Corporate Technological Capabilities and the State:

A Dynamic Historical Interaction[1]

David M. Hart

Kennedy School of Government

Harvard University

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Introduction: Bringing the State in from the Margins of Business History

Business historians are ambivalent about the state. On the one hand, political forces are often simply too important to be ignored. Alfred D. Chandler, Jr., for instance, acknowledges that differences across nations lead to differences among businesses, a conclusion that helps to organize his volume *Scale and Scope*. On the other hand, any causal significance assigned to things political diminishes the creative agency accorded to managers, whose stories constitute the central threads of most business history narratives. *Scale and Scope* is primarily about the managerial exploitation of technological and market opportunities; it is not called *National Varieties of Capitalist Enterprise*.[2]

The tendency of business historians to downplay the influence of the state (and, indeed, a range of other social and cultural factors that shape business) has been widely noticed. Richard John's twenty-year retrospective on *The Visible Hand*, for example, points out that some of

Chandler's most vigorous champions as well as some of his most vehement critics have sought to incorporate politics into the master narrative. Chandler's champions argue that the state interferes with management and that this interference helps to accounts for differences among otherwise similar businesses. The critics assert a more constitutive role for the state (and, more generally, the polity), shaping markets and even managerial mindsets, and thereby shaping business organization.[3]

Mainstream business historians may be ambivalent about the state, but they are positively paradoxical in their treatment of technology. Technological opportunities are the prime movers of the Chandlerian narrative, placing fundamental constraints on corporate strategy and structure. The sources of these opportunities lie outside the narrative, despite their importance in explaining differences across industries. At the same time, managerial agency is the essential force that converts technological opportunities into business realities. By integrating backward into knowledge production and by investing in the capacity to manage new knowledge, successful firms demolish rivals, transform business processes, and open new markets. Technology is simultaneously a rigid constraint on businesses and a flexible tool for them.[4]

This paradox, too, has been widely noticed. A growing body of literature seeks to address it by softening the conceptual boundaries that constrict the mainstream account. This work locates the sources of technological innovation, whether radical or incremental, in inter-organizational "systems" or "networks" of innovation, which encompass but go beyond corporate R&D labs and production facilities. Several types of innovation systems-- regional, industrial, and global--can be delineated, but the *national* innovation system is particularly important for my purposes. State agencies are important participants in the national innovation system. More importantly, public policies profoundly shape the relationships not only between public and

private actors, but among private institutions as well. Technological innovations made by firms can be seen, in this framework, to owe as much to non-market exchanges and non-market incentives as to internal R&D and market-mediated transactions.[5]

If one adopts the innovation systems approach and if one continues to hold, with Chandler, that technological innovation is a key element in the evolution of business organization, then one must accept the following conclusion: the state is a critical area for business history research, because the state has a central place in the national system of innovation. A quick glance at several of the key growth industries of the late twentieth century lends empirical support to this conclusion. In pharmaceuticals, electronics, and aircraft, government organizations, government-funded university laboratories, government procurement, government regulations, and publicly provided infrastructure have been essential to technological change and the organizational development of firms. But the argument is not confined to recent times. During the late nineteenth and early twentieth centuries, the period that most occupies chandler's attention, and even before, national innovation systems profoundly shaped business history.

Louis Galambos and Jane Eliot Sewell's *Networks of Innovation: Vaccine Development at Merck, Sharp & Dohme, and Mulford, 1895-1995*, which won the Newcomen Prize in 1997, demonstrates that the innovation systems approach has begun to have some influence on business history. As the title suggests, Galambos and Sewell attend to the traffic in knowledge across organizational boundaries that dates back to the origins of Merck. Constrained by the "corporate biography" genre, however, the book remains essentially a Chandlerian story of managerial and scientific opportunity-seeking, enriched at the margins by reference to actors and forces outside the firm, including public hospitals and research organizations, regulations, patent laws, and the like.[6]

This paper goes beyond Galambos and Sewell's pioneering effort, in identifying ways to bring the state further in from the margins of business history. My claim is that the state shapes corporate technological capabilities fundamentally. The agency of managers is not eliminated in this approach, but they must share the spotlight with other actors. A deeper understanding of the linkages between firms and the rest of the innovation system will strengthen the explanatory power of business history. Equally important, business historians can add substantial value to the ongoing interdisciplinary dialogue about innovation systems. As Richard R. Nelson, a major figure in this dialogue puts it, firms comprise "the heart" of innovation systems. Most of us are general practitioners when it comes to diagnosing the system, and we could use a few more cardiologists.[7]

Corporate Technological Capabilities

Corporate capabilities distinguish firms as organized entities from mere bundles of resources. Entrepreneurs and managers assemble resources, including other people, facilities and equipment, money, and some forms of knowledge (such as licensed intellectual property); they attempt to add value to this assemblage by linking these resources together in specific ways. These linkages lead over time to the development of commitments, routines, practices, and firm-specific knowledge, which comprise the capabilities that allow the firm to execute its strategy.[8]

Technological capabilities are a subset of corporate capabilities. They allow the firm to discover, develop, assimilate, deploy, and extend new ways of doing things. Whereas Chandler conceives of the essential function of "organized human capabilities" as the "exploit[ation of] the potential of technological processes," the definition advanced here emphasizes the firm's creativity. This creativity is embedded in people, including R&D personnel and production

workers as well as the managers who devise strategies and allocate resources. It may be enhanced by certain routines and practices and perhaps even by the layout of equipment and facilities (including the architecture of information systems).[9]

Corporate technological capabilities have consequences of great importance to business historians. As Chandler (among many others) shows, creative firms grow rapidly, and they evolve in form and function. They produce goods and services that large segments of society value. They create jobs and contribute substantially to the overall growth of the economy. They may also produce negative externalities, including new forms of environmental degradation and displacement of older forms of economic life. Firms that have developed significant technological capabilities are, as Joseph A. Schumpeter famously put it, the main agents of "creative destruction."[10]

Although managers assemble the resources to build technological capabilities, they could not do so in the absence of an institutional infrastructure in which the state figures significantly. For example, technological capabilities depend heavily on public goods, such as ~~a~~an highly educated population. Firms are unlikely to invest in the education of people who can take their human capital out the door at the end of their contracts, but contracts with terms long enough to reap the benefits of such investments would look suspiciously like slavery. Government subsidies provide one way around this impasse. Similarly, firms are unlikely to create technological knowledge unless they have some protection against the threat of imitation by competitors. Without this protection, all firms have an incentive to free-ride on knowledge created by others. In the extreme, these incentives create a prisoner's dilemma in which no firm will create knowledge. Intellectual property rights, enforced by public institutions, provide one solution to this conundrum; public spending on R&D provides another.

