SYMPOSIUM COMMENTARY

Pondering the Globalization of R&D: Some New Questions for Business Historians

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Mira Wilkins has presented business historians with questions and challenges that are at once bold and almost overwhelming in terms of our being able to answer them with any degree of confidence. Wilkins asks us to examine firm "behavior over borders." My goal here is to extend the questions and challenges she offers by focusing on but one element of firms' crossing borders, the international dimensions of industrial research and development (R&D) in the pre-World War II period and the globalization of industrial R&D in the post-World War II era. I present not a research paper but rather a research agenda – a series of observations that maintain the thrust of Wilkins's article and that might serve to inspire historians of business to think about the phenomena of globalization of business in perhaps a slightly different way. A central question cuts across this series of observations: How have *national* political, legal, social, educational, and cultural traditions and structures influenced the *international* patterns of industrial research and development? Gaining some answers, however tentative, to this question promises not only to inform us about the past, but also to provide some understanding of the present as globalization of R&D proceeds apace.[1]

During the last fifteen to twenty years historians of business have gained a better understanding of industrial R&D as yet another aspect of the rise of big business. Firms invested in R&D, just as they invested in manufacturing and marketing. Investment in R&D served to build corporate capabilities not only in new product and process development but also in the improvement of existing products and processes. Building such capabilities was part of the process of vertical integration whereby firms relied less and less on the market for innovation and instead generated inventions and processes internally. By treating investment in industrial R&D laboratories and organizations within the framework of organizational capabilities and vertical

[1] For evidence of the rapid globalization of R&D, see the latest edition of *Science & Engineering Indicators* [National Science Board, 1996, pp. 4.42-4.48].

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integration, historians have gained enormously in their comprehension of the history of business during the last century and a quarter.[2] Yet, as Wilkins reminds us, historians have not paid close enough attention to the international dimensions of business. Those who take up the Wilkins challenge by seeking to understand the international or transnational character of firms, however, must be sensitive to the manner in which national political, legal, social, educational, and cultural structures modulated the behavior and performance of firms.

Consider, for example, Arthur D. Little's widely reprinted Presidential Address to the American Chemical Society delivered in 1913. The creator of one of the United States's first private, for-profit R&D firms that offered an array of testing, analytical, and consulting services (Arthur D. Little, Inc.), Little celebrated the recent achievements in the establishment of organized industrial R&D laboratories and programs in the United States. Little opened his address, however, by saying that the world's leader in industrial R&D, as well as scientific and engineering research in general, was Germany. Yet he went on to stress that "the preeminence of Germany in industrial research is by no means indefinitely assured. A new competitor is even now girding up his loins and training for the race, and that competitor is strangely enough the United States" [Little, 1913, p. 793]. After providing a litany of examples of the new industrial R&D programs in the United States, such as those of General Electric, AT&T, DuPont, and Kodak, Little said the following: "In striking contrast to the secrecy maintained between individual workers in large German research laboratories is the almost universal custom in America to encourage staff discussion" [Little, 1913, p. 796]. What are we to make of such a remark? Do we attribute it to a chauvinist bent in Little, or was there something behind his comment that is worthy of further exploration?

Compare Little's remarks about researchers in German companies with those written almost eight decades later by a U.S.-born and -educated research director who managed R&D in three different German multinational firms and who sat on the board of directors of one of these firms for more than a decade, Francis Honn:

> The route to the top in these [German chemical] companies is normally from university to R&D to production...to business management, with time out for overseas duty...The fact that most senior managers start their careers in research is certainly beneficial in that there is consistent support, in good times and bad, for sizeable R&D budgets and ambitious programs. But there are harmful effects as well. Because German patent law requires a company to compensate its employees for the use of their inventions via substantial royalty payments, top managers are often able to

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[2] Alfred D. Chandler [1990] provides the clearest statement of technologically based firms' three-part investment in R&D, manufacturing, and market capabilities. Hounshell [1996] develops this point further in a broad survey or research in the United States. See also Smith [1990].

