Revolution from Above: The Role of the State in Creating the German Research System, 1810–1910

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Discussions of modern scientific research’s organization point to the 19th-century emergence of German research universities as evidence that state investment in nondirected academic research, when coupled with beneficial relations between academic research and industry, and when stimulated by appropriate incentives such as protection of intellectual property in an open, competitive system, can lead to explosive growth in scientific knowledge and rapid improvement of industry. This paper examines three episodes in the evolution of Germany’s research system pointing to the roles of state interests and innovative ministerial leadership in fashioning the research system to meet state needs.

I. Economic Engineering: 1806–1848

The first period considered is that bracketed by the Prussian defeat by Napoleon’s armies and the 1848 Revolution. Discussions of the research university quite naturally focus on the Humboldt reforms and the University of Berlin’s founding in 1810. But the Humboldt reforms should be considered together with the Stein-Hardenberg economic reforms aimed at fostering private initiative through removing guild restrictions on trade as well as a sweeping set of anti-feudal land and labor reforms. In a nearly unbroken line of policy until 1845, Karl H. F. Stein, Karl A. F. Hardenberg, and their successors, Gottlieb J. C. Kunth, Ludwig F. V. Bülow, and especially Christian Beuth and Christian Rother, attempted to stimulate industrial development. They employed a variety of means, from dissemination of technical information to handing over government-purchased foreign technology to private parties as capital investment, and from the creation of organizations to generate development funds for new industrial start-ups to actively building state-financed industries employing the newest technologies and organizational techniques, in all order to pressure Prussian industry to modernize its production methods (see William D. Henderson, 1958; Ulrich Peter Ritter, 1961; Ilja Mieck, 1965; Wolfgang Radke, 1981; Hubert Kiesewetter, 1989; Hermann Fernholz, 1991; Werner Vogel, 1993).

Another key feature of the Prussian plan to modernize German industry was new types of educational institutions to free industry from its tradition-bound practices. Stein and Kunth identified “Bildung” as the most useful form of state aid, and Beuth argued that where science is not introduced into industry, there can be no securely based industry or progress. Beuth opened the Gewerbeschule (School of Trade and Industry) in Berlin in 1821, to provide rudimentary instruction to handwork-ers and manufacturers in mechanics and chemical-technical subjects. The school was expanded within a few years to include a third class, the “Suprema,” which treated the scientific basis of technology as a unified field of study.

The Humboldt university reforms were also conceived as regenerating the nation’s spiritual foundation, particularly through institution of the seminar, nourishing intellectual independence and initiative. Elite young minds trained in close interaction with faculty working on independent research problems would become the next generation’s bulwark.

But the university Humboldt envisioned did not include laboratory training as a regular part of the science curriculum. In fact, Humboldt’s planned science curriculum was primarily devoted to “pure” theoretical science, particularly mathematics and physics. While chemistry and physiology were included in this picture, laboratories were only deemed important for supporting technology.

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II. Research Competition, and...
important for supporting lecture demonstrations and for the professor’s private research needs. The model of Wissenschaft um sich selber willing that emerged in this environment was heavily opposed to any association with handwork. Between 1830 and 1848, laboratory exercises were tolerated as entrepreneurial activities professors might initiate for fees which they would plow back into lab equipment (R. Steven Turner, 1971, 1974; Charles McClelland, 1980).

The response of the Prussian ministry and university faculty to a scathing critique of the system launched in 1840 by Giessen chemist Justus Liebig sums up the pre-1848 situation of natural sciences in universities. To Liebig’s claim that chemistry was an independent discipline worthy of its own institute, rather than simply an adjunct field for medical students, leading faculty members responded that Liebig’s recommendations to combine the pursuit of new chemical knowledge with laboratory work based on standardized and easily taught methods of analysis undermined the university’s purpose. Liebig’s program combined pursuit of pure knowledge, typical of science academies, with work appropriate to technical institutes, which trained students in material production. According to an old-guard professor, Liebig personified the time’s central academic evil: just after discovery in order to attract more students. The true purpose of university science, according to this professor, was to transmit solid, proven knowledge to men training in useful professions to serve the state (Turner, 1982).

II. Research Imperative, Decentralized Competition, and Institute-Building: 1848–1871

A fundamental shift occurred in the organization of academic science in Germany from the mid-1840’s through the mid-1870’s, connected with the emergence of a prestige market driven by a new research ethos (Joseph Ben-David, 1971). This shift in many ways realized Liebig’s vision of science. As Ben-David argued persuasively, in large part the shift during this period was due to competition among different German states for intellectual talent as they vied for cultural leadership of a hoped-for unified Germany. Intense competition existed among the leading state ministries of culture and education to stock their universities with the best professors, now defined as discoverers of new knowledge. A state ministry’s appointments were based on international reputation for research and publication as evaluated by a review process established within the ministry and drawing on faculty peer review. In an environment where several universities could compete for a single professor’s talents, highly visible scientists were able to make laboratory space, assistants, and equipment a condition of their acceptance. These academic market forces meant that nearly every German university got at least a small institute of chemistry, and similar developments occurred in physics and physiology. Having grown out of traditional teaching functions in which laboratory work was seen as at best formalizing traditional student training, once the new labs were in place entrepreneurial directors were recruited who would use the facilities to advance their own research and to encourage research among advanced students, in turn reinforcing the scientific achievement of the professor/lab director.