These public policies -- and the institutions that comprise innovation systems more generally -- can be characterized as responses to market failures that derive from the properties of knowledge itself. Knowledge simply cannot be exchanged in the same way that material goods can.[11] This understanding of innovation systems poses a challenge to the Chandlerian paradigm, but it is only a beginning. Political popularity, military effectiveness, and a host of other motivations that go far beyond the desire to perfect the market influence the development of these systems. Corporate technological capabilities emerge not merely from market processes nor from deliberate attempts to solve market failures, but from a range of societal endeavors, including those of the state.

National Systems of Innovation: Big Structures, Huge Comparisons

The evidence linking national innovation systems to corporate technological capabilities is just beginning to be amassed. In this section, I simply want to establish a *prima facie* case that such a linkage exists, to set the stage for a more detailed discussion of the mechanisms through which it works. The *prima facie* case turns on (as Charles Tilly would have it) "huge comparisons" that illuminate these "big structures."[12] One set of comparisons is between premodern and modern societies. Lacking states, premodern societies were technologically stagnant and organizationally sluggish. The second set of comparisons ranges across modern states. Differences among states coincide with differences in patterns of technological innovation. These patterns also coincide with variations in forms of economic organization, several of which confusingly share the same label, "capitalist." These two huge comparisons suggest that modern states and business enterprises (including corporations from the mid-nineteenth century on) evolved together and together gave birth to industrial technology.

Martin van Creveld writes that "the rise of the state is inseparable from that of modern technology." Before there were modern states (which he defines as abstract, self-authorizing, and territorially exclusive organizations), the pace of technological innovation was relatively slow, even in empires that could concentrate vast resources on their intellectuals and craftspeople. China, for instance, which was far and away the world's most technologically advanced society during Europe's Middle Ages, did not generate an industrial revolution, despite the possession of nearly all the requisite physical components. In the absence of a state that provided incentives for private risk-taking and accumulation of wealth, Chinese technology stagnated when the imperial court turned conservative.[13]

Early European states did not have the luxury of such stagnation. Their constant conflicts stimulated them to seek new ways to fight wars and to pay for them. These efforts, in turn, helped to transform social and economic institutions. In western European (and North America) in particular, as Nathan Rosenberg and L.E. Birdzell argue, states secured legitimacy in part by withdrawing from major spheres of economic activity, although they continued to guarantee property and contracts and to provide other essential services. The complex bargains that produced this withdrawal, ironically, enabled the state to extract more resources from society than ever before, because they accelerated the pace of innovation and thus wealth creation. The new legal regime made possible "economic experiments," not merely with new technologies, but with new organizational forms for making and selling them as well.[14]

The corporate organizational form that emerged from these experiments proved especially well-suited to technological innovation. It spread risk more widely and allowed larger long-term investments than earlier forms of enterprise. These properties made possible the backward integration of corporations into scientific research in the late nineteenth and early

twentieth centuries. Science in the service of industry, from which it had previously been isolated, produced extraordinary entrepreneurial opportunities. The development of corporate technological capabilities also made it possible for firms to take advantage of science produced outside the firm, leading to the emergence of knowledge networks that spanned private, public, and academic boundaries.[15]

Where "economic experiments" were restricted, as they were in much of southern and eastern Europe through most of the modern era, innovations made elsewhere might be adopted and even imitated, but little more. The twentieth century socialist experiments of the Soviet Union and Mao-era China demonstrate the point even more vividly. These states made impressive strides in catching up to their western rivals, but only when they focused enormous resources on doing so, for instance, in strategic weaponry. Otherwise, the citizenry made do with shoddy copies of western goods, if that. Both states and corporations were necessary to produce the most technologically innovative societies of the twentieth century.[16]

Although the differences between capitalist and communist political economies in innovative capacities were most dramatic, capitalist nations differed (and continue to differ) from one another in this regard as well. Such distinctions among "varieties of capitalism" (as a growing literature in political science labels them) have been obscured for most of the twentieth century by the Cold War dichotomy, even as the varieties multiplied with the economic success of japan, korea and other newly industrialized countries. Early work in this vein focused on differences in capitalist states' macroeconomic and planning capabilities; a second generation of work concentrated on labor relations and financial systems. Henry Ergas pioneered the incorporation of innovation systems into the typology of capitalisms in the mid-1980s, and his example has now been widely followed.[17]

Ergas argued that some capitalist countries tend to "shift" from one technological trajectory to the next, while others "deepen" their capabilities within an existing trajectory. Japan, he claimed, does both. These differences in technological style across national systems of innovation cannot be fully accounted for by state-monopolized activities, such as military R&D spending; private decisions shaped by public policies are critical. Even multinational corporations seem to innovate differently in different countries. Parimal Patel and Keith Pavitt, for instance, have used a patent data base to show that "revealed technological advantage" varies systematically across countries in the OECD. If one looks at other sorts of indicators, especially those that track the interactions between corporations and other institutions, such as trade associations and universities, the cross-national differences are even more stark.[18]

