Symposium: The Historiography of American Technology

THE BIG QUESTIONS IN THE HISTORY OF AMERICAN TECHNOLOGY

GEORGE H. DANIELS

One way of approaching an assignment on the “state of our field” would be to recite for you the number of technologists whose biographies are yet unwritten, of industries that remain unstudied, of machines whose origins are still shrouded in mystery, of captains of industry whose rise is yet unchronicled. I could then close with a plea to assign your graduate students these topics and assure you that we would soon have a complete understanding of our subject.

However useful this approach might be in certain fields, I am persuaded that in the history of American technology it would be both depressing and superfluous—depressing because, in truth, we have barely scratched the surface of any of these important areas, and the lists would be very long; and superfluous because I am sure that every historian of American technology already has more ideas for dissertation topics than he will have graduate students for a good many years to come.

I therefore concluded that perhaps the best contribution I could make would be of an altogether different nature. During the past year, I have read a great deal about the history of American technology. Is there anything I can conclude from all this reading? I asked myself. Now that these studies have been made, the articles and books written, what do we know with a relative degree of certainty about the history of American technology? What do we have reason to suspect? In light of our present knowledge, what seem to be the most fruitful lines for further study? These lists, I find, are a great deal shorter.

DR. DANIELS, of Northwestern University, is the author of American Science in the Age of Jackson. This paper and the following comments by Professors Burke and Layton comprised a program session at the meeting of the Organization of American Historians, Philadelphia, April 1969.
In setting myself up as a "supplier of useful questions," I realize that I am treading on dangerous ground, for, of course, no one is sure what the "right" questions are—perhaps it is in the nature of things that they will always vary according to the interests of the person asking them. One man's big question may well be another man's irrelevancy. Yet, it seems worthwhile to start somewhere.

Having confessed the subjective nature of what is to follow, let me bare some basic assumptions for you. First, let us reject for our purposes the definition of technology as "how things are done or made," and let us regard it rather as including this but also including why they are done or made the way they are rather than in a number of other possible ways and what difference it makes to the society in which the doing or the making is done. "How things are done or made" is not, strictly speaking, a historian's question, and if we study the history of technology under this restricted definition of our subject matter, a more apt title for us would be "antiquarians of technology." For a second basic assumption is that no matter how specialized a historian may become, his major goal must be to contribute toward the understanding of how some society works and why it works the way it does. The big questions for us, then, will all have to do with technology as a social phenomenon. Other questions are not irrelevant; indeed, they may be indispensable as means to an end; they are simply not "big."

* * *

Roger Burlingame was the first American historian who tried to deal with these big questions against the broad expanse of American history, and in the essentials, at least, most historians of technology have followed his lead. The picture of technology as a motive force in American civilization which Burlingame sketched in two books written in the late thirties¹—that of technology as the major force leading to our unity as a nation—is a dramatic one which assigns to technology a central—one might even say a determining—role in American history.

The key methodological concept in the Burlingame analysis is that of the "social lag," a concept formalized by the sociologist Ogburn in 1923² and generally adopted by historians of technology ever since. Technology, so the notion goes, changes society by

¹ Roger Burlingame, March of the Iron Men (New York, 1938); idem, Engines of Democracy (New York, 1940).
Questions in History of American Technology

changing our environment, to which we, in turn, adapt. Between the change and the adaptation, however, there is always a lapse of time, the social lag. Technology, in this view, is the primary active force; sooner or later other institutions come into conformity with it. The social history of technology, then, is the story of institutions trying to catch up with technological realities. Thus the failure of politics to catch up with technology was a cause of the Civil War; the individualism of the 1870s was another example of social lag; the persistence of privately owned utilities is still another.

There is probably something to the concept of a social lag, at some times and in some places, but I would like to suggest that uncritical adoption of it is one of the great difficulties besetting us in the history of American technology. For the question of whether, on the whole, technology causes social change or social change causes technological change is one of the "big," and still unresolved, questions before us. Treating it as a fully resolved matter has been a cause of much confusion and, I think, misdirected effort, and it has obscured the nature of some of the other big questions.