While the open system blossomed during this brief period of German academic history, the earlier mercantilistic concerns of state ministries were nonetheless still present. In my view, interaction between these two tendencies gave the system its distinctive features. Recruiting star faculty was only one of the items on state ministers’ agendas during this period, characterized at best by modest economic growth and more often by stagnation and decline. Enhancing their universities’ prestige was an important goal, but increasingly for the smaller German states, stimulating their economies was another. While universities competed for faculty, they also competed with one another for students; a reason for recruiting star faculty was to increase student enrollments. Since the largest growth sector of student matriculation in this middle period was in medicine, ministers tried to increase their competitive advantage for medical students by hiring the faculty and constructing the ancillary support facilities for medical education. A second, larger, area of concern of state ministers during the late 1840’s–1850’s was the need to stimulate the economy. While
states like Prussia could appoint a few professors in highly visible universities without consideration of the support facilities' integration with other programs, smaller states felt increasing pressure to utilize their resources efficiently, dovetailing appointments with other initiatives. Peter Borschiedt's (1976) study of Baden illustrates how this competition for students, combined with the effort to harness chemistry to stimulate agricultural production, led to impressive expansion of chemistry facilities at the University of Heidelberg.

Elsewhere (Lenoir, 1997), I have shown that a similar pattern can be seen in the building of first-class science and medical institutions at the University of Leipzig by Johannes Falkenstein, the director of the Saxon Kultusministerium. Falkenstein was to Saxony what Beuth and Rother were to Prussia (see David Cahan, 1985; Alan J. Rocke, 1993; Lenoir, 1997). As Kultusminister of the most industrialized German state, Falkenstein was not as pressed as his Baden colleagues to generate immediate economic benefit to industry and agriculture from investment in the natural sciences, but he had consistently promoted economic modernization and industrialization as a means to long-term prosperity and social stability. But one of his concerns as Kultusminister was to boost enrollment at Leipzig, particularly by attracting students from other German and foreign states. Leipzig had not done particularly well in student enrollment during the 1840's and early 1850's. In an era when the medical faculty was a university's "bread and butter," Falkenstein concentrated his resources in the area of his existing strength: clinical medicine. He made plans to improve the Leipzig natural-science faculties and build a new science and medical campus.

The retirement of the professor of physiology allowed Falkenstein to implement his plan. He recruited Carl Ludwig, Germany's leading physiologist, for Leipzig's clinical medicine program. Although Ludwig was famous for introducing physics-based instrumentation into physiology, his work had never had much direct contact with clinical medicine. Falkenstein perceived a perfect fit between Ludwig's advancing research programs and the work of the star he already had in the Leipzig medical stable, the clinician Karl Wunderlich. Since the late 1850's, Wunderlich had been deeply involved in his studies on thermometry, strengthening his conviction that the closest cooperation ought to develop among experimental physiology, chemistry, pathological anatomy, and diagnostic techniques for the clinic. Falkenstein built new institutes for physiology and pathology, each with positions for assistants in physiological chemistry and microscopic anatomy, the goal being to integrate these various enterprises into a collaboration between Ludwig and Wunderlich. In order to promote this cooperation, these institutes were all situated adjacent to one another with connecting corridors and walkways. The integration of experimental clinical medicine, long considered a defining moment of the 19th century's medical revolution and the first step toward rational science-based medicine, can be considered the outcome of strategic planning on the part of enlightened state bureaucrats (see Kiesewetter, 1988).

The efforts of ministers like Falkenstein to optimize interactions among their different research faculty and to coordinate facility use led to systemic interactions among disciplines, improving the content of science in ways that no one could have predicted by simply betting on each discipline's stars pursuing their own personal research programs. While this system building was considerably short of targeted research and development, it prepared the way.

III. Academic Science and Industry's Needs: 1877-1910

The final phase of development I want to consider is between 1871 and 1910, culminating in the formation of the Kaiser-Wilhelm Institutes. As the two periods I have already discussed demonstrate, the view that state-supported research at the universities should stimulate industry in certain ways was at best a rhetorical position in the German nation's political and cultural transformation. For the most part, few scientists other than Liebig thought their work had direct relevance to industry, and the highest rewards were to be obtained by emerging as "bearers of culture," rather than as scions of industry. In the period between 1871 and 1876, conditions shifted radically. The state had earlier characterized academic and industrial research. This cultural shift increased relevance of economic performance, bringing about this new cooperation. Friedrich Althoff, Karl-Heinz Manger, 1974; Bernhard von Hase.