> reward themselves financially for work done while they were at the bench. This "conflict of interest" makes it difficult for outsiders to sell technology to German companies. The NIH [Not-Invented-Here] factor is very real...
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> Germans are noted for their punctuality and attention to detail. These characteristics find their way into the conduct of R&D projects, where meeting a promised deadline can be more important than uncovering worthwhile results, or where a line of research can be pursued ad infinitum when a few well-designed experiments would do the job. Also, Germans, despite their outwardly jovial appearance in beer halls, are a serious lot who find their U.S. colleagues rather light hearted and perhaps light headed when it comes to undertaking R&D projects. This observation, together with the German propensity for intense specialization, convinces them that Americans, who tend to be generalists, are in truth quite superficial in their education and shallow in behavior.
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> The openness of Americans, and their habit of using first names at first meeting, is admired and envied by Germans. But it also makes them uncomfortable in the same manner as an open door to a lab or office. They are also disturbed by the work ethics of Americans, who tend to spend long hours on the job and take few holidays and short vacations. Virtually everyone I know in BASF and Henkel is busy planning the next vacation, and no wonder because the law mandates at least three weeks for every employee...
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> Another interesting characteristic of a German researcher is his fear of reporting negative data. It once took me three trips to Germany to convince Bayer R&D executives to include negative results in their reports on a joint project with an American firm. They simply could not understand why we wanted to know what did not work! Finally they gave in to please me. While negotiating this point, I concluded that German chemists are afraid to report failed experiments because they are a reflection on their level of knowledge, or lack thereof. In German schools, they may be taught, for example, that there are three ways to do something. They are expected to play back those three ways in their exams in a nice, tidy way. So when a planned experiment doesn't work, their sense of neatness is offended, especially if they are forced to reveal such untidiness in public [Honn, 1992].

These words speak volumes about the unique opportunities available to business historians to contribute to a deeper understanding of the so-called "globalization of R&D" that is commanding so much attention and so many resources today. During the last decade or so, economists, using statistical data gathered from such organizations as the OECD and the NSF and from a large number of surveys of multinational enterprises, have written extensively on the

globalization of R&D.[3] Yet I find their work largely unsatisfactory in explaining the behavior of firms in terms of internationalizing or globalizing their R&D. They are unsatisfactory because they have not gotten inside the firm to examine the competing motivations of managers in the establishment and operation of R&D facilities outside the home bases of their firms. Of critical importance, they have not recognized how differences in national laws, national education systems, social and cultural practices, and work ethics govern the actual performance of so-called global R&D. History matters, culture matters, legal structures matter, and education matters. In rising to the challenges that Mira Wilkins sets before us, business historians will reap very large rewards.

Statistics on Global R&D

The National Science Board reports in its *Science & Engineering Indicators 1996* that the 1980s and 1990s have been marked by the internationalization or globalization of R&D. Three measures clearly suggest this trend. First, there has been a "sharp increase in transnational joint research funding" manifest most clearly in strategic technology alliances of one sort or another [National Science Board, 1996, p. 4.43]. Second, U.S.-headquartered firms moved an increasing amount of their research abroad. In the decade from 1985 to 1995, U.S. companies doubled their research spending overseas, principally in Europe and Japan, from 5% to 10% of their overall R&D budgets. In some sectors, firms spent considerably more than this figure. Third, foreign-based firms built R&D facilities and capabilities in the United States at a significantly greater rate than domestic firms. By 1995 more than 300 European and Japanese firms were operating some 635 R&D facilities in the United States. Japanese firms alone funded 219 R&D facilities in this country. In 1993 foreign firm investment in U.S. industrial research totaled about 12% of all industrial R&D in the U.S., double the percentage in 1985. Altogether, firms throughout the world spent in 1995 more than $20 billion on R&D conducted outside their home base, and this sum is rising rapidly. Clearly the globalization of R&D is upon us [National Science Board, 1996, pp. 4.42-4.48]. But is this an entirely new phenomenon? Certainly not.