I do not wish to be understood as arguing that technology does not have social consequences—of course it makes a difference in the life styles of every human being in a society whether production is by machine or by hand. In American history, it is perfectly true that the drift to the cities which accompanied growing industrialization altered the whole social hierarchy and political control of the nation. Nor would I be inclined to argue that the atomic bomb did not have important implications. What I do believe is that no single technological innovation—and no group of them taken together in isolation from nontechnological elements—ever changed the direction in which a society was going before the innovation. Even when the innovation is imposed from without, anthropologists have demonstrated that societies display a remarkable ability to adapt it to their own life styles. Urbanization in American history, for example, was a phenomenon in which technology was involved—but the process itself was a broad social movement, beginning before the technological innovations that are often cited as its determinants; and its explanation involves immigration, population growth, finance, and other matters as well as technology. And I further believe that the direction in which the society is going determines the nature of its technological innovations. Of course, these are at present unproved assumptions, although I think that recent studies lend them a certain amount of credence.

At any rate, the biggest question of all has to do with the nature
and direction of causation, and at present we know very little about it. There is a pressing need for studies that will shed light on this question; the only advice I have is that we realize that it is a question.

Despite the lack of evidence, most scholars who have concerned themselves with the relations between technology and society have implicitly adopted the point of view of Ogburn and of Burlingame by framing their research questions in such terms as: What was the effect of the automobile, the railroad, the typewriter, or the radio, on society? They have then observed the uses of such single innovations and assumed that the innovation was the direct cause of the uses. This was the "impact" of the innovation. In this, both those who deplore technology and those who believe that it can solve all of man's problems agree. Thus Ogburn and Nimkoff studied certain changes that have taken place in the American family and attributed them all to recent technology, with no consideration of trends antedating the technology. In the same manner, Ogburn counted well over a hundred "impacts" of the airplane.\(^3\)

General American historians, on those rare occasions when they deal with technology at all, also adopt this framework. If he knows anything about technology, the general American historian is likely to have at least two facts available which he places somewhere in his book to demonstrate his virtuosity: (1) The cotton gin fastened slavery on the South and thereby was a major cause of the Civil War, and (2) the typewriter brought women to work in offices and thereby "liberated" them. An unscientific survey, which consisted of going to the library and looking through a shelfful of high school and college texts, indicated that almost all of them contained these two "facts." Gilfillan, in commenting upon the second of these claims, made the obvious point that in Japan there were women office workers, neither liberated nor getting much help from the typewriter.\(^4\) More to the point than Gilfillan's objection is the fact that American women had been in the process of being "liberated" for a full generation before the appearance of a typewriter. Women had already been working in American offices, and they were beginning to do so in increasing numbers. Women had, in fact, been working previously at a great variety of jobs in America; their moving into offices, I suspect, can be directly correlated with the increase in


Questions in History of American Technology

the total number of workers at this kind of job. One may as well credit the invention of the tin can, the contraceptive, or any of a hundred other things with the emancipation of women, a purely social process which took advantage of appropriate inventions when they appeared and perhaps, in fact, stimulated the appearance of those inventions. The fact that the typewriter in America brought more women into the offices is not altogether irrelevant. It fit neatly into a preexisting social process and facilitated that process, as did the tin can and the contraceptive. Would the contraceptive have been accepted in a society that firmly believed the lot of women was to be forever bearing children? Contemporary experience suggests that it would not. What would have happened had the typewriter been invented in a society where the very idea of women in offices was unthinkable? This is probably an unanswerable question, although there is a related one that could be answered; namely, what happens when typewriters are introduced into societies where they have not been used before and where women do not hold jobs outside the home? Do they bring women into offices? I doubt it, but the answer would help us to understand the role of our own technology better.

The same case could be made about the other familiar example. It is perfectly true that technology contributed to the profitability of slave labor, as it did to free labor, not simply in the form of the cotton gin, but with spinning machinery, power looms, and other equipment which left only the production of raw materials relatively unmechanized. But slavery was already fastened on the South, and it was on the rise before the introduction of the gin because of the opening of new lands. The allegation that slavery would have disappeared and there would have been no Civil War without the cotton gin is therefore pure romanticism. The problem in the 1790s was that of using all the cotton that could be produced with the available labor supply; thus, invention was aimed at remedying the balance. It was a case of the same technological disequilibrium that Rosenberg found to be such a potent stimulus for innovation in the late 19th-century machine-tool industry.⁵ A high productive capacity at one level of the process stimulated invention at another. Far more significant than what the gin did to slavery is the fact that the gin was invented in a society where the labor system was based on slavery. I remain relatively certain that had there been no Eli Whitney and no cotton gin, Southerners would have found other uses for their slaves. I also remain convinced that had there been no slaves, but there had still been a flying shuttle, invention would have

been aimed primarily at the production stage of cotton manufacture.