In the previous section, the conditions for a post-industrial society and the role of new knowledge in industry and research proved fertile tools for developing these institutions, and the trend had gone into the low-level training. The turn of the century simply provided a research by request, not by request. I have suggested that developments with Ludwig's colleague, another refinements in the structure, and the autonomy of the academic institutions were shaped by the time. It is not clear how such a system was established, given the divisions in Germany and the structure of the universities. The specific solutions involving the necessary advanced research, the awareness of the academic scrutiny of the state and the university. The relationship with the research workers in the Imperial Institute for Bordetella and Koch's lab of diphtheria, etc.
stable, the clinician in the late 1850's, deeply involved in his specialization, strove to preserve the cooperation among experts in medical physiology, anatomy, and diagnostic medicine. Falkenstein's physiology and pathology were not just a collection of facts and theories, but a collaborative effort to integrate these disciplines in a comprehensive approach to medical knowledge.

In the previous sections, we have described the conditions for a powerful state of institutions that generated scientific research and the production of new knowledge. But by 1890, the recognition dawned that the fusion of teaching and research provided the rationale for developing these institutions in fact hindered science's advance, since the bulk of resources had to be directed to support time-consuming research. The progress of science at the turn of the century depended more on simply providing good (and time-consuming) research by reducing their teaching. In addition, I have suggested in the previous section that developments such as those connected with Ludwig's call to Leipzig pointed toward another refinement of the system through stimulating interconnections between otherwise autonomous disciplines. Although favorably disposed to such cross-fertilization, Althoff did not hold out much prospect for its realization, given the rigid hierarchies and social divisions in German universities. The solution to these structural problems depended on establishing an Archimedean point outside the universities. The impetus for change and the specific solutions to the problems of establishing the necessary institutional conditions for advanced research came about as a result of acute awareness of the increasing importance of academic science for industry, and the centrality of industry to the German Imperial State.

The relationship between Farbenkompagnie Hoechst, a dyestuff manufacturer, and the research workers in Robert Koch's laboratory at the Imperial Institutes of Health (Reichsgesundheitsamt), following the discovery in Koch's lab of the first biological antitoxins (diphtheria, tetanus) illustrates how closer links between industry's demands and academic science's interests were forged. A constellation of factors stimulated research and development in the field of pharmaceuticals at Hoechst. Foremost among these was the economic crisis faced by the industry, most severe between 1881 and 1885. The increased costs of finding new dyes in an evermore competitive market and dyestuffs' actual decline in price forced major chemical firms producing dyes, such as Hoechst, to seek to diversify their products (John Joseph Beer, 1959; Borscheid, 1976).

Hoechst moved into pharmaceuticals by establishing consulting arrangements with the directors of university laboratories, supplying them with both funding and materials to work on subjects of potential interest to the firm. Within a few years, owing to the increasing complexity of research requiring facilities unavailable routinely in universities and problems of reliably managing such consulting arrangements, firms like Hoechst moved to internalize these research capabilities. Early experiences with the privatization of Emil Behring's work on sera at Hoechst led Althoff to be concerned about insuring the expansion of basic research, but also making it available for commercial development. A first experiment was the establishment of the Frankfurt Institut für Serum-Prüfung-und-Forschung with Paul Ehrlich as director. Though not yet a for-profit research institute, the Institut was firmly based on mutual cooperation among state, industry, and academic science. This institute presaged a more ambitious endeavor to pursue rational drug therapies and production of artificially synthesized drugs based on Ehrlich's discoveries of certain dyes' ability to block trypanosomes' toxic capabilities (see Ernst Bauern, 1984; Lenoir, 1997 pp. 179–202).

The Georg-Speyer-Haus that Ehrlich proposed and eventually constructed was an interdisciplinary institution whose director would define problems to be attacked through exchange of ideas among physiologists, biochemists, microbiologists, bacteriologists, pharmacologists, and clinicians working in-house. An unspecified percentage of the profits from patents was reinvested in the institute to cover its operating costs, including the costs...
of undertaking new research. The firms of Hoechst and Casella contributed substantially to the initial endowment and also supplied the raw materials used in the department of chemistry’s research. In exchange, the two firms received first refusal on any marketable patents. But the choice of research problems was left to be determined solely by Ehrlich and his students.

Concrete results, such as the production of Salvarsan, the first cure for syphilis, were undoubtedly instrumental in supporting the conviction that the pattern of a multidisciplinary institute combining the advancement of basic science with the needs of industry embodied in the Georg-Speyer-Haus was capable of more general application. It was because of its success that Ehrlich sat on the board of advisers who laid the plans for the Kaiser-Wilhelm-Gesellschaftsinstitute (see Manfred Rasch, 1987; Jeffrey Allan Johnson, 1990; Rudolf Viehhaus and vom Brocke, 1990).

REFERENCES


