sociological Review*, XXXIX (1974), p. 584.

May 1991 to January 1992, which combined structured and unstructured formats and lasted almost two hours. They were transcribed verbatim.

Of the 47 industrial scientists interviewed, 43 were male (37 white, 5 Asian, 1 black) and four female (2 white, 1 black, 1 Asian). All but two had a doctorate in bacteriology, biology, biochemistry, computer science, electrical engineering, inorganic chemistry, materials science, mathematics, medicinal chemistry, microbiology, organic chemistry, physical chemistry or physics. Four had published over 100 articles; 12 had published over 50; 14 had published over 25; the rest around 10 articles. One held a Nobel prize and eight had received the highest award given by their company for sustained technical achievement. Six had received an award for 25 or more patents issued. All had worked in industry for at least five years (25 for over ten years and four for over 20).

Our research revealed eight important ways in which this workforce is affected by the restructuring of corporate laboratories.

Losing control over choice of project: Under the autonomous model, scientists do research on topics which interest them and which also fall within their firm's general goals. They consider various factors such as the firm's previous research, technical feasibility, scientific developments and the time and resources available. Managers generate projects only when scientists first join the laboratory or are needed for urgent projects. The most common process of assignment involve consultation or discussion between managers and scientists.

Under the linkage model, scientists have less say in their projects, which are dictated by purely business interests. Projects are imposed in two ways. The most common method is indirect. Scientists must check that their research interests coincide with those of business divisions. Research cannot merely be theoretically relevant or vaguely related to company products, but have to be closely aligned to both products and processes. Scientists have to define a causal chain from the start of a project to at most one year later, by which time the proposed work has to have an important outcome.

Sometimes, projects are directly imposed on scientists. Projects emerge when business and research managers agree on what scientists should do. Managers inform scientists that a certain piece of research is required by a business division. This pattern is described by one of our interviewees: "Earlier some of my projects came from my managers while for others I got the idea myself . . . Now my projects come mostly from [business divisions]. It started . . . with the changes in the funding system . . . [The business divisions] approach scientists directly for the work that is relevant to them. Now my projects are being dictated by the people who do hardware."

Justifying projects to managers with a non-technical background: Managers of corporate laboratories have a degree in science or engineering. Under both linkage and autonomous models, scientists have to justify their proposals to them. Their immediate manager supervises five to ten scientists; managers at the second and third levels supervise perhaps 25 and 50 scientists, respectively. The higher the manager the less he or she knows about a specific project. Even when their superiors have a technical background, scientists have difficulty in explaining their work to managers at the upper level under the autonomous model. To obtain financial support, scientists must now deal with business managers who usually have no scientific or engineering background. In discussing research with managers, scientists have to stress the business aspects of their work and minimise the importance of technical issues. As one scientist said: "Our [new managers] are not technical oriented people. It is very difficult to convince them."

Loss of autonomy: Under the autonomous model, scientists decide how their own research interests are to coincide with their firm's goals and interests. They do long-term research with perhaps very little tangible result for years. Managers control their work indirectly, by approving their research. The evaluation of projects is informal. Scientists recruit immediate managers and later make a formal presentation to upper management. Proposals are judged in terms of how they match the firm's goals, and their cost, technical feasibility, the time they require for completion and a scientist's previous achievements.

Under the the linkage model, financial considerations have, in effect, displaced technical criteria. Basic long-term research will not be supported because it is a financial risk. As one of those interviewed put it, "business [managers] don't want to consider anything which will take more than a few months". Scientists have to be very specific. Proposals are reviewed by both laboratory and business managers. Today industrial scientists spend much time building relationships with customers who will sponsor their work. The new reality is that "the person who controls the money dictates the themes".

Shifting scientists to different projects: The linkage model has made the funding of research more complex and time-consuming for scientists. Those who do not find a sponsor must work for scientists who are better supported, and thus they risk losing control of their own projects and careers. A scientist explained: "Let's say my expertise is in the area for which the business is not that excited. So, they are not going to fund my work any more. Now I have to find something else to do, in some cases, to switch to a completely new area which has funds."

Many scientists are also driven to work on several different short-term projects to raise a certain amount of funds: "Right now, I have four different projects. There is no way I can be expert in four different areas. These projects are only moderately related to each other."

Reduced time for research: Under the autonomous model, scientists participate in both planning and technical meetings. In planning meetings, scientists and their managers exchange ideas, evaluate projects and review progress; such meetings link scientists' research interests to corporate goals. In technical meetings, scientists present their work to colleagues and managers, answer technical questions and exchange technical information. Scientists like technical meetings and have reservations about the frequency and agenda of planning meetings, which are often perceived as unwanted or irrelevant to their research.

Under the linkage model, more planning meetings are necessary because of the greater number and shorter duration of projects. The diversification of stakeholders for more numerous projects means that more managers with diverse interests must be convinced of a particular project's value. Scientists change their presentations in order to gain support from diverse interests. When potential supporters suggest revisions, the scientists have to agree to them. Many planning meetings with different presentations are required to get support for a project, consuming a significant amount of scientists' time. "I started a project in the end of May. By July, that project was reviewed three times, and revisions were made accordingly. This . . . project . . . was taking only a part of my time . . . So you end up spending much more time in presenting your stuff than working on it."