In both these cases and in many others that could be mentioned, the real effect of technical innovation was to help Americans do better what they had already shown a marked inclination to do. This, I suggest, and not a lack of talent or imagination on the part of historians, is the reason that after so many efforts have been made, we are still unable to point to any broad social consequences of an innovation. Historians who deal in such matters, it seems to me, have simply been asking unanswerable questions. The use of an invention does modify the user's habits, but there is no evidence that it has markedly changed the direction of the total complex of habits. Habits seem to grow out of other habits far more directly than they do out of gadgets.

* * *

Recent trends in economic history, I think, may offer us a more realistic and more satisfying framework than that of the social lag—provided we make sufficient allowances for economists' biases. For a very long time, economists and economic historians tried resolutely to ignore technology. They looked upon it as an alien force which occasionally disturbed the equilibrium of the economy they were studying. "Assuming that the state of the arts remains constant" was a frequently encountered phrase in their work, and this simplifying assumption helped them to understand other elements of the economy. When they did discover technology, their characteristic response was to try to deny its equilibrium-disturbing character. The economist concerned with the question of economic growth generally draws smooth curves showing a steady rise in productivity. His curves can contain the introduction of the telegraph, the telephone, the railroad, the automobile, or the airplane and yet show no trace of a revolution. It is possible, of course, that the sheer weight and complexity of the economic structure, especially one so weighty and complex as that of the United States, can disguise revolutionary changes. The shifting of resources and effort as some industries become obsolescent, the local effects of changing patterns, the ruining, for example, of thousands of small businessmen with the rise of the mail-order house—such things will not be revealed by gross figures such as the GNP. When dealing with economic historians, we must be on guard against this possibility. But I do believe that their smooth curves, even with their limitations, give us a more realistic picture of the historical process than the historian of technology with his dramatic revolutions and his discontinuous leaps.
Economic historians have taken their penchant for continuity quite far—too far, at times, one might argue. Thus Fogel used statistics, logic, and argument to demonstrate that the railroad innovation had no particular economic consequences. Others have shown that even great bursts of technological activity, such as those promoted by wartime conditions, can be contained in the smooth curves that existed independent of the bursts. The Civil War has recently suffered such a downgrading as a causal factor. Schmookler came close to transposing the inventor—that eccentric, unpredictable, lonely individual of legend—into an economic man, rationally calculating relative advantage, assessing the market and inventing or not inventing, changing directions from railroads to electric shop motors in response to the same economic forces that the pawnbroker, the industrialist, or the merchant obeyed. Schmookler's key point was that invention was essentially an economic activity, and from this relatively simple concept a great deal followed.

Although I would not like to exchange one hackneyed stereotype for another, there is a great deal to be said for Schmookler's picture of the inventor, and in studies carried out over the ten years before his recent death, he gathered a great deal of evidence to support it. He concluded that new goods and new techniques are unlikely to appear unless there is a preexisting demand in the society. In other words, more significant than a "social lag," there exists at any time a technological lag, a chronic tendency of technology to lag behind demand. This is the same point that Gilfillan made intuitively in 1935 and Friedrich Engels much earlier, but now Schmookler has brought what seems to me impressive evidence to support it. Studying a wide range of industries, he generalized that inventive effort varies directly with the output of the class of goods the inventive effort is intended to improve, with invention lagging slightly behind output. Increasing sales for one class of goods invariably produced an increase in inventions pertaining to


that class; declining sales were followed by a decline in inventions.

The existence of the lag implies that causation could not have been the other way around. The recent business practice of setting research budgets at a fixed percentage of sales tends to assure this relation now, but it existed long before research became institutionalized and the practice became common.11

Although the points are not nearly so well substantiated, Schmookler even believed that basic inventions establishing new industries are induced by these economic forces, and that the case holds even when a scientific discovery underlies an invention, for a discovery may contain the seeds of many potential applications, only some of which will be realized.12 Schmookler's view is in marked contrast with the earlier view of Ogburn, who insisted that an invention may answer no social need but may simply be a product of a scientific advance. The dispute between the two points of view is fundamental: in the one, technology is tied to society; in the other, it is tied to science. If we accept the contention of Price13 and others that science and technology develop independently of each other, we shall have to cast out Ogburn's view—although doing so will not yet establish the rival view.