Continuities with the Past

In the post-World War II period, numerous U.S. firms established or inherited R&D organizations in Europe for a variety of reasons, including the transfer and adaptation of U.S. products and processes to European markets and the monitoring of European scientific and technical developments coming

[3] The economic literature on globalization of R&D is growing extensively. See especially the following work: Ronstadt [1977]; Mansfield, Teece, and Romeo [1979]; Håkanson and Zander [1988]; Chesnais [1988]; Casson [1991]; Patel and Pavitt [1991]; Granstrand, Håkanson, and Sjölander [1992]; Dunning [1994]; and Zander [1994, 1996a, 1996b].

out of both universities and competing firms [Ronstadt, 1977]. But as Mira Wilkins's own work has shown, the transfer and adaptation of U.S. products and processes to Europe began in the nineteenth century, not the second half of the twentieth century [Wilkins, 1970, 1989]. Moreover, European-based firms that moved to sell products in U.S. markets in the late nineteenth and early twentieth centuries, such as the German synthetic dyestuffs manufacturers, developed agencies that provided technical support for their U.S. sales, which was certainly a form of R&D [Steen, 1995].

If we look carefully at the founding of many of the first formal R&D laboratories in the United States by U.S. firms, we can see that the dynamic that drove this process was international competition, or the threat of international competition, the same process that seems to be driving the current wave in the globalization of R&D. Consider four of the firms that I have labeled "the R&D pioneers," General Electric, DuPont, AT&T, and Kodak. As Leonard Reich has so clearly articulated, General Electric established its research laboratory because of the threat posed by illumination technologies that were emerging primarily (but not exclusively) from Europe, including the Nernst lamp and metallic filament bulbs [Reich, 1985, 1992]. DuPont's entire R&D thrust in the late nineteenth and early twentieth centuries stemmed from the development of the new explosive dynamite and the new propellant nitrocellulose, the former invented by Alfred Nobel and developed extensively in Germany and England, the latter emerging from Europe with Christian Schönbein's early (1846) production of guncotton and years of development in nitrocellulose chemistry and chemical processing. The agreement that DuPont reached with the British and German members of the Nobel dynamite cartel in 1897, which divided world markets for explosives thus keeping both the British and Germans out of the American market, grew by 1907 into a broad information-sharing agreement, which gave DuPont critical access to European explosives developments. The new DuPont R&D laboratories served as vehicles for the transfer and adaptation of this foreign technology. The 1907 agreement would eventually serve as the basis for the extremely broad Patents and Processes Agreement of 1929 between DuPont and Imperial Chemical Industries, which I will discuss below [Chandler and Salsbury, 1971; Taylor and Sudnik, 1984; Hounshell and Smith, 1988; Smith, 1992]. Acutely aware of increasing, competitive threats from Europe, especially from the German dye firms that had been diversifying into all manner of fine chemicals including photographic chemicals and film, George Eastman established the Eastman Kodak Research Laboratory in 1912 and placed it in charge of an Englishman trained in science and practiced in photographic chemicals manufacture, C.E. Kenneth Mees [Jenkins, 1975, pp. 300-30; 1981]. American Telephone and Telegraph established its first formal research laboratories in 1907 in response to what initially seemed to be a primarily domestic threat from radio [Reich, 1985], but as Hugh Aitken's work demonstrates, the international stakes in radio were extraordinarily high [Aitken, 1985]. R&D in radio in the first third of this century was anything but

domestic.[4] Furthermore, R&D organizations played a critical – and varied – role in the phenomena of cartel formation and disintegration during the last two decades of the nineteenth century and the first four decades of the twentieth century [Hounshell and Smith, 1988; Erker, 1990, 1995; Smith, 1992; Reich, 1992]. The entire history of cartels, I believe, demands reexamination from the vantage point of R&D and particularly the transfer of technology.

Cartelization and Research

Thanks to the antitrust laws of the United States and the Department of Justice's interpretation that these laws covered international market-sharing agreements, we know quite a bit about cartels. But surprisingly, historians have not carefully examined the implications of these cartels for the R&D and technology transfer programs of most of those technology-intensive firms that joined them.[5] Neoclassical economic orthodoxy would suggest that cartelization would remove incentives for innovation or the adoption of new technology, hence biasing participants against the pursuit of costly R&D. But we know that most of the U.S. firms that pioneered in R&D and that made substantial contributions to the development of their respective technological bases entered into various kinds of cartel agreements. How can we account for these seemingly contradictory behaviors? I would suggest that in spite of cartelization, technological dynamics – Joseph Schumpeter's "winds of creative destruction" – were sufficiently strong to push some firms to continue to do research, perhaps even to do more research than in a dog-eat-dog world of "pure" competition.[6] Of course, cartel agreements differed significantly from each other, but many had provisions for sharing technical information.