Scientists need to develop skills in marketing their ideas to laboratories and business managers. As one scientist put it: "Now salesmanship has a lot to do with getting support . . . We have to sell the idea that our work is significant."

Receiving rewards on the basis of funds: Under the autonomous model, scientists are rewarded for the quality of their work. Under the linkage model, they are rewarded if they generate funds for their projects. This has changed the basis of scientific collaboration. When the value of research is measured by its "contribution to knowledge", all members of a team share in the recognition that results, even if the team leaders normally get the most credit. Financial reward, however, tends to be exclusively associated with whoever secured the financial support in the first place.

The new system of recognition has encouraged scientists to work more in groups and less as teams. An interviewee described the effects thus: "Right now team work means I will have mostly people other than PhDs working on my projects. I may have one or two PhDs but they would work on my project and we would not work together. In other words, there is team work, but it is hierarchical."

Decreasing technical assistance: The success of experiments often depends on technicians. As equipment becomes increasingly sophisticated, the importance of technical support grows. With decreasing funds for research, fewer technicians are being assigned to scientists, though the number of projects conducted remains the same or has increased. Hence scientists have to perform more technical functions themselves. One scientist said, resentfully: "Our lab has been reduced from 50 to 37. So I have to do everything . . . Give me more manpower."

Terminating projects: Under the linkage model, many projects have been brought to an end despite a long history of company research in those fields. Scientists used to pursue certain goals that were recognised within the industrial firm and by the scientific community, but there is now little confidence among scientists that such recognition will ensure the longevity of their research. Business managers change their minds in response to market forces, so the connection between corporate goals and research strategies is no longer clear. We were given the following example: "I was involved in a project. There were four of us working. One day our manager came and announced that we cannot work on that anymore. It was just like that, totally sudden . . . The project got terminated because the perception changed. It has nothing to do with the technical merits of the projects."

With projects terminated, many scientists have left corporate laboratories for academic, governmental and other organisations. Other scientists have taken on different projects in the same company. The quality of research in some corporate laboratories has become questionable. Scientists have had to reorganise their groups and establish working relationships with new colleagues. Staff changes and the uncertainty of financial support are likely to affect both the quality of scientific work and the quality of working life for scientists.

Proletarianisation versus Professionalism of Scientists

Clearly, the shift from an autonomous to a linkage model has changed the working lives of industrial scientists, often for the worse. Scientists have lost privileges they once enjoyed. They no longer control the way projects are selected. The autonomy of their research is being curtailed. They must work on short-term projects. Non-technical managers influence research decisions to a greater extent. The number of projects on which scientists work has risen, but the time and resources devoted to them has declined. The availability of funds rather than the promise of new knowledge relevant to industry is determining both the direction of their research and the careers of industrial scientists.

Industrial firms conduct research in order to make a profit. When scientists join such firms, their freedom to select research projects is affected by their firms' goals and interests. Mertonians and Marxists are both correct in observing that working for such firms limits the autonomy of scientists and thus generates conflict. However, in many corporate laboratories, controls are internalised.[38]

Both Mertonian and Marxist notions of autonomy and control pertain to an era when corporate laboratories enjoyed extensive autonomy. Scientists

[38] Bailyn, Lotte, "Autonomy in the Industrial RD Labs", *Human Resource Management*, XXIV, No. 2 (1985), pp. 129–146; Sutton, John R., "Organizational Autonomy and Professional Norms in Science: A Case Study of the Lawrence Livermore Laboratory", *Social Studies of Science*, XIV, No. 2 (1984), pp. 197–224.

formulated projects within the framework of company goals and interests. Even in basic research, their projects were shown to be useful to their laboratories. Our interviewees did not do basic research for its own sake, but to demonstrate the feasibility of applied work. They seemed satisfied with the degree of freedom they had to set research objectives, though the Mertonian and the Marxist traditions might suggest otherwise.

Those who hold the Mertonian viewpoint declare that, as professionals, scientists must be left alone with their work. This kind of thinking led to the separation of research from development and planning. Scientists' ideas and inventions often were not utilised because of this separation of research from the business divisions of a firm. The growth of the linkage model reflects an inability to define the benefits of research conducted under the autonomous model.

Marxists contend that workers' conditions will deteriorate in advanced capitalism. Under the linkage model, the conditions of scientists have indeed deteriorated. Funding by business now determines which projects are stopped or initiated and how they can come to fruition. Scientists clearly disagree with the new procedures for allocating research funds and are concerned about the highly applied nature of their work.

There is evidence to support the thesis of immiseration, both at the level of the global economy and in the organisational transformations reported by our interviewees. But there is opportunity as well as threat in the organisational changes currently taking place. These opportunities most probably reside in transforming "linkage" into a "partnership" model of science and social forces.