The most recent work in this genre labors to give these indicators a microeconomic underpinning by showing that systematic differences among the varieties of capitalism produce systematic differences in the innovation strategies of the firms that are governed by them. Richard Whitley, for instance, offers six types of capitalism, characterized by thirteen features, which he maps onto five types of corporate innovation strategies. Peter Hall and David Soskice offer a more parsimonious typology of two capitalisms, five arenas of firm endeavor, and two corporate innovation strategies. Although this stream of work is still in its infancy, both conceptually and empirically, it suggests that there is a correlation between each variety of capitalism and the technological capabilities of firms that reside within it.[19]

Why differences among varieties of capitalism should emerge and endure are complex and challenging questions, and it is not my intention to answer them here. By most accounts, the institutional arrangements that differentiate them and their constituent national systems of innovation are path-dependent; in other words, barriers to alternative paths of development

(including convergence to a single, global variety of capitalism) have been erected by societal investments in existing structures.[20] Or, to put it crassly, these social scientists have concluded that history really matters. Business historians, plainly, have much to add to this discussion, particularly if they redirect their attention to research sites where the state's influence on corporate technological capabilities can be traced.[21]

From National Systems To Corporate Capabilities: Four Mechanisms of Influence

The literature on the varieties of capitalism seeks to find a one-to-one correspondence between each national innovation system and the dominant strategy of its domestic firms. The desire for law-like causal statements, which drives this effort, forces this school's exponents into overly-broad generalizations that transcend industries, technological systems, and historical eras. By attempting to explain too much with too little, they open themselves to a devastating empirical critique. They also wash out many of the details that motivate historical research, details which -- given the presumption of path-dependency -- are necessary to build a convincing causal story.

On the other hand, mainstream business historians, to the extent that they consider the state at all, err in the opposite direction. A contract here, a tax break there, and a lawsuit over there sometimes add up to a set of incentives that drives the scientific and technological investment of a firm in a new direction. In telling the story of a firm, a corporate biographer of course ought to attend to such instances. Yet, this approach tends to push too much into the background the long-term and pervasive policies and institutional processes that shape the firm's underlying technological capacities. The interactions between public and private are more intricate and subtle than can be captured by following the headlines.

An alternative to both of these approaches arises from new thinking about the nature of the state. Political scientists, who have debated the issues intensely over the past couple of decades, disagree about whether the state stands (to use a crude metaphor) within, outside, above, or beneath the rest of society. Historians need not choose among these factions. Rather, they may simply observe that each approach identifies a mechanism by which the state may influence the corporation and that the importance of each mechanism undoubtedly varies over time, among countries, and across economic sectors. This debate, then, supplies a checklist of potentially promising research questions that can be used to explore particular historical cases. The checklist that I work through below encompasses four ways of looking at the state -- as organization, fisc, system of rules, and normative order.[22] Each of these "states" may shape corporate technological capabilities, and sometimes all do so simultaneously. This approach navigates between the one-size-fits-all approach of the "varieties of capitalism" literature and the custom tailoring of the corporate biographers.

The State as Organization

One way to see the state is as an organization (or collection of organizations) that participates in markets just like firms. Though the state has a different revenue source and authority structure than the firm, these distinctive features are more or less irrelevant in interactions mediated by the market. Corporate technological capabilities are shaped by this state in much the same way that they are shaped by other firms: as customer, insurer, supplier, and competitor.

The state as customer is the most familiar and most important of these relationships. Public tasks have often proven to be the "killer app" that launched important technological

innovations as commerical products. Jet aircraft, nuclear power plants, and electronic computers, for instance, were supplied to military organizations before they found civilian uses. Thomas Watson, Sr., the founder of IBM, famously stated that the market for computers was limited to a few big government customers. The Atomic Energy Commission was a particularly important customer for early computers; the U.S. Air Force and Navy also bought them and much other high-technology hardware. Security provided by government customers allows firms to invest in people, equipment, and knowledge that become crucial assets in the long-run battle for civilian markets. Public customers, in turn, sometimes serve as "lead users" that provide knowledge essential for making incremental improvements in products and processes. World War II era relationships among procurement officers and aircraft manufacturers illustrate this sort of relationship, in which the customer's influence extended deep into the innovation and production processes and provided producers with feedback essential for making improvements in design and manufacturing.[23]

The influence of the state as customer may be so pervasive that it affects the organizational structure and strategic decisions of the firm. Some firms, for example, establish divisions specifically to serve government organizations, while others eschew this segment of the market for fear that relationships with these customers will undermine their ability to compete in other markets. These organizational decisions may have important consequences for corporate technological capabilities. Whether new technologies can be "spun off" from government to non-government uses, for instance, may depend on whether networks within the firm span internal boundaries created in response to government customers.[24]

Government organizations exert a somewhat weaker gravitational pull on corporate technological capabilities as insurers than they do as customers. The insurer may encourage

investments in such capabilities by sharing the risk taken by consumers of new products, or it may refuse to do so and have the opposite effect. U.S. government health insurance plans, for instance, have generally been unwilling to cover experimental medical treatments. Pharmaceutical and medical device companies that bring these treatments to market must find knowledge and legitimacy elsewhere. (The reader should bear in mind, though, that these treatments are often subsidized in other ways, such as through direct and indirect support of R&D.) On the other hand, government insurance has typically paid high prices for such treatments once they are proven, setting the pattern for private insurers as well.[25] The latter effect seems to have been the stronger one, helping U.S. firms to become among the world's most innovative (and profitable) in these industries. While health coverage is the biggest element of the American state's insurance portfolio, crop insurance, mortgage insurance, and disaster assistance might also be cited as potential influences on corporate technological capabilities.[26]

