Technological Determinism and the Firm

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Business history and the history of technology, although devoted to the study of closely-related phenomena, have diverged in recent years. Differences in the methodologies and received wisdom of the two fields can be seen clearly in how leading theorists have approached the question of technological determinism. After reviewing divergent trends in the analysis of this question, I shall discuss research that holds out the possibility of cross-disciplinary synthesis, and offer three propositions about the deterministic nature of technology within the context of the firm.

Technology History: The Triumph of Contextualism

American academics who study the history of technology are nearing methodological consensus. As John M. Staudenmaier shows in *Technology's Storytellers*, the field originated as a sub-specialty of the history of science dominated by engineers and other design-oriented specialists, or "internalists," who were interested mainly in machine design technics and in celebrating the transforming "impact" of successful technologies on Western societies. Broadly-conceived, humanistic studies by the likes of Lewis Mumford were rare. But the formation of SHOT (The Society for the History of Technology) in 1957 marked the institutional embodiment of a methodology that came to be known as "contextualism" or "constructivism." (Although usage by some authors suggests subtle differences between these two terms, I shall use them interchangeably.) Proponents of this approach see technology as inextricably embedded in society, a view embodied in the title of SHOT's journal, *Technology and Culture*. Internalists remained, but contextualists soon dominated the pages of the journal [40, pp. 1-34].

Technology history monographs published in the 1980s reflected the same trend. Among the most prominent was Thomas P. Hughes' *Networks of Power*, which chronicled the evolution of three big-city electrical systems in different Western nations, showing how each system evolved idiosyncratically to embody indigenous social political, economic, and geographical conditions [24]. Other key works published within a year of *Networks* similarly demonstrated how in other contexts social relations molded technological hardware, often taking precedence over efficiency. In *More Work for Mother*,

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Ruth Schwartz Cowan described how, for example, Americans' abiding reverence for individualism and privacy favored household laundry facilities over more efficient communal arrangements [12]. And in *Forces of Production*, David Noble argued that advocates of numerically-controlled machine tools sought worker control more than increased efficiency [33]. It is now customary for technology history to focus on the dialectic between technology and society, tracing sinuous connections in the "seamless" techno-social web and elucidating how values, social structure, bureaucracy, gender, economics, and other factors interact with design to shape the ways technology is created, diffused, employed, and modified. Scores of research universities now feature Science-Technology-Society programs (or some variation) that abide by the contextualist methodology, and monographs in technology studies, especially essay collections, regularly feature in their titles the words "social," "society," "culture," "context," or "construction" [4,11,17,33,34,35,42]. This historiographic movement did not take hold without resistance; sociologists prominent in the movement have drawn criticism for the highly theoretical nature of their work [3]. But few historians have challenged the fundamental constructivist premise.

Business History: The Challenge of Convergence

While social constructivism was emerging in technology history, business history followed a different path, viewing technology as a fundamentally defining or determining variable in the story of Western industrial progress. At the risk of oversimplifying diverse and complex approaches, one can identify two distinct traditions in the rise of academic business history in the last generation. The first is associated with pioneer business historian Thomas C. Cochran, who examined the emergence of an "American business system" in which firms and industries shaped and were shaped by values and social norms, education, religion, and politics. Cochran, Stuart Bruchey, and others working in this tradition hardly would discount the importance of, say, scale economies in making possible the emergence of core industries. But they have emphasized other factors, viewing technology as one key variable among many [2,8,10;37, pp. 254-57]. In 1974, for instance, Cochran challenged the "general or classic approach [that] assigns a primary or basic function to technology" rather than to the "business-political-social system" [9, p. 1449].

The other leading analytical tradition in business history, of course, was founded on the writings of Alfred D. Chandler, Jr., whose corpus of work explicates "the rise of managerial capitalism" [5,6,7]. Regular readers of this journal will require no summary of Chandler's work, nor likely dispute the assertion that the Chandlerian approach has dominated the academic study of business history in the last generation. This is not to say that Chandler is without his critics or that he has provided the only useful interpretative framework in the field, only that his writings have defined its direction more than others.