If the pattern of invention thus depends in large measure upon socioeconomic change, we see once more why it is futile to attempt to trace social changes to technological innovations. Such broad social forces as urbanization, declining family size, changing status of women, increases in population and per capita income—the whole range of matters often attributed to technology—are themselves determinants of the direction of technological innovation. Technology, in a word, is used to help people do better what they were already doing for other reasons, and what they are doing for other reasons determines the nature of their future technology.

Even the notion that economic progress depends upon technological innovation remains at this time an unproved assumption, yielding us another of the big questions. Obviously, there is some relationship between technical change and economic growth, but recent studies, far from delineating the precise nature of the relationship, have called into question all of the knowledge we once thought we had and left nothing solid in its place. To be sure, recent studies indicate

12 Ibid., p. 18.
that only about 13 percent of the increase in output per worker in
the United States between 1910 and 1950 could be statistically
explained by increases in capital per worker. These studies, conducted
in the late 1950s, provided a valuable check on the then prevailing
view of economists which placed undue weight on capital formation,
and, I think, these studies do show that technological change has
been far more important than mere growth in supplies and labor
inputs—thus confirming what most historians of technology had
believed despite the economists. But let us not celebrate our victory
by running too far in the other direction and concluding too hastily
that innovation accounted for the 87 percent left over. Mere increasing
familiarity with techniques accounts for some of the increase in output,
organizational changes are no doubt involved, the shifting of resources
and economies of scale cannot be denied their percentage, and a
host of other matters will clamor for attention when we begin to
analyze more carefully. What is needed are careful efforts to sort
out the great number of factors involved in productivity and arrive
at a measure for the amount due to technology.

Thus far, we have done little more than raise the question, but I
think that recent work, involving a new approach to the study of
industry, shows great promise. Earlier studies of American industry
were trapped in a Marshallian approach which involves the definition
of an industry as a collection of firms producing a homogeneous
product. It now appears that a first step in studying the importance
of technological innovation must be to discard this aspect of Marshellan
economics, for it is ideally designed to mask the influence of
technological factors. Rosenberg has suggested that 19th-century
developments may be understood more effectively in terms of certain
functional processes which cut entirely across industrial lines. The use
of machinery in the cutting of metal into precise shapes is one such
functional division, which explains the convergence of firearms, sew-
ing machines, and bicycles. Rosenberg shows that where an inno-
vation may have only marginally affected the industry for which
it was created, it often had great importance in some entirely dif-
f erent industry. If studies of other such functional groups are made


15 Rosenberg, p. 423.
along the lines suggested by Rosenberg, we may finally determine a measure for the impact of technological change in this one area.

* * *

After we have made up our minds about the impact of technology, then we can ask what kind of technology? Major breakthroughs? Revolutionary changes? Or, perhaps, are minor modifications of detail more important in the long run? This is an important question, for the manner in which it is resolved will determine the most useful lines of research for the future, and it has important policy implications as well. I think it is fair to say that most historians of American technology have tended to emphasize the more impressive at the expense of the run-of-the-mill improvements. Schumpeter is probably responsible for elevating this cult of the heroic into scholarly respectability, for throughout his widely accepted works he showed excessive concern with the more dramatic and discontinuous aspects of innovation and consistently neglected the cumulative effect of small innovations.

At present the question remains open, although recent works have given us some indications. There is at present no evidence which establishes definitely that technical or economic progress receives greater contributions from the few and rare large advances in knowledge than from the many and frequent smaller improvements. Economically, in fact, some scholars have concluded that it might for a period well pay a community to starve its scientific and major technical work and to devote its resources to the most thorough and systematic gathering together and exploitation of all the immediate and tiny practical improvements in ways of manufacture and design. The few detailed studies that we have seem to bear out the economists on this point. Hollander, in his study of the Dupont rayon plants, concluded that such things as patents issued and expenditures for formal research and development projects, favorite indices for “inventive activity” in econometric studies, bore little relation to the important changes in technique and productivity. He found that the technical changes which did lead to increased efficiency came not through major innovations but through an accretion of minor changes by the technical assistance staff at the operating level.17


lander's study is, of course, subject to the same criticism made earlier of Marshallian economics, but even though his framework may have concealed the importance of major technical change, there can be no doubt that he has demonstrated that minor increments were more important than we generally recognize.