Sharing technical information across firm boundaries and across international borders no doubt had major effects on firm capabilities. First, I would suggest that cartelization significantly lowered the costs and uncertainly of obtaining or transferring technical information, which allowed firms to devote more monies to actual research and development than to reconnaissance. Second, sharing technical information across international borders, even in

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[4] See also the important study by Daniel R. Headrick [1991] and the work of Pascal Griset [1995]. As Margaret Graham and Bettye Pruitt stress in their book on Alcoa research, international developments pushed that company into developing greater research capability through the establishment of its Technical Department [Graham and Pruitt, 1990].

[5] The notable exceptions to this generalization are cited in the immediately preceding paragraph.

[6] In their classic book, *Cartels in Action*, George W. Stocking and Myron W. Watkins suggest that the incandescent lamp cartel reduced incentives for innovation by its smaller members, yet they are unable to explain why GE continued to fund electric light research even after it gained a dominant position with its gas-filled, tungsten filament lamp other than to allude to "General Electric's jealous safeguarding of its technical pre-eminence" [Stocking and Watkins, 1946, pp. 350-52]. The paradox of firms that were party to international cartel agreements undertaking extensive R&D has parallels to patterns William Lazonick has analyzed in his work on the decline of the British cotton textile industry [Lazonick, 1986].

narrowly defined areas, served to give researchers and research managers a sense that research styles and capabilities varied across firms and international boundaries, providing them with a deeper insight about their own firms' research strengths and weaknesses. Such insight also provided many researchers and research managers with a heightened sense of their own firms' assumptions about and approach to research.[7]

Although the 1929 Patents and Processes Agreement between DuPont and ICI might have been unique in that the chief executives of both companies agreed informally to share research information almost from its inception above and beyond their formal agreement to cross-license virtually all the companies' patents and processes, its history is nonetheless instructive [Hounshell and Smith, 1988, Chapter 10]. To the Antitrust Division of the Justice Department, the DuPont-ICI agreement was nothing more that a device to get around the technicalities of the Sherman Act, the 1890 antitrust law of the United States. Rather than simply dividing up the world markets and hence restraining trade or fixing prices, the two companies agreed to grant to each other exclusive licenses on their intellectual property – patents and processes – to be worked in prescribed territories. The end result was indeed a market-sharing, trade-restraining agreement. But the informal provision for sharing research information offered the companies a good deal more. Through the regular exchange of thousands of research reports, through the continual flow of research delegations from one company to another, and through the developing network of formal and informal communications between researchers in various divisions and laboratories of the two companies, DuPont and ICI gained an enormous amount of information that would have been expensive to obtain another way. Researchers and research managers also learned a good deal about differing corporate research styles, differing university research traditions, and differing strategic thinking by corporate executives. Certainly the agreement was not ideal – and indeed DuPont's actions often rankled ICI's managers – but the agreement was far more that a market-sharing device. By aligning with ICI through the Patents and Processes Agreement, DuPont gained not just greater domestic market security, but also a greatly extended research capability that helped it and ICI to prosper in the interwar years.[8]

We need to have analyses of the international R&D connections of other U.S. firms comparable to that carried out by John Smith and me before we are in a position to grasp fully how cartels influenced the R&D behavior of

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[7] For evidence of how cartel agreements led firms to examine more critically how they themselves conducted research, see, e.g., the cases of DuPont and I.C.I and I.G. Farben, as discussed in Hounshell and Smith [1988, Chapter 10].

[8] In 1948 when DuPont was forced to abrogate its agreement with ICI, DuPont's organic chemicals department estimated that it would have to hire thirty first-class research chemists to generate the amount of research that the department was receiving on the single, critical problem of dyeing new synthetic fibers being developed by the company's fibers department. See Hounshell and Smith [1988, pp. 204-05].