The key question at hand regarding Chandler's work, which I consider below, is whether it implicitly reflects or explicitly embraces technological

determinism. Here I wish to emphasize the more general point that Chandlerian business history seeks to reveal common patterns in the evolution of firms, industries, and industrial economies. Its impulse is toward convergence rather than divergence, toward structural identity or similarity rather than uniqueness. Chandler's work draws much of its explanatory strength from its success at identifying patterns across industries and nations. This purpose runs converse to--and Chandler's findings pose a distinct empirical challenge to--the prevailing methodology in technology history. If technology is socially constructed, readers of Chandler must ask, how does one explain the strikingly persistence of "core" industries over time, or their parallel clustering in disparate national settings?

The Question of Determinism

Like its close cousins--ethical, logical, theological, physical, psychological, and historical determinism--technological determinism is antithetical to human freedom. Just as the doctrine of theological determinism asserts the ineluctable, inevitable character of God, technological determinism holds that technology possesses a logic--the logic of efficiency--that acts independently of and determinatively upon human affairs. In each variety of determinism, human actions are determined unilaterally, not interactively [41, pp. 359-73].

Several philosophers, however, have posited varieties of partial or "soft" determinism, wherein only some human actions are determined. In religious fatalism, for example, God is said to providentially determine certain outcomes, leaving others to choice. Similarly, many historians reject the notion of complete historical determinism yet speak of a "necessary overall direction" in history that results from one or more underlying "laws" of development (such as the Hegelian-Marxist dialectic). Thus, "soft" historical determinism allows a degree of serendipity and contingency, which historians find difficult to ignore, while preserving some measure of human freedom, which most of us find reassuring. Still other philosophers, most notably William James, have rejected the validity of this distinction by arguing that determinism is an "all or nothing" proposition [15, pp. 373-8; 41, p. 368]. This debate is important to keep in mind as we turn to recent conceptualizations of technological determinism, where one can discern the same tension between determinism and human freedom, as well as a similar impulse toward the middle ground.

Technological Determinism and Contextualism

James's dissent aside, most of the key writings on technological hegemony in the last two generations have articulated some variety of "soft" determinism. The complex, influential works of Lewis Mumford (late in his career), Jacques Ellul, Langdon Winner, and others defy easy summation, yet share common themes: that technology is "autonomous," meaning it operates according to an internal logic and is neutral in relation to human values; and that its influence on society is becoming overwhelming, largely because

society has internalized and sanctified technology's attributes. But while technology may have become the single most determinative force in human affairs, the transformation is both "destructive and correctable," for "soft" determinists discern a measure of human freedom. For them, technology is ominous but not omnipotent [16;22, pp. 443-53;30;44].

Many contextualists are sympathetic to this position, especially to the extent they share its anti-modernism. In fact, social constructivism is antithetical to technological determinism. If technology is an inseparable dimension of society, one variable (however hegemonic) among many, it cannot determine all other aspects of human endeavor. Even so, the determinism question, hardly moot among contructivists, continues to reemerge in the literature [17, pp. 6-16; 27]. This is because it lies at the heart of present-day technology and society studies; claims against technological determinism are coterminous with justifications for the contextualist approach. Indeed, contextualism derived its original *raison d'etre* from the desire among certain scholars to debunk the well-established tradition that not only affirmed the existence of technological determinism, but also saw its presence in positive terms. Like other fields of history, technology history had succumbed to a Whig view that associated technical change with human "progress." And, as in other fields, that view eroded in the wake of twentieth century socio-technical disasters such as the holocaust, the atomic bomb, and the environmental crisis [22, pp. 443-72].

Technological Determinism and Business Convergence

To ascertain whether Chandlerian business history advances the determinist's cause, one must look beyond the fact that Chandler finds trans-industry and trans-national patterns. After all, contextualists have found patterns of technological convergence as well (and have offered reasonable alternative explanations for them, such as parallel causation by capitalism, rationalism, or paternalism). Rather, one must search in Chandler's work for an explicit causal link between the character of technology and its pattern of implementation, one that overrides other factors such as organization, social structure, and political economy.