Government organizations, in the U.S. context at least, are more often customers or insurers of private firms than they are competitors. One exception to this generalization was the Tennessee Valley Authority (TVA) of the 1930s, which was intended to serve as a "yardstick" for private power producers and to spur technological innovation among electric appliance manufacturers and fertilizer makers. The TVA'S "business model" of high-volume, low-cost electricity and electricity-using devices changed the practices of its private competitors, a response which ultimately forced the TVA itself out of these markets. (A few decades later, the TVA served as a lead user of privately-produced nuclear power plants, an effort also intended to serve as an example to private utilities.)[27]

Government organizations may supply technological ideas as well as products and services to businesses through the market. Indeed, ideas produced by government organizations have increasingly been offered to the private sector on commercial terms over the final third of the twentieth century. Cooperative research and development agreements (CRADAs) between governments and firms have put pricetags on the know-how of PUBLIC organizations, like-the laboratories of the Department of Energy and the National Institutes of Health. CRADAs are intended to nudge the technological capabilities of their corporate participants in directions that meet public goals, such as environmental protection. They also aim to extend the time horizon of private R&D, encouraging firms to engage in long term projects that private capital markets will not support. Twenty-first century firms may produce more environmentally-friendly vehicles and devise the next generation of lithography technology more quickly as a result of CRADAs. The shift to CRADAs and other market mechanisms for mediating the transfer of knowledge across the public-private boundary is surely a subject that will attract future historians.[28]

States, then, influence the technological capabilities of firms within their jurisdictions, because they are comprised of organizations with the capacity to participate in markets. Organs of the state can buy and sell goods, services, and ideas, and they can provide insurance. In doing so, states may shift the incentives of the firms that they deal with in ways that lead those firms to employ different sorts of people, invest in different sorts of projects, and adopt different sorts of practices. Treating the state in this fashion is but a modest extension of existing practices in business history. Studies of industries, business groups, and supply chains have already moved down this path. The way that states as organizations influence firm technological capabilities is

similar to the way that of firms influence one another. Other mechanisms of state influence, however, are more distinctive.

The State as Fisc

Although the state may sometimes appear to be just another participant in the market, appearances are deceptive. The state has at least two crucial monopolies. One is its monopoly on legitimate force, which, among other things, allows it to impose taxes. The other is its monopoly on the means of exchange; unlike firms, the state can print money and spend it. The state's power to tax and spend has important consequences for the technological capabilities of firms within its jurisdiction. The fiscal state can create markets for innovations where none would have existed otherwise, subsidize or penalize specific firms, groups of firms, or organizations involved in science and technology, and regulate the availability of funds that might be used to make investments in technological capabilities.

Excessive taxation, of course, can crush all forms of business activity, including innovative activity. For my purposes, however, the scale of taxation is less interesting than the taxing authority's ability to privilege some business activities over others. The increasing thickness of the Federal tax code illustrates the United States Government's burgeoning capacity to deploy such incentives. Especially in periods in which resistance to direct spending has been high, tax breaks have spurred firms to augment the resources devoted to technological capabilities. The U.S. research and experimentation tax credit, for instance, subsidizes spending on research personnel. The pharmaceutical industry has taken advantage of this credit more fully than any other industry. This industry has also used other provisions of the tax code, like the possessions and “orphan drugs" tax credits, to reduce the cost of drug development and

manufacturing. Although the scale of these incentives has been too modest to noticeably shape the capacities of the largest pharmaceutical firms, start-up firms have grown up in the lee of their shelter. Genzyme, for instance, took advantage of orphan drug protection to bring key early product, Ceradase (for the treatment of Gaucher's disease) to market.[29]

Direct government subsidies (including "soft" loans and the like) are a more precise tool for fostering the development of specific technologies than tax breaks, and such policies are sometimes enacted even when the state is not the main customer for the end product. The Airbus consortium, which has benefited from generous government "launch aid," for instance, brought contemporary Europe into the large civilian aircraft industry in the 1980s. Airbus accelerated the pace of innovation in the industry by introducing, among other things, “fly-by-wire” technology. Withdrawal of U.S. government subsidies for Boeing's supersonic transport (SST) in 1970, by contrast, ended the SST development effort (probably to Boeing's benefit if one considers the experience of the Concorde). Advocates of such subsidy programs usually claim that they will be temporary and that the firms that they benefit will ultimately be subject to market discipline. Nonethless, firms receiving even temporary support evolve differently than they would in the absence of such subsidies. The development and production processes of Airbus, for instance, have historically been distributed according to the political weight of its national sponsors, and the firm is also seen as having a special responsibility to keep jobs and contracts in Europe.[30]

The state also subsidizes universities and other non-corporate scientific and technological organizations, with important consequences for the technological capabilities of firms. Public and tax-privileged charitable contributions have accelerated the growth of important new scientific and engineering disciplines, for instance. Molecular biology grew largely because of the support of the Rockefeller Foundation and the National Institutes of Health (NIH). Computer

science thrived at the hands of the Advanced Research Projects Agency (ARPA) of the Department of Defense (DOD) and the National Science Foundation (NSF). These new fields of knowledge, in turn, generated inventions with important industrial applications, which in some cases eroded the value of investments made by Chandlerian firms. The packaged software industry, for instance, put the existence of IBM, once the dominant player in the computer industry, in doubt in the early 1990s. Today, university-connected biotechnology start-ups threaten pharmaceutical giants, while e-commerce spinoffs put "bricks and mortar" retailers at risk. Chandlerian firms must adapt under such circumstances, for instance, by hiring outsiders (as Galambos and Sewell show that Merck did) or by acquiring newer firms.[31]

Finally, the state's role as macroeconomic stabilizer has important consequences for corporate technological capabilities. By manipulating the public budget, interest rates, and exchange rates, Keynesian policies stabilized the growth of aggregate demand, assuring firms that their investments would not go unrewarded. Investments in technological innovation (or, as the economist Seymour Harris put it, "optimum expenditure in science") were among those that Keynesians had in mind. These hopes have largely been realized, even though the business cycle has not been entirely eliminated. The mindset of those who fund R&D in firms, the technology community's business confidence, if you will, is in part a product of the fiscal state.[32]

The State as a System of Rules

The organizational state participates in high-technology markets, and the fiscal state funds R&D and related activities. A third mechanism by which the state may shape corporate technological capabilities is by establishing and enforcing the rules under which market participants engage one another. This arrangement, in which a player is also the umpire, may not

seem entirely fair, and sometimes it is not. Like excessive taxation, collusion between privileged enterprises and legal authorities may destroy private incentives for innovation. Yet, the lack of a system of rules may be even more stifling. In between the extremes, where the most technologically advanced states operate, the details of the rules and the nature of compliance with them are critical to the determination of corporate technological capabilities.