U.S. technology-intensive firms.[9] One thing is certain: the pattern was not as clear and as unmixed as those in the late New Deal's and the Square Deal's Antitrust Division would have had us believe.

Post-World War II

World War II and a truculent wave of anti-big business sentiment in the United States, especially in the Antitrust Division of the Justice Department, served to bring an end to many of the cartel agreements that had been formulated earlier in the century [Hawley, 1980]. Of course, the war itself forced many U.S. firms to terminate their agreements with German, Italian, and Japanese firms. Virtually every major U.S. firm possessing extensive R&D capabilities faced some type of antitrust inquiry in the postwar period, many pursued to rid the world of cartel activity.[10] Thus the war and the consolidation of power in Washington meant a change in the order of business in the West. After the war, the German chemical giant I.G. Farben, which had come to symbolize the worst of cartel behavior with its "tentacles" reaching throughout the world economy and its collaboration in the Nazi-led holocaust, was split up, as though it had lost a domestic antitrust case.[11] The Allied victors also dictated to research-intensive firms in the former Axis what kind of research they could and could not do in the early post-war period.[12] At home, American firms were forced to abrogate their international agreements that smacked of cartel behavior. These changes, coupled with the fallout of wartime weapons development projects and the emergent Cold War, produced a profound reordering of industrial research and development in the United States and abroad that has received but scant attention by historians.[13] There are so many dimensions to these changes and the territory is so largely uncharted that I can only highlight a few items that should be on the agenda of historians interested in the globalization of R&D.

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[9] Two studies by Erker [1990, 1995] for German and Dutch electrical companies are helpful.

[10] Unfortunately the history of these antitrust activities and their implications vis-a-vis R&D activities and competitive strategy of large, technology-intensive firms in the United States has not been written. For the effect of these activities on the strategies and R&D programs of two firms, Alcoa and DuPont, see respectively Graham and Pruitt [1990] and Hounshell and Smith [1988].

[11] On the breakup of I.G. Farben, see Stokes [1988]. Of course, many of I.G. Farben's managers were tried by the Allies at Nuremburg for war crimes. See, among other works, Borkin's book on I.G. Farben [1978].

[12] The case of Siemens and semiconductor research, as presented by Paul Erker [1992], is very illustrative of how the United States restricted the kind of research German firms could undertake.

[13] I have tried to suggest at least the dimensions of this reordering in Hounshell [1996].

Recruitment of Non-U.S. Native Research Personnel

The nation-wide expansion of R&D activities following the war, which was heightened and reshaped by the Cold War, led to a situation where U.S. companies were forced to recruit research personnel from abroad because the researchers simply did not exist in the United States. U.S. firms had always hired immigrant research personnel and had sometimes recruited specifically targeted research personnel from Europe,[14] but the situation was dramatically different in the 1950s. Some firms looked to the industrial research ranks in Germany for specific, well-known talent.[15] But many more simply recruited newly minted Ph.D.'s from European universities and brought them to their American-based laboratories to carry out research. As far as I know, no comprehensive data exist on this phenomenon, but the anecdotal evidence is highly suggestive. The English actually spoke of a "brain drain" to the United States during the 1950s and 1960s [Jones, 1967; Chorafas, 1968].

Establishment of U.S.-Owned R&D Facilities in Europe

In the post-World War II period, U.S. firms came to manage an impressive number of R&D facilities in Europe well before the recent frenzy of such activities induced by the European integration movement and aggressive Japanese penetration of U.S. markets. Most of these laboratories were established or acquired initially for the specific purpose of transferring technology from U.S. firms' operations to their European subsidiaries and affiliates. (This would also include product modification to fit local standards and tastes.) The creation of these laboratories, which began shortly after the war ended, suggests that they served one of the functions that cartels and cartel-like agreements had fulfilled in the pre-war era. As already noted, the cartels had been, among other things, vehicles for the international transfer of technology. The new laboratories of the emerging U.S.-based multinational firms would assume this role. A majority of these laboratories evolved into customer support laboratories and even beyond these functions into more full-line research enterprises. Some firms established "from scratch" broad-ranging laboratories in Europe designed to generate new research findings based on the work of European researchers who were tied into European university research networks. Some of the same firms also established what they called "world product" laboratories charged with the development of products for a

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[14] Evidence for this statement is provided in Thackray et al. [1985] and Hounshell and Smith [1988].