In his introduction to *Scale and Scope*--Chandler's most theoretically evolved book and the most useful for our purposes because of its comparative nature--Chandler states that the success of the modern industrial corporation depended on "innumerable decisions made by individual entrepreneurs, owners, and managers." These choices "were limited and the outcomes uncertain, but almost always there were choices." These choices, he states, must be considered in relation to the ever-changing cultural differences indigenous to each industrial nation, including educational systems, legal systems, and markets. In short, one must consider "context" [5, p. 9]. Hardly the words of a determinist, this seems to be a classic statement of the contextualist position. Case closed?

Not exactly. Chandler has much more to say about technology and causality in his carefully-constructed framework. His central argument, stated briefly, is that the giant, leading firms that prospered and survived in the

"core," capital-intensive, oligopolistic, manufacturing industries of the U.S., U.K., and Germany were those that became more efficient because their managers made critical "three-pronged" investments in "production" (minimum efficient scale plants), "distribution" (forward integration into marketing), and "management" (managerial hierarchies for internal coordination). Technology and markets played critical roles in this process. To explain why "large hierarchical firms appeared in some industries and not others," Chandler points to "the differential between the potential scale-and-scope economies of different production technologies" [5, pp. 3-8].

The key to isolating the role of technology in this framework, it seems to me, is to identify necessary and sufficient components of success, and necessary sequence. Chandler argues that "actual economies of scale and scope ... are organizational." But the behavior of managers in organizations, he also suggests, is a necessary condition for success which must follow sequentially and dependently on the heels of another condition for success: the right "potential" technology. Fruitful investment and organization building occur in growing markets within a subscribed range of technological contexts. Chandler states that without the "potential" to exploit scale-and-scope economies, "manufacturers had much less incentive" to invest, although his empirical findings strongly suggest that such a manager would be not only undermotivated but foolhardy [5, pp. 24, 41, 45].

Chandler is concerned more with the diffusion and adoption of technologies than with their creation. For the contextual historian of technology, many questions remain about how these revolutionary "high throughput" methods and machines emerge for ready exploitation by big business. Questions about the relationships among invention, innovation, and demand--questions which have so intrigued historians of technology--are tangential to Chandler's story. Once these technologies of production enter the domain of the firm, however, we can observe in Chandler's account their ongoing incremental improvement for the sake of efficiency.

Surely, then, Chandler is not a strict or "hard" technological determinist who argues that only technology matters or that choice is not possible. But within his realm of investigation--the dominion of the modern industrial enterprise--technology limits options. The playing field of contextual factors is not level. Organization is as essential for success as appropriate technology, but as a second condition. Big business managers certainly can choose to invest in production, distribution, and management in the wrong industries (that is, those without potential scale-and-scope economies), but ultimately they will fail. This underlying "soft" technological determinism is echoed in many works of business history.

Theories of Large-Scale System Evolution: Toward Synthesis?

The recent work of several scholars holds out some promise of reconciling this historiographic divergence. None adopts an antipodal position in the debate, either pure technological determinism or neutral social constructivism. And most of these writings, not surprisingly, pertain to the evolution of large-scale systems, wherein technology is most apt to exhibit independence and salient characteristics, not be overshadowed and subsumed, as when existing on a smaller scale.

Prominent among these works are Thomas Hughes's writings on "the evolution of large technological systems." Such systems "contain messy, complex, problem-solving components"--from machines and organizations to laws and natural resources--that change in connection with each other. But beyond this straightforward constructivist formulation, Hughes identifies a number of common patterns of evolution and enduring attributes, most notably (for this discussion) the tendency of large technological systems to assume "momentum." "Massive systems...," he writes, "have a characteristic analogous to the inertia of motion in the physical world. Their mass of technical, organizational, and attitudinal components tends to maintain their steady growth and direction." Such "powerful vested interests" take the form of skills, hardware, infrastructure, attitudes, financial investments--virtually any component of a system that possesses semi-permanence or an abiding interest in continuity [23].

Other scholars have shown that technological momentum can be manifest on a personal level and shape the creation of nascent technologies, not just large-scale systems in motion, as illustrated in David Hounshell's study of the telephone's development [20]. In reviewing these and related works, John Staudenmaier identifies several facets of technology that lend it momentum through their inherently "enduring nature": existing technical concepts, artifacts, government policy, financial interests, technological enthusiasm, and cultural values [40, pp. 149-67].