One fundamental set of rules distinguishes between domestic and international trade. By expanding the scope of the market, Adam Smith tells us, states extend the division of labor. The exceptionally large U.S. domestic market, within which interstate commerce was constitutionally protected from interference, for example, gave American manufacturing firms a technological leg up on their foreign counterparts in the nineteenth and early twentieth centuries. Before the dramatic expansion of the Federal government in the New Deal and World War II, this "customs union" was probably the most important way in which the American state shaped corporate technological capabilities The post-World War II closing of the gap by some European and Asian firms, in turn, owed much to the free trade policies of the *pax americana*, which leveled the playing field to a great extent. Under some conditions, trade restrictions may more effectively cultivate firms' technological capabilities than openness. Tariffs that limited foreign competitors' access to the U.S. market were an important complement to the customs union. A similar combination of domestic trade protection and aggressive exporting were essential ingredients in Japanese manufacturers' rise to global leadership more recently.[33]

Another fundamental set of rules establishes property rights, including intellectual property rights (IPR). As with trade restrictions, the state must strike a balance in this area if it is to foster the technological capabilities of its subject firms. Too loose an IPR regime will deter private investment in researchers and knowledge out of fear that competitors will free-ride; too

strict a regime will raise the ratio of lawyers to engineers to stifling levels. In their high-tech heydays, General Electric (1920s and '30s), IBM (1960s and '70s), and Microsoft (1990s and 2000s) all faced bitter complaints that their imitative capabilities, made possible by loose IPR regimes, suppressed otherwise competitive entrepreneurs who were unable to protect their innovations from these giants. On the other hand, aviation, automobiles, and radio were all plagued in their early years by patent deadlocks that hamstrung the innovation process in these industries. Survey research has shown that the pharmaceutical industry relies most heavily of all industries upon IPR. Nor surprisingly, changes in the U.S. IPR regime around 1980, such as the Bayh-Dole Act (which expanded the scope of universities' IPR) and the *Chakrabarty* decision (which authorized patents on genetically engineered life forms), contributed significantly to a restructuring of the innovation process in this industry, including the strengthening of academic-industry relationships, the emergence of new firms, and the reorganization of old ones.[34]

Financial regulations comprise a third item on this list of essential rules. By regulating the mechanisms with which firms raise capital, the state structures their capacity for taking risks, including technological risks. The U.S. venture capital sector boomed, for example, only when banking and securities regulations were altered in 1979 to permit a very high-risk component in pension fund portfolios. The venture capital industry has facilitated the creation of many new technology-based firms, not just in new sectors of the economy but in older industries as well. Indeed, entire regional economies, particularly those of Silicon Valley and the greater Boston area, have been energized by venture investments.[35]

A state is not really a state without trade, property, and financial rules. But the regulatory state typically extends far beyond these minima. Codes of conduct or, in the American lexicon, fair trade practices, for example, may place limits on cooperation among competitors and on

mergers and acquisitions and other means of corporate reorganization. These limits may significantly affect firms' technological capabilities. The merger wave at the turn of the twentieth century in the U.S., for example, was provoked in part by an antitrust policy that outlawed market sharing agreements. This movement set the stage for the establishment of central corporate research laboratories by dominant high-technology firms in the ensuing decades. The tightening of antitrust enforcement in the 1930s and 1940s and the imposition of compulsory patent licensing as a remedy for violations of antitrust law helped strengthen the technological capabilities of smaller and weaker firms in the post-World War II era.[36]

Many other forms of regulation have also influenced firms' technological capabilities. Price regulation in the U.S. aviation industry between the 1930s and the 1970s created incentives for rapid technological change, particularly in luxury features, since these became the primary basis for airline competition. In the telephone industry over roughly the same period, a regulatory regime of price controls combined with monopoly to limit the pace of change in switching and transmission technology, even as it fostered basic research at Bell Labs. The rules governing labor relations affected the pace and direction of technological innovation, too, as when firms sought to substitute capital for labor to ward off unions that threatened their control and cost structure. More recently, environmental, safety, and health regulations have changed the innovation investment calculus. In some cases, these regulations have forced the development and diffusion of new technologies; in others, they have frozen the "best available control technology" (as many U.S. environmental laws put it) in place.[37]

The regulatory state infiltrates the mindset of actual and would-be innovators more profoundly than does the fiscal state. In a well-functioning regulatory state, the threat of enforcement, rather than enforcement itself, deters smuggling, infringement of property rights,

and non-compliance with other regulations. Indeed, compliance may come to seem natural, even in areas in which the initial intervention by the regulatory state provoked shock. The threat of enforcement may be reinforced as well by the moral sentiment of citizens both inside and outside of business. The process of deploying new technologies on the shopfloor, for instance, involves consultation with and adaptation to the workforce in some settings for legal, business, *and* normative reasons, while in other settings all three of these motivations may be absent. The regulatory state thus helps to erect and maintain a set of norms that influence the process of technological change.[38]

The State as Normative Order

The norms that attach to the regulatory state illustrate the fourth mechanism by which the state influences corporate technological capabilities. The shared beliefs and experiences of citzens who serve corporations as scientists, engineers, managers, and workers shape the way that they carry out that service. Nationalism, liberalism, socialism, and plenty of other –isms, not to mention a bundle of less well-articulated elements of political culture, motivate and channel their energy and attention.