Such a finding is of obvious importance for an understanding of the role of technology, and, if borne out by other studies, it will have broad implications. For one thing, it may help us finally to overcome the penchant for substituting biographies of inventors for careful analysis of social processes. Of more use to the historian would be knowledge of shop practices, activities of lower-level technicians in factories, and so forth—and all of these are still relatively unexplored. For another thing, it may help us to understand such otherwise perplexing conclusions as those of a Brookings Institute study which found that there was no standard pattern in the relationship between highway investment (technological progress) and economic development. Sometimes such investment proved profitable to the country, sometimes neutral, and sometimes ruinous. The exact impact seemed to depend upon such things as existing economic patterns, character of the resources, and, of all things, the attitudes and entrepreneurial capabilities of the people. There is, so it is beginning to appear, no simple connection between the diffusion of technology and economic growth. That there is some kind of connection seems obvious to us, but what its nature is and how it operates appears even more mysterious than ever. In fact, the more one studies, said two students of world history in 1966, the more one wonders whether the countries that industrialized became rich because they industrialized or industrialized because they were rich. Kuznets, of course, had made the same point much earlier.

Such a question has obvious implications for our current drive to westernize the world, but this is not the place to go into them. More to the present point is the fact that it immediately raises questions about our own industrialization process. What were the forces which within less than two generations—between 1800 and 1850—raised a technologically backward nation to such a level that it could begin to export to the "advanced" European nations a manufacturing technique and machine tools so different that the whole performance


became known as the "American system." It is one of the really big questions about the history of American technology with which every writer on that subject has had to grapple. A careful count, I am convinced, would probably yield a hundred or so reasons that have been alleged. Foreign commissioners, both in the 1850s and the 1950s, emphasized such social factors as differences in the nature and diffusion of education in America, absence of rigidities and restraints of class or craft, freedom from hereditary definition of the tasks and ways to go about them, high focus on personal advancement and drives to higher material welfare, and, above all, a belief in the moral need for ever greater productivity. "Men serve God in America," concluded a visiting productivity team from England in 1853, "in all seriousness and sincerity, through striving for economic efficiency." Many historians have accepted their explanation.

These ideological factors, whether they explain innovation or not, really did exist, and deliberately to ignore them, as Peter Temin does on the grounds that "the economic importance of these characteristics is not very clear," is inexcusable. For one thing, they probably do explain the relative lack of resistance by workmen to labor-saving machines. Workers, undoubtedly accepting the widely current belief in the continual expansion of America and the consequent need for ever greater productivity, evidently did not fear being replaced by machines. And since America's industrial revolution came during a period of rapidly increasing population as well as geographical expansion and transportation improvements, the belief was probably well founded. To what extent this doctrine of manifest destiny expedited the transition to machine production is still one of the big unknown questions in the history of American technology.

But there are many other explanations. America's comparative advantage in agriculture has been cited by some as a stimulus to industrial efficiency. It was necessary to be efficient in order to compete, so the explanation goes. To Burlingame, it was primarily a lack of skilled technicians which forced manufacturers to adopt labor-saving devices. More recently, Habakkuk has lent the weight


Questions in History of American Technology

of his scholarly reputation to that relatively simple explanation.\textsuperscript{23} Since men could not be found who could do the work, there resulted an intensive search for machines that could. Whenever they were found, they were widely adopted. Peter Temin, reacting to Habakkuk's work, insisted that both the high wages paid to labor in the United States and the widespread market possibilities were statistical illusions—the first because writers had confused money wages with real wages (which some recent students have found to be no higher than in England), and the second because they had confused the geographical with the economic extent of the market. Temin, finding that the most important and pervasive of differences between English and U.S. technology was the use of less capital per worker, concluded that the high interest rate, rather than a fictional "labor scarcity," was the primary factor in shaping American technology.\textsuperscript{24}

The difficulty in accounting for the rise of the American system has been compounded by the fact that no one is yet quite sure what is being explained. Thanks to the meticulous work of Woodbury,\textsuperscript{25} no one except writers of American history textbooks believes any longer that a complete system of interchangeable-parts manufacture sprang full-blown from the mind of Eli Whitney. But there is still some doubt as to the nature and extent of use of the major principles of the system—quantity production, interchangeable parts, specialized machinery. Uselding, as a result of an exhaustive study of the records and equipment of the major arms makers, now doubts that any American arms manufacturer had a system of interchangeable parts in the 1840s. He has demonstrated beyond any doubt that the method of rolling gun barrel scalps, patented in England in 1811, was not brought to America until 1856, when it was observed at the Enfield armory after Enfield had begun using American machines. When one realizes that approximately 15 percent of the labor expended in producing a musket was absorbed in making the barrel, he is led to reflect that the American system was perhaps not so highly developed by the mid-century as has been assumed.\textsuperscript{26}