From another corner have come economists working with evolutionary theories of technical change that emphasize path dependencies. Paul David's famous article on the "economics of QWERTY" vividly demonstrates how historical decisions at critical, formative junctures in a technology's development can set a course from which it is difficult to retreat, even when the logic of efficiency dictates otherwise. This explains why the QWERTY (standard) typewriter keyboard, hardly the most efficient now available, is nearly impossible to supplant, given the interests of its producers and its millions of owners and trained users [13].

Theories of path dependency and complementary assets also inform organizational theory on many levels, from the transactions-specific assets emphasized by Oliver Williamson, to the plethora of learning curve and embedded knowledge theories that apply to capabilities ranging from tacit worker skills, to strategic planning, to R&D know-how [14,28,31,43]. Indeed, virtually any theory of organization, including Chandler's, which emphasizes the importance of self-reinforcing linkages between corporate technology and

management, public policy, or markets can be seen to support the concept of technological momentum within the business (system) setting.

We also know that technology reconfigures consumer options, tending to extinguish earlier possibilities. Each choice affects the range of choice at the next step. When a new system is introduced, its diffusion often renders prior systems obsolete, in a process akin to Joseph Schumpeter's "creative destruction" [38]. Automobile travel not only outpaced the horse, its diffusion made horse-travel virtually impossible in modern urban life. In effect, this shaping of consumer choice acts as another "vested interest" that conservatively reinforces system momentum.

Momentum, path dependency, creative destruction, and related concepts suggest ways in which technologies gain power, direction, and focus. By attributing to technology certain salient characteristics, they contradict the assertion that technology is "neutral." At the same time, these formulations preserve human freedom and do not wrench technology from the social fabric.

Conclusions and Propositions

The absolutist position toward technological determinism seems untenable for several reasons. As a human endeavor, technology is inherently messy. All inputs cannot be controlled to optimize outputs. The process of determining optimal efficiency would require endless, impractical cost-benefit analysis. Noble, Cowan, and others have demonstrated that in at least some cases, non-technical factors predominate. Nor can we assume that design intentions always lead to desired outcomes. As Hugh Aitken reminds us, technology is not "passive, controlled, and predictable," but instead sometimes "seems to take charge of events and exercise what is almost a legislative power of its own" [1, pp. 24, 26].

This is not to say, however, that technology--especially in the form of large-scale systems--possesses no salient characteristics of a determinative nature. In technology history, as in other realms of history, we are confined to a domain of propensities and probabilities rather than certainties. Technology does not determine society, but is more deterministic in some manifestations than in others. One important task for the historian, then, is to identify these conditions. Theories of momentum, path dependency, and creative destruction have moved us far in this direction, but much work remains. In that spirit I offer the following three propositions:

The greater a technology's efficiency, the greater generally its deterministic nature.

To the extent that technology augments human capabilities, it displays a vast array of potency across applications. This potency--a reflection of the ratio of resources employed to results achieved--reflects the instrumental character of technology, that is, its efficiency. (Of course, efficiency is dynamic, changing relative to and in response to other variables.) My first proposition, then, suggests that when technology is configured in ways that yield relatively great efficiency, such configurations are more likely to bring about the compromise of other social variables.

Consider two cases mentioned above: electric power and machine tool numerical control. The efficiency achieved in the generation of electricity using central station systems has been remarkable. In the United States, scale economies in electric power increased at a rate higher than in any other industry in the first half of the twentieth century [25, p. 139]. Hughes and others have identified important variations in the ways that electrical systems evolved--but those are variations on a dominant theme. In nations of every political, economic, ethnic, social, and geographic stripe throughout the world, electricity is generated, transmitted, and distributed using analogous central station alternating current systems. The similarities outweigh the differences.

Noble's study of machine tool numerical control demonstrated that social relations (in this case, the power of managers over workers) played an important role in the new technology's faulty application. Yet *Forces of Production* also reveals the remarkable complexities and subtleties of the machining process, which made it an especially challenging candidate for automation. In terms of efficiency, automated numerical control turned out to be little better than human operation. Not surprisingly other factors came into play to a greater extent than technics in socially constructing the technology. Thus, Noble's choice of technology was critical to his thesis. Machine tooling probably requires more worker skill than any other shop floor task. Noble could not have made the same argument had he examined, say, telephone switching, where efficiency gains from automation were dramatic.