The most powerful of these norms has been nationalism. Even the academic scientific community, which maintains a powerful counter-norm of internationalism, has been riven regularly by nationalist sentiment. The fervor with which professors served their nations' militaries in World War I, for instance, stunned the community's idealists. Close collaboration between the national security apparatus and high-technology companies has been even more common than military-academic collaboration. To be sure, money changes hands in these relationships, hopefully from state to business and not the other way around. But they are sealed

by shared beliefs. IBM engineers who worked with the U.S. National Security Agency undoubtedly wanted to safeguard national secrets and break Soviet codes as well as get paid and stay at the cutting edge of technology.

Patriotic sentiments need not be harnessed to national security to have an effect on industrial innovation. The project of nation-building through the development of energy, transportation, and communication systems, for instance, may mobilize the efforts of the corporate technical community. Companies like Bombardier and Nortel, which are centers of excellence in the Canadian national system of innovation, have their roots in such a project. One would expect to find this pattern in developing countries when technological innovation in the private sector is perceived to be a necessary element of any growth strategy. Technical elites in these countries, whether in the public or private sector, are quite likely to be ardent nation-builders.[39]

The conception of the state as normative order also embraces economic and political values other than nationalism. Individualism, for example, permeates the U.S. system of innovation, in which entrepreneurial spinoffs from large companies are a critical component. Fairchild, itself a spinoff from Bell Labs, was the spawning ground for some of Silicon Valley's most innovative new firms in the 1950s and 1960s. American culture's acceptance of risk-taking and failure enables entrepreneurs in the U.S. to start up new firms more easily than those in other countries. Such risk-taking occasionally finds expression even in larger firms. In societies in which risks are more fully socialized, bet-the-company efforts like the IBM 650 or the Boeing 747 would be even more difficult to carry off than they were in the U.S.[40]

Economic individualism is not incompatible with the civic republicanism that has been prominent at times in U.S. history. The provision of new goods and services to all the people

can be conceived of as a fulfillment of one's duty in this schema, and industrial innovation, therefore, a means of national service. Richard John, for example, finds traces of this ideological commitment in Theodore Vail's universal service strategy for AT&T. In the twentieth century, rights-based liberalism has overshadowed civic republicanism, and it too has had an influence on industrial innovation. The gay rights movement's deep involvement with AIDS drug development is one powerful example.[41]

The state as a normative order is not monolithic. States usually encompass regional or ethnic variations as well as dissenting individuals. The degree and extent of cultural variety may have implications for corporate technological capabilities. Minority groups, for instance, like Jews and overseas Chinese, have been disproportionately represented in the annals of industrial science and technology. Immigrants may bring new ideas and perspectives with them; contemporary Silicon Valley thrives as much on these newcomers as on good old American know-how, although it should be noted that many of these immigrants have been trained in the U.S..[42]

The End of Business History?

The state shapes the technological capabilities of firms through a variety of mechanisms. It is a participant in markets, a channeler of financial flows, a maker of rules, and a creator of beliefs and attitudes. Cumulatively, these influences are so profound that the combined technological capabilities of all the firms in each nation differ substantially from one another. National innovation systems are marked by variations in institutional pattern, innovative output, and technological style. Firms account for much of this variation in large part because they are shaped by states.

One might conclude, if one accepts these claims, that institutional history, narrowly construed, should be scrapped once and for all. Their boundaries blurred, corporations and government agencies no longer provide satisfactory units of analysis to explain larger social outcomes. We must think more comprehensively, it might be argued, about industrial networks, for instance, or policy communities. I think this extreme conclusion is unwarranted. The existence of an organizational hierarchy (or an array of such hierarchies) has important and often decisive consequences for the mobilization of capital, skills, and attention. It shapes communication patterns and structures conflict and cooperation. Historians of business, government, and technology ignore formal organization at their own peril. Excellent studies of corporate R&D laboratories and highly innovative companies should continue to be welcomed. However, they will be less welcome if their authors strap on the organizational blinders too tightly. Corporate biographies should be of the "life and times" variety, setting their subjects in a social, political, and cultural context. Galambos and Sewell point the way.

The recognition that the state is an intimate partner of the corporation is not the end of business history, but rather a new beginning. This way of thinking expands the range of potentially fruitful loci for research, providing, as I suggested earlier, a checklist of opportunities. We might want to take a closer look, for instance, at corporate functions (and the people who perform them) that span organizational boundaries, particularly between government and industry. Legal, financial, public relations, and government relations offices whose work bears on science and technology come to mind. Consultants might also be interesting subjects.

Moving further away from the organizational approach, business historians might indeed take networks and communities as subjects more often. Studies could be built around perceived problems and the people in a variety of organizations who aim to solve them. They might center

on regions or on educational cohorts. Such research would illuminate organizational questions by indicating the constraints and opportunities that organizational boundaries create, but it would move beyond these questions by incorporating social, political, and cultural influences on corporate science and technology.[43]

There may also be industries, times, and places in which state-corporate interactions that usually lie in the background come to the fore. Moments of contention and transition bring to the surface norms, rules, patterns of allocation, and inter-organizational relationships that are otherwise taken for granted. Historians working in this mode are likely to focus on the emergence of new industries and periods of depression, social conflict, and war. Similarly, studies of technologically lagging countries, including relationships between these countries and the leading countries, seem more promising than those of the leaders themselves in this regard.