\begin{thebibliography}{9}
\bibitem{23} H. J. Habakkuk, \textit{American and British Technology in the Nineteenth Century} (Cambridge, 1962).
\bibitem{24} Temin, p. 294.
\bibitem{26} Paul Uselding, "Henry Burden, the ‘Magnificent Scotchman’" (Urbana: University of Illinois, 1969). John Hall at the Harpers Ferry Rifle Factory apparently used a system of interchangeable parts for a brief period after 1824, but it was a small operation and not influential.
\end{thebibliography}
Outside of gun making—to whatever degree it was actually used—and clock making, the fully developed American system was for the most part confined to woodworking. The United States, in general, was backward in the production and fabrication of iron. Seizing on this point, two economic historians have recently noted that the woodworking machines popular in America and neglected in England were not only labor saving but also wasteful of wood. The adoption in America and neglect in England might, they thought, be attributable primarily to the cheapness of wood in the United States and its high price in England, not to differences in the capital-labor ratio. To back up their point, they adduced abundant evidence to the effect that American practices were relatively well known in England long before the New York Exposition, traditional date for the “discovery” by Europe of American technology, but were deliberately rejected as unsuitable for English conditions. This discovery, in itself, certainly suggests that our traditional explanations are questionable.

While I do not believe that American technology can be explained in terms of factor endowment at all—either labor or capital scarcity—Temin, I believe, has pointed out fatal weaknesses in what is currently the most popular explanation. It is certainly true that the main features of the American system were highly developed before any of the grand explanations became operative and at a time when comparative advantage might have argued for other lines of growth. Until after the mid-century, the total internal American market was much smaller than that of Britain and was markedly reduced as an effective market by geographical spread and inadequate transportation. It is remarkable, I think, that historians of technology can, in the same breath, speak of “primitive transportation systems” and a “domestic market of continental proportions.” As a matter of fact, it is possible that the very lack of “a domestic market of continental proportions” may have been a stimulating factor in diffusing technology and contributing to the buildup of technical skills. For one thing, it encouraged the kind of openness that many historians have observed as being characteristic of American technology. As Ferguson noted, information was exchanged readily between American manufacturers, in marked contrast with the situation in England where industrial secrets were closely guarded, both by the government and

Questions in History of American Technology

by individuals. It is easy to exchange information if one does not regard the seeker as a rival.

Sanford has collected a great deal of evidence indicating that early manufacturers, sincerely believing that they were setting a national example of manufacturing morality and skill, were often generous in encouraging the establishment of other factories. This was partly because of their realization of the need to gain acceptance by an anti-industrial people, partly because it could do them no serious harm, and partly, no doubt, because of a genuine sense of mission. Despite the counterexample of people like Oliver Evans, our present knowledge suggests that openness and, yes, generosity were characteristic of American manufacturers during the first half-century of industrialization. Independent of manufacturers' wishes, of course, the extraordinary mobility of American labor meant that industrial secrets could not be kept. Might not this openness be an important part of our explanation for the rise of American technological dominance? If so, it is a reflection of the pattern of life of Americans—which can in part be traced indirectly to technology—during that period. Only further study directed toward assessing the real extent of it and comparing it systematically with the situation elsewhere will tell.

* * *

A closer look at the American scene at the time of industrialization reveals further weaknesses in the received explanation. It appears, for example, in the light of recent studies that the lack of skill has been overemphasized. While I would not argue for a return to the "Yankee ingenuity" explanation, I believe that historians have paid too much attention to statements by men like Whitney and Colt, which were surely motivated by a desire for self-aggrandizement, and have not reflected sufficiently upon the fact that there were a great many Whitneys and Colts in the population. Too often, I think, historians, upon being shown that a given explanation is inadequate, tend to reject what is sound in the explanation along with what is unsound. This has been the case, I think, with "Yankee ingenuity," an explanation that is not so much erroneous as it is tautological. That ingenious devices are created by people of at least relative ingenuity should occasion no controversy.