[15] Selective recruitment of German researchers stemmed from the information gathered immediately after the war by U.S. and British researchers about German research and technology developments. The extent of gains from this process are suggested in Gimbel [1990]. Private-firm recruitment of German scientists and engineers was paralleled by the U.S. federal government's strategic "recruitment" of scientists and engineers, as recounted in Lasby [1971]. See also Bower [1987] and Simpson [1988].

global market. Although a few of these various laboratories were established beginning in the immediate post-war period, they became more numerous in the late 1950s and especially in the 1960s and 1970s following the creation of the Common Market [Ronstadt, 1977].

Certainly not all technology-intensive U.S. firms established European R&D facilities during the 1950s and 1960s. For example, DuPont had not only been forced to abrogate its Patents and Processes Agreement with ICI in 1948 and had then been prosecuted for and found guilty of restraining trade in the United States, but it also encountered difficulty in accepting the new era of global competition. Crawford H. Greenewalt, the chief executive officer of DuPont from 1948 to 1962, said that he had to wait until two members of the company's Executive Committee retired before he could move the company into European markets through the establishment of overseas manufacturing capacity. Older executives, wedded to the idea of "rightful territories," simply would not accept the idea that DuPont would need to invest in Europe as a way of insuring its continued vitality and protecting its domestic investments. Greenewalt also said that he considered DuPont's belated but then aggressive move into Common Market countries his greatest contribution to the long-term health of the company [Greenewalt, 1983]. Nevertheless, DuPont did not build research capabilities in Europe until comparatively recent times.

Most of the firms that did establish R&D facilities in Europe sent U.S. research managers to direct these operations. These positions were often viewed like tours of duty, with finite limits and therefore not leading to stable, long-term research strategies. We need to learn a lot more about how these laboratories worked under "foreign" (i.e., American) managers, how these managers recruited and treated European researchers, how their research laboratories interacted with the U.S.-based research organizations, and what contributions these labs made to the objectives of the corporations that founded them.[16] An enormous amount of research needs to be done on this topic.

Establishment of Foreign-Owned Research Capabilities in the United States

Although we know comparatively little about how U.S. firms managed research abroad and how the different national research cultures interacted and no doubt conflicted, as far as I am aware there is no published historical work on the establishment of foreign-owned research organizations in the United States. Examining how the three chemical firms – Bayer, BASF, and Hoechst – that were broken out of I.G. Farben by the U.S. after World War II entered (or reentered) the U.S. market and how they have organized their R&D in the

[16] The work of Ronstadt [1977], although helpful, falls far short of the analysis that I hope can be developed. Chesnais's work [1988] lacks historical perspective as does the work of most current writers on R&D and multinational enterprise. See, e.g., Pearce and Singh [1991] and Casson, Pearce, and Singh [1992].

United States is instructive.[17] Space considerations prevent even the barest details. However, some generalizations are in order.

In most cases, these German firms, each of which has become larger than both DuPont (sans Conoco) and Dow, entered segments of the U.S. chemicals market through acquisitions of U.S.-owned companies or through joint ventures with U.S. firms. In some cases, the German company purchased American firms because it wanted to gain access to technologies that it did not have. In those cases, the acquired American firms, all of which had their own R&D organizations, exercised a surprising amount of autonomy vis-à-vis the management of R&D. These American organizations often retained their American R&D managers, but sometimes the German parent sent German research managers and German researchers to the United States In most of these cases, the German R&D organizations located in Germany did not dictate research policy, at least not until the parent firm had developed sufficient expertise in the technology. In other instances, German firms acquired U.S. firms simply to gain access to their marketing organizations or simply to acquire U.S. manufacturing capacity for products that the parent firm also researched, manufactured, and marketed in Europe. In these cases, the German firms exercised very heavy hands in the management of the R&D organization of their acquired American assets, and they often either severely restricted or even eliminated these American organizations altogether. With both scenarios, the distinct and different American and German research cultures often clashed, and the kinds of behaviors observed by Arthur D. Little in 1913 and Francis Honn in 1992 manifested themselves.[18] This was also sometimes true in the instances of joint German-American ventures.