In short, where such great disparities in efficiency exist, technology is more likely to conform to the engineer's design ideal at the expense of other social influences.

Technology is more deterministic when employed within the context of the firm than when not.

This seems to be true of two reasons. First, firms are systems. They represent the marshalling of resources--capital, workers, machines, knowledge, ideas--and thus embody vested interests with conservative momentum like other systems. (Indeed, Hughes's definition seems to suggest no discernable difference between a "large technological system" and a large firm.) Second, the importance to firms of profits, especially in the face of strong competition, places a high premium on efficiency. Firms have a focused mission that impels them to utilize technology instrumentally. This, combined with their inherent momentum, gives firms a deterministic propensity. To be sure, the search for efficiency is itself often inefficient. The process of technological competition causes wasteful duplication of effort, and the most efficient methods do not always triumph [32]. Still, new technologies tend to be more efficient than those they supplant.

The firm may change as a locus of technological determinacy as its fundamental mission undergoes transformation. Business historians have observed that in the twentieth century the American corporation no longer concentrates solely on the bottom line; increasingly it is compelled to consider the interests not merely of stockholders but of an array of other stakeholders, including employees, environmentalists, mass media, and regulators [18]. (Marketing, for instance, has become "societal," concerned not just with selling

but also with the individual and social consequences of doing so [26, pp. 19-21].) By incorporating into corporate policy and purpose an increasing array of non-firm agendas (or externalities), this trend promises to soften the deterministic nature of firms and of technological systems.

In the long run, large technological systems tend toward rigidity, but also evolve by accommodating the needs of both system advocates and system users.

This proposition, the broadest and perhaps most provocative of the three, is as much an assertion as a call for research. It suggests a way of thinking about technological change and determinism that differs from much current thinking; that seems supported my recent empirical research; and that calls for further investigation.

The proposition differs from Hughes's momentum model in two key respects. First, it distinguishes more sharply between system advocates and system users. (Of course, some individuals, such as utility employees, occupy both roles--and feel the pull of conflicting loyalties.) The latter, for Hughes, are one among several system "components." But if one is to make any claims of hegemony or determinacy on the part of the system, one must demarcate between the proponents and patrons who interact at the "consumption junction" (to borrow a term from Ruth Schwartz Cowan) [11]. Second, whereas Hughes's momentum metaphor suggests that large technological systems move with increasing force in established directions, my proposition asserts that large systems increasingly move toward the accommodation of advocate and user interests. This is related to the fact that large-scale systems often must serve a diverse spectrum of users and user needs.

New research that lends a social history perspective to the analysis of technological systems sheds light on this issue. Consider the case of the telephone. Claude Fisher's recent sociological study of the diffusion of telephone usage in American before 1940 reveals marked disjunctions between consumer demand and telephone marketing. Promoters initially spurned rural markets--with their relatively low incomes, thin populations, and presumed lack of interest in the modern technology--courting instead urban business customers. Still, before 1900 telephones were used by farmers, who founded thousands of cooperative exchanges, more than non-farmers. And whereas telephone marketers viewed phone socializing as "trivial," women (especially in the rural Midwest) used the technology more than men to overcome their isolation and cope with emergencies. Moreover, consumer income was an overriding determinant of telephone use; demand for the monopolies' services was elastic. In these and other ways, Fischer concludes, consumers exhibited a notable degree of "autonomy" in the face of the giant networked systems. At the same time, consumer choice was constrained, as phone companies offered a limited range of options (or none, for a time, to some customers) and rendered impractical some previous modes of communication. By the 1920s telephone companies began to reorient their marketing and technology toward real demand, welcoming and even promoting rural demand and social conversation, while also gaining legitimacy and stability through merger and regulation. Thus, the system configuration that had evolved through

accommodation at the consumption junction gained rigidity and permanence [17].