We may come to see the Chandlerian firm as a special case of the innovation process that was the product of particular historical conditions. It is ironic that a schema that aimed to make sense of a late nineteenth and early twentieth century phenomenon continues to hold sway in business history at the beginning of the twenty-first century. The era of big government stands between us and Chandler's era, and it may not be over yet, despite the rhetoric issuing from Washington in recent years. I suspect that when historians of economic, scientific, and technological institutions look back fifty years from now, they will be students of some kind of inter-organizational synthesis, which retains the best of contemporary business history but enriches, enlivens, and complicates it.[44]

Notes

[1] Helpful comments were provided by Colleen Dunlavy, Peter Dobkin Hall, Carl Kaysen, and the editors of this volume.

[2] Alfred D. Chandler; Jr., *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge: Belknap Press, 1990).

[3] Richard R. John, "Elaborations, Revisions, Dissents: Alfred D. Chandler, Jr.'s *The Visible Hand* After Twenty Years," *Business History Review* 71:151-200 (1997); Peter Dobkin Hall, "The Managerial Revolution, the Institutional Infrastructure, and the Problem of Human Capital," *Voluntas* 7(1):3-16 (1996). This volume takes a similar approach.

[4]Michael J. Piore and Charles F. Sabel, *The Second Industrial Divide: Possibilities for Prosperity* (New York: Basic, 1984), 25-26.

[5] For an introduction, see Bengt-Ake Lundvall, "Introduction," in Lundvall, ed., *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning* (London: Pinter, 1992), 1-19.

[6] Louis Galambos with Jane Eliot Sewell, *Networks of Innovation: Vaccine Development at Merck, Sharp & Dohme, and Mulford, 1895-1995* (New York: Cambridge University Press, 1995).

[7] Richard R. Nelson, "Preface to Part V, in Giovanni Dosi, *et al.*, *Technical Change and Economic Theory* (London: Pinter, 1988), 309.

[8] This "resource-based" view of the firm is typically contrasted with the "nexus of contracts" perspective. See Nicolai J. Foss, ed., *Resources, Firms, and Strategies* (New York: Oxford University Press, 1997); and Naomi R. Lamoreaux, Daniel M.G. Raff, and Peter Temin, eds., *Learning By Doing in Markets, Firms, and Countries* (Chicago: University of Chicago Press, 1999). There are, of course, forms of business enterprise other than corporations, and my

arguments may not apply to all of them. The vast bulk of technological innovation in the contemporary private sector, however, occurs within corporations.

[9] This section draws on the articles included in Foss, 1997, and on Mary O'Sullivan, "The Innovative Enterprise and Corporate Governance," *Cambridge Journal of Economics* 24:393-416 (2000). Quote from Chandler, 1990, 24.

[10] Joseph A. Schumpeter, *Capitalism, Socialism, and Democracy*, Harper Colophon ed. (New York: Harper and Row, 1950), 81

[11]Richard R. Nelson, "The Simple Economics of Basic Scientific Research," *Journal of Political Economy* 67:297-306 (1959); Kenneth J. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity* (Princeton: Princeton University Press, 1962); Paul M. Romer, "Endogenous Technical Change," *Journal of Political Economy* 98:S71-S102 (1990).

[12] Charles Tilly, *Big Structures, Large Processes, Huge Comparisons* (New York: Russell Sage, 1984).

[13] Martin van Creveld, *The Rise and Decline of the State* (New York: Cambridge University Press, 1999), quote from 377; Joel Mokyr, *The Lever of Riches* (New York: Oxford University Press, 1990), 209-238.

[14] Van Creveld, 1999; Nathan Rosenberg and L.E. Birdzell, *How the West Grew Rich* (New York: Basic, 1986), 117-123; Nathan Rosenberg, "Economic Experiments," in *Exploring the Black Box* (New York: Cambridge University Press, 1994), 87-108. See also Charles Tilly, *Capital, Coercion, and European States*, rev. ed. (Cambridge: Blackwell, 1992).

[15] Rosenberg and Birdzell, 186-268.

[16] Rosenberg, 1994; Manuel Castells, *End of Millennium*, 2nd ed. (Oxford: Blackwell, 2000), 4-46.

[17] Andrew Shonfield, *Modern Capitalism* (New York: Oxford University Press, 1965); William Lazonick, *Business Organization and the Myth of the Market* (New York: Cambridge University Press, 1991); John Zysman, *Governments, Markets, and Growth* (Ithaca: Cornell University Press, 1983); Peter J. Katzenstein, *Small States in World Markets: Industrial Policy in Europe* (Ithaca: Cornell University Press, 1985); Henry Ergas, "Does Technology Policy Matter?," in Bruce R. Guile and Harvey Brooks, eds., *Technology and Global Industry* (Washington: National Academy Press, 1987), 191-245.

[18] Ergas, 1987; Parimal Patel and Keith Pavitt, "National Innovation Systems: Why They Are Important, and How They Might Be Measured and Compared," *Economic Innovation and New Technology* 3:77-95 (1994); Richard R. Nelson and Nathan Rosenberg, eds., *National Innovation Systems* (New York: Oxford University Press, 1993).

[19] Richard Whitley, "The Institutional Structuring of Innovation Strategies: Business Systems, Firm Types, and Patterns of Technical Change in Different Market Economies," *Organization Studies* 21(5):855-886 (2000); Peter A. Hall and David Soskice, "An Introduction to Varieties of Capitalism" in Soskice and Hall, eds., *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage* (Oxford: Oxford University Press, forthcoming).

[20] Paul Pierson, "Increasing Returns, Path Dependence and the Study of Politics," *American Political Science Review* 94:251-268 (2000).

[21] One demonstration of the promise of this approach is Johann Peter Murmann, "Knowledge and Competitive Advantage in the Synthetic Dye Industry, 1850-1914: The Coevolution of Firms, Technology, and National Institutions in Great Britain, Germany, and the U.S.," *Enterprise and*

Society 1(4):699-704 (2000), which won a dissertation prize from the Business History Conference.

[22] This typology draws on Stephen D. Krasner, "Approaches to the State: Alternative Conceptions and Historical Dynamics," *Comparative Politics* 16:223-246 (1984).