Legal, Educational, and Cultural Differences: Some Final Questions

Little's and Honn's statements about the differences between German and American research organizations in the chemical industry pose some interesting questions when explored against the general pattern of research organizations' crossing borders. Consider the question of differences in legal systems between the U.S. and Germany or between Britain and Germany. German patent law mandates that inventors receive royalties on the intellectual property they generate while working for a company. We have already noted Honn's assessment that this legal structure produces definite conflicts of interest for managers making decisions about committing the company to certain products or processes. A.D. Little suggested in 1913 that German

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[17] This history has not been written, unfortunately. But see Arora, Landau, and Rosenberg [1996].

[18] These generalizations are based on a wide reading of the chemical industry trade literature in the post-World War II period. See also Leon Starr's descriptions [1989, 1992] of how the acquisition of Celanese by the German firm of Hoechst affected the management or R&D at Hoechst. Starr was at the time of the acquisition the director of Celanese's R&D. My generalizations have also been deeply informed by Francis Honn [1992].

researchers were highly secretive. Was this owing to pure self-interest on the researchers' parts? Did this self-interest stem from the German legal structure? In the United States and Britain, companies typically retain all rights to the intellectual property generated by their employees. Many companies offer bonuses for innovations, but almost none pays royalties. Some companies, such as DuPont, extend bonuses to whole teams of researchers who are responsible for successfully bringing a new product to market or a new process on line.[19] Do such systems create incentives for teamwork and openness within an organization rather than secrecy? What happens when companies move researchers and research organizations across borders? Are they and their staffs able to adapt readily to different legal structures? Do they change their behavior when they cross borders in response to different incentive systems?

Although the scientific community is often viewed as something that transcends national boundaries, differences in educational systems in nations clearly affect how science is pursued within both universities and industry. We partially understand how differences in educational systems help explain differences in what Richard Nelson and others have termed "national innovation systems" [Nelson, 1993]. But how do these educational differences matter when a firm globalizes its R&D, sending researchers and research managers from the home nation to a laboratory in another country? Are there differences in how a Ph.D. student in Germany relates to her or his professor (and the overwhelming majority of students and professors are male) as compared to a student studying in the same discipline in the United States, and if so, do these differences influence the behavior of fresh-out-of-school researchers in an industrial laboratory? What happens when industrial researchers coming from very different educational systems are put into the same research organization?

Finally, we know that nations produce citizens with very different cultural outlooks and social norms from those of other nations. Authority is viewed differently in different nations. Work ethics vary. Expectations of social mobility are not the same. How do these different cultural patterns play out in the globalization of research? For example, when a Japanese research manager presides over a research organization based in the United States, does that manager expect the same relationship with researchers as that manager has experienced with all-Japanese researchers in Japan? Do Americans look upon their Japanese research manager in the same way they would an American manager? What are the expectations when the research is carried out in Japan under the direction of American managers?[20]

If legal, educational, and cultural differences exist, how do these differences affect the overall performance of internationalized or globalized industrial R&D? Are these factors the primary determinants of how a firm

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[19] On the DuPont bonus system, see Hounshell and Smith [1988, pp. 305-306].

[20] Some of the tensions in such arrangements are suggested in Johnstone [1992] and Pollack [1993].

allocates its research resources across borders? Or are allocation decisions made based solely upon "pure economics"? How did legal, educational, and cultural differences shape firm behavior during the era of cartelization, especially in the interactions of respective research staffs who were responsible in large part for technology transfer between companies and across borders? These are important questions that few historians of business have asked vis-à-vis industrial R&D. They are central to any complete history of a research-based multinational company. They are in large part inspired by Mira Wilkins's challenge to think big, to think small, and above all to think internationally.