David Nye's *Electrifying America*, which examines "the process of electrifying America from the general public's point of view," ostensibly adopts the same perspective found in *America Calling* [34, p. xi]. But in spite of this agenda, Nye concludes that the balance of power in the story he tells weighs heavily on the side of the electric utilities, trolley car companies, government agencies and courts, technical elites, and other system advocates who not only secured centralized control of the production and sale of electricity but also used the commodity to reinforce their conceptions of how society itself should be ordered. Electricity's "shape was culturally determined," he states, but "the new technology was used to concentrate economic power" [34, p. 385].

But set against this hegemonic evidence are Nye's acknowledgements that electricity was adopted eagerly by and benefitted most consumers. Apart from the jeremiads of anti-modern intellectuals, the public offered few alternative visions of how electricity should be used (versus controlled) [34]. Moreover, when the electric utility industry marshalled massive resources to promote energy-inefficient electric vehicles, consumers soundly rejected the technology [39, pp. 342-61]. The industry's history reflected consensus more than conflict at the "consumption junction," particularly after electricity became universally available. Had Nye followed the story into the second half of the century, the impression would have grown, for utilities enjoyed widespread popularity and confronted little opposition prior to disputes over energy crisis rate hikes and nuclear accidents [19]. Efficiency gains drove down rates, which satisfied the utility's desire for secure revenues while pleasing customers. The demands of system proponents and system users coincided.

This process of accommodation over the long term also can be observed in the case of corporate research and development, which often is thought to be internally directed and relatively isolated from the demands of the market. Leonard Reich's study of R&D at GE and Bell explains how those pioneer facilities were born from their sponsors' desire to meet commercial challenges [36]. Other studies, including David Hounshell and John K. Smith's comprehensive history of R&D at Du Pont, demonstrate that even within the largest and most research-intensive corporations, "pure" research leading to breakthrough products (like nylon) has been the exception that proves the rule [21]. Development--incremental product improvements to suit demand--has mattered the most in terms of investment and profit [5, p. 33]. To be sure, firms often discover new products through research and profit handsomely. But it is now abundantly clear that the most effective R&D organizations are well integrated with in-house manufacturing and marketing functions. In the words of one economist, "successful innovations must be based upon knowledge about the needs of potential users, and this knowledge is as important as knowledge about new technical opportunities" [29, p. 350] Thus, while corporate R&D can act to reinforce momentum, as noted above, it also can serve as an accommodating mechanism, continuously monitoring consumer needs and redirecting corporate resources.

Technology historian Melvin Kransberg has observed that "although technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions" [27, p. 249]. Still, most technology is employed by firms within capitalist nations, with important implications. That technological change commonly takes place within the context of the firm in some ways reinforces its deterministic nature. At the same time, the marketplace acts on many levels to monitor the process and guide the direction of large-scale systems toward a degree of accommodation with consumer needs--certainly much more than in command economies.

It may be that historians of technology now are enthralled with context and contingency because their subject long was governed by assumptions about the universal character of technology. And it may be that many business historians now emphasize common institutional patterns because they are emerging from a tradition that emphasized the heroic actions of inspired leaders. In any event, those now striving toward the center, toward the middle realm of technological propensity, face a challenging and exciting task.