29 Sanford, pp. 1-16.
A priori, there are a great many reasons for believing that technical skills were rather abundant in the population. Between 1760 and 1820, there were concerted efforts in every area, both by states and private organizations, to stimulate household manufactures, many of them notably successful. Extensive household manufacturing would clearly produce a vast number of people who were at least familiar with machinery. Furthermore, the movement, due to the English embargo, reached its height just before the period of the emergence of the American system. The embargo, one might argue, not only forced Americans to industrialize but forced a certain amount of originality. One careful student of New England textile machinery emerged from his study of the Lowell mills to declare that "the Industrial Revolution in its infancy produced surprisingly few basic skills not already familiar to American mechanics."30

In short, I think that the presence of skills, not their absence, will be an important part of the explanation. If this is so, we are led immediately to another big question. Where, then, did those skills come from? It is becoming increasingly clearer that many of them were imported as the need arose, and some came in from the outside quite by chance. Our preoccupation with our later inventiveness and eminence as the world's leading industrial nation has made us, until recently, overlook this source of much of our technology and, consequently, to misunderstand its nature. It is generally understood that by the end of the colonial period most of the trades known in Europe were practiced in America—primarily because of the importation of skilled labor. Ferguson points out that in the 19th century itinerant craftsmen may have brought essential skills and instructed American mechanics.31 The continuous influx of population during that period, even if it were random, must have provided many such cases as the one well-documented case Ferguson found. Wilkinson, in a study of the Brandywine industries from 1791 to 1816, demonstrated that in such key industries as textiles, tanning, powder mills, and papermaking, essential techniques, equipment, and workers came from England and France. Studies of the half dozen or more river valleys where the first factories appeared should give us a better idea of the extent of such borrowings.32

We will probably never know the real extent of the importation of

31 Ferguson, p. 12.
skilled workers and techniques during the first few decades after the Revolution. Finding out is especially difficult in the case of the United States because the historian gets no real clue from “foreign names.” At any rate, it was much greater than anyone ever dreamed before case studies began to be made. Much of this importation, we know, was at the encouragement of Americans, acting as quasi-official representatives of the government in direct violation of British law. This was, in fact, no less than de facto American political policy. The pace was so rapid that one student concluded that the smuggling of machinery and the seduction of mechanics was turned into a “fine art” immediately after the Revolution.33 We have long known of the importance of Samuel Slater, whose success has turned him into a legend; we are only now beginning to realize that he was only one among many. The process continued for a very long time, and it brought skills essential to our developing technology—tinsmiths from Wales in the late 19th century, chemical technology from Germany after the First World War, German rocket experts after the Second World War. In general, the contributions of the later technologists are better known than those of the earlier ones—yet it is clear that the earlier group was of great importance in shaping our technology. How many there were, when they came and why, and what skills they brought to American technology, are big questions for some future historian.

Another fact that cannot be dismissed is that throughout the early 19th century Americans do seem to have been far more interested in British discoveries than the British were in American developments, resulting in a definite asymmetry in the flow of information which became a positive advantage for Americans. Perhaps this was due to that “higher degree of education” which is often alleged of American workmen, perhaps only to the feeling of inferiority which Americans, beneath the surface of their blustery nationalism during that period, continued to feel toward Europeans; or perhaps the fault lies simply in a peculiar British reluctance to learn from former colonials. At any rate, it is a fact that Americans, much to their advantage, eagerly assimilated British improvements while the British ignored American improvements of which they had full knowledge.34 This is an important point which has been too often ignored.

We also know, thanks to the work of recent scholars, that American

mechanicians went abroad in large, but still unknown, numbers in search of know-how. The practice of going to Europe for information, or even machines, continued well into the 19th century. Prior to the beginning of the Erie Canal, an agent was sent to England. The Pennsylvania Society for the Promotion of Internal Improvements sent an agent to Europe to report on technological developments in 1826. Precisely what information these and other agents like them brought back and to what use it was put are unknown matters. Ferguson tells of the Maudslay lathe slide rest that was smuggled out of England and brought to the Philadelphia shop of William Mason and Rufus Taylor in 1822. Mason and Taylor, making only minor (albeit essential) changes, produced a sturdy and widely accepted American version. One has only to try the experiment of using a lathe without a slide rest in order to comprehend the transcendent importance of this introduction to the American system.

Although these examples have only scratched the surface of the transatlantic movement of technology, they make it clear that a great deal of our technology involved in the American system came from Europe, principally England. Every new study that is made on the subject turns up further evidence. The study of Uselding referred to earlier, for example, shows an essential part of the machine production of muskets being brought to America in the late 1850s. It also demonstrates that Americans did not have a monopoly on labor-saving inventions.