[23] Kenneth Flamm, *Targeting the Computer: Government Support and International Competition* (Washington: Brookings, 1987); Allen Kaufman, "In the Procurement Officer We Trust: Constitutional Norms, Air Force Procurement, and Industrial Organization, 1938-1947," manuscript, 1997; Jonathan Zeitlin, "Flexibility and Mass Production at War: Aircraft Manufacture in Britain, the U.S., and Germany, 1939-1945," *Technology and Culture* 36:46-79 (1995). In many cases, of course, the public customer also subsidized, protected, or otherwise helped its supplier firms. These activities fall elsewhere in my typology; their coincidence in some, but not all, cases emphasizes the point that these approaches to the state are complementary, not exclusive.

[24] John A. Alic, *et. al*, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press, 1992); Ergas, 1987.

[25] Richard A. Rettig, "Medical Innovation Duels Cost Containment," *Health Affairs*, Summer, 1994, 7-27.

[26] Rebecca Henderson, Luigi Orsenigo, and Gary P. Pisano, "The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions Among Scientific, Institutional, and Organizational Change," in David C. Mowery and Richard R. Nelson, eds., *Sources of Industrial Leadership* (New York: Cambridge University Press, 1999), 267-311; David A. Moss, *When All Else Fails: The Government as the Ultimate Risk Manager* (Cambridge: Harvard University Press, forthcoming).

[27] David M. Hart, *Forged Consensus: Science, Technology, and Economic Policy in the United States, 1921-1953* (Princeton: Princeton University Press, 1998), 68-71; Gregory B. Field, "'Electricity for All': The Electric Home and Farm Authority and the Politics of Mass Consumption," *Business History Review* 64:32-60 (1990); Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996).

[28] Christopher T. Hill and J. David Roessner, "New Directions in Federal Laboratory Partnerships with Industry," *Science and Public Policy* 25:297-304 (1998); David H. Guston, *Between Politics and Science: Assuring the Integrity and Productivity of Research* (New York: Cambridge University Press, 2000), 113-137.

[29] United States Congress, Office of Technology Assessment, *Pharmaceutical R&D: Risks, Costs, and Rewards* (Washington: GPO, 1993).

[30] Laura D'Andrea Tyson, *Who's Bashing Whom: Trade Conflict in High-Technology Industries* (Washington: International Institute of Economics, 1992); Mel Horwitch, *Clipped Wings: The American SST Conflict* (Cambridge: MIT Press, 1982); Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel* (Washington: Brookings, 1991).

[31] Henderson, Orsenigo, and Pisano, 1999; Flamm, 1987; Galambos and Sewell, 1995.

[32] Hart, 1998, 145-174, quote from 157.

[33] Richard R. Nelson and Gavin Wright, "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective," *Journal of Economic Literature* 30:1931-1964 (1992); David Hounshell, *From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States* (Baltimore: Johns

Hopkins University Press, 1984); Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Palo Alto: Stanford University Press, 1982).

[34]Richard C. Levin, *et al.*, "Appropriating the Returns from Industrial R&D," *Brookings Papers on Economic Activity* 1987, no. 3, 783-820; Henderson, *et al.*, 1999.

[35]Samuel Kortum and Josh Lerner "Assessing the Contribution of Venture Capital to Innovation", *Rand Journal of Economics* 31:674-692 (2000); Martin Kenney, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region* (Stanford: Stanford University Press, 2000).

[36] David C. Mowery, " The U.S. National Innovation System: Origins and Prospects for Change," *Research Policy*, 21:125-144 (1992); Hart, 1998, 84-96.

[37] Richard H.K. Vietor, *Contrived Competition: Regulation and Deregulation in America* (Cambridge: Belknap, 1994); Kenneth Flamm, "Technological Advances and Costs: Computers vs. Communications," in Flamm and Robert W. Crandall, eds., *Changing the Rules* (Washington: Brookings, 1989), 13-61

[38] Jeffrey Keefe, "Do Unions Hinder Technological Change?," in Lawrence Mishel and Paul B. Voos, eds., *Unions and Economic Competitiveness* (Armonk, NY: M.E. Sharpe, 1992), 109-141; Kathleen Thelen, *Union of Parts* (Ithaca: Cornell University Press, 1991).

[39] Mark Elam, "National Imagination and Systems of Innovation," in Charles Edquist, ed., *Systems of Innovation* (London: Pinter, 1997), 157-173; Jorge Niosi, "Canada's National System of Innovation," *Science and Public Policy* 18:83-92 (1991).

[40] Gordon Moore (with Kevin Davis), "Learning the Silicon Valley Way," paper presented at Stanford University, July 28, 2000.

[41] Richard R. John, "Vail and Universal Service," paper presented at the Business History Conference, Chapel Hill, NC, March 7, 1999; Steven Epstein, *Impure Science: AIDS, Activism, and the Politics of Knowledge* (Berkeley: University of California Press, 1996).

[42]Annalee Saxenian, "Silicon Valley's Immigrant Entrepreneurs," Public Policy Institute of California, June, 1999.

[43] Some recent examples include Ann Markusen, *et al.*, *The Rise of the Gunbelt: The Military Remapping of Industrial America* (New York: Oxford University Press, 1991); Robert Kargon, Stuart W. Leslie, and Erica Schoenberger, "Far Beyond Big Science: Science Regions and the Organization of Research and Development," in Bruce Hevly and Peter Galison, eds., *Big Science* (Palo Alto: Stanford University Press, 1992), 334-354; Saxenian, 1999; Philip Scranton, "Manufacturing Diversity: Production Systems, Markets, and American Consumer Society, 1870-1930," *Technology and Culture* 35:476-505 (1994).

[44] Much of what I say here echoes Louis Galambos, "Technology, Political Economy, and Professionalization: Central Themes of the Organizational Synthesis," *Business History Review* 57:471-493 (1983).