References

1. Hugh G. J. Aitken, *The Continuous Wave* (Princeton, 1985).
2. Stuart Bruchey, *Enterprise* (Cambridge, MA, 1990).
3. R. A. Buchanan, "Theory and Narrative in the History of Technology," *Technology and Culture,* 32 (April 1991), 365-76.
4. W. Bernard Carlson, *Innovation as a Social Process* (New York, 1991).
5. Alfred D. Chandler, Jr., *Scale and Scope* (Cambridge, MA, 1990).
6. _____, *Strategy and Structure* (Cambridge, MA, 1962).
7. _____, *The Visible Hand* (Cambridge, MA, 1977).
8. Thomas C. Cochran, *Business in American Life* (New York, 1972).
9. _____, "The Business Revolution," *American Historical Review,* 79 (December 1974).
10. _____ and William Miller, *The Age of Enterprise* (New York, 1942).
11. Ruth Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in Bijker et al., eds., *The Social Construction of Technological Systems*, 261-80.
12. _____, *More Work for Mother* (New York, 1983).
13. Paul A. David, "Understanding the Economics of QWERTY: the Necessity of History," in William N. Parker, ed., *Economic History and the Modern Economist* (Oxford, 1986), 30-49.
14. Giovanni Dosi, David J. Teece, and Sidney Winter, "Toward a Theory of Corporate Coherence: Preliminary Remarks," in Dosi, et al., *Technology and Enterprise in Historical Perspective* (Oxford, 1992), 185-211.
15. W. H. Dray, "Determinism in History," in *The Encyclopedia of Philosophy,* Paul Edwards, ed. (New York, 1967), vol. I.
16. Jacques Ellul, *The Technological System* (New York, 1977).
17. Claude S. Fischer, *America Calling: A Social History of the Telephone to 1940* (Berkeley, 1992).
18. Louis Galambos and Joseph Pratt, *The Rise of the Corporate Commonwealth* (New York, 1988).
19. Richard F. Hirsh, *Technology and Transformation in the American Electric Utility Industry* (New York, 1989).

20. David A. Hounshell, "Elisha Gray and the Telephone: On the Disadvantages of Being an Expert," *Technology and Culture*, 16 (April 1975), 133-61.
21. _____ and John K. Smith, *Science and Corporate Strategy* (New York, 1988).
22. Thomas P. Hughes, *American Genesis* (New York, 1989).
23. _____, "The Evolution of Large Technological Systems," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems* (Cambridge, MA, 1987), 51-82.
24. _____, *Networks of Power* (Baltimore, 1983).
25. John W. Kendrick, *Productivity Trends in the United States* (Princeton, 1961).
26. Philip Kotler, *Principles of Marketing* (Englewood Cliffs, New Jersey, 2nd. ed., 1983).
27. Melvin Kranzberg, "One Last Word--Technology and History: 'Kranzberg's Laws,'" Stephen H. Cutcliffe and Robert C. Post, eds., *In Context* (Bethlehem, PA, 1989), 244-58.
28. William Lazonick, *Business Organization and the Myth of the Market Economy* (New York, 1992).
29. Bengt-Ake Lundvall, "Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation," in Dosi, et al., *Technical Change and Economic Theory* (London, 1988), 349-69.
30. Lewis Mumford, The Myth of the Machine, Vol. II, *The Pentagon of Power* (New York, 1970).
31. Richard Nelson, "The Roles of Firms in Technical Advance: A Perspective from Evolutionary Theory," in Giovanni Dosi, Renato Giannetti, and Pier A. Toninelli, eds., *Technology and Enterprise in Historical Perspective* (Oxford, 1992).
32. Richard R. Nelson and Luc L. G. Soete, "Policy Conclusions," in Giovanni Dosi, et al., eds., *Technical Change and Economic Theory* (London, 1988), 630-5.
33. David F. Noble, *Forces of Production: A Social History of Industrial Automation* (New York, 1984).
34. David E. Nye, *Electrifying America: Social Meanings of a New Technology* (Cambridge, MA, 1991).
35. Arnold Pacey, *The Culture of Technology* (Cambridge, MA, 1983).
36. Leonard S. Reich, *The Making of American Industrial Research* (Cambridge, England, 1985).
37. Steven A. Sass, *Entrepreneurial Historians and History* (New York, 1986).
38. Joseph Schumpeter, "The Creative Response in Economic History," *Journal of Economic History*, 7 (November 1947), 147-59.
39. David B. Sicilia, *Selling Power: Marketing and Monopoly at Boston Edison, 1886-1929*, (Ph.D. diss., Brandeis University, 1991).
40. John M. Staudenmaier, *Technology's Storytellers* (Cambridge, MA, 1985).
41. Richard Taylor, "Determinism," in *The Encyclopedia of Philosophy*, Paul Edwards, ed. (New York, 1967), vol. I.
42. Anthony F. C. Wallace, *The Social Context of Technology* (Princeton, 1982).
43. Oliver E. Williamson, *Markets and Hierarchies* (New York, 1975).
44. Langdon Winner, *Autonomous Technology* (Cambridge, MA, 1977).