What is now needed is an effort to determine the full extent of the borrowing, to assess its importance, and to study characteristic changes (if any) that Americans made in the equipment and techniques they borrowed from Europe. The evidence that is now in, although it remains fragmentary, suggests that characteristic American changes in imported technology increased its marketability by either making it cheaper or adapting it for broader uses. Native inventions generally had these same features. The metallic woodworking plane, described by Welsh, is a good example of such an invention. The "consumer orientation" of American technologists and inventors may turn out to be one of the important distinguishing features. One gets the idea that when Americans invented, they tended to concentrate on devices with immediate widespread sales possibilities. As the milling machine and the grinding machine indicate, both of which had widespread

35 Ferguson, p. 10.

sales possibilities because of technological convergence, this was even true of American industrial inventions.

The market orientation, which Burlingame thought began with Edison, now seems to have been a characteristic of American inventors before the beginning of the century. Europeans often invent at a stage removed from sales; they have concentrated on such things as heavy machine tools, steam boiler improvements, construction equipment, and huge industrial equipment. This may have been because American inventors were also entrepreneurs; they therefore always looked at the potential market. By contrast, British inventors esteemed their position in scientific societies and society in general; they therefore gave greater weight to machines that were "complex" and impressive from a technical point of view.\(^{37}\) This, I emphasize, is an impression only. Detailed comparative study will be necessary in order to test it. Only through further investigation of such questions as these can we begin to understand what is unique in American technology and what have been its driving forces.

* * *

There is one other contrast between European and American technology that has curiously been passed over with only a mention here and there. This has to do with the organization of work, and if the little that I know about the matter turns out to be accurate, it seems that American practice both testified to a broader diffusion of skills and proved to be precisely right for stimulating inventive activity of the type involved in creating the American system. Ferguson, in his study of the origin of American know-how, tells of George Escoll Sellers visiting England in 1832 and being told by a mechanician that he could not understand how machine works could be successfully run without a strict division of labor, as in England, where each workman mastered only a single operation, such as turning, filing, or wielding a cold chisel.\(^{38}\) The English practice, however efficient it might have been, militated in two ways against the possibility of developing an "American system" and, I think, might go a long way toward explaining why such a system did not develop in England. First of all, the workman, confined to his cold chisel, his file, or his lathe, had no way to develop a sense of the job as a whole—he corresponded in this respect to the modern American assembly-line worker. Second, those who planned the manufacture thought in

\(^{37}\) I owe the origin of this idea to a conversation with Paul Uselding.

\(^{38}\) Ferguson, p. 13.
terms of breaking down a job into human actions—as we know, the
great obstacle that 19th-century inventors had to overcome. The
machine sequence is usually not similar to the sequence of human
actions in performing a job.

The Blanchard lathe, for example, which is really a sequence of
sixteen different machines, first used in processing gunstocks, was a
characteristic American invention. The essential point about the
Blanchard lathe is that while each replaced standard carpenters’ tools
and also the labor of skilled carpenters, the sequence of operations
performed by Blanchard lathes does not correspond to the sequence
of manual operations, and one cannot associate particular lathes with
particular carpenters or tools. Only someone thoroughly familiar with
the job of making a gunstock, as opposed to cutting a blank, filing,
or fitting a gunstock, could have conceived of the Blanchard lathe.
And this, during that period, implies an American mechanician. Too
early division of labor may be a positive disadvantage. Had historians
taken Drucker up on his suggestion that the organization of work
be used as a unifying concept in the history of technology, I might
be able to report many other interesting comparisons.39 Thus far,
however, his suggestion seems to have fallen on deaf ears.

* * *

As mass production seems to be the chief distinguishing feature of
our technology, it is only natural that so much effort has been devoted
to its origin. But what of its effects? Considerable effort has been
devoted to these as well. A frequently encountered allegation is
that mass production produced standardization and this standardization
has led to a standardization of thought and opinion. This point was
emphasized by Burlingame, who at times took a rather dim view
of the technology which he had invested with such active force.
Once again there is an element of truth in the allegation, but it is
not directly traceable to machinery. Indeed, the fact that American
conditions and American thought were amenable to standardization
may have had a great deal to do with the success of mass production.
Long before the machine age—long before the first glimmerings of
interchangeable parts and mass production—even if one be as charitable
as possible and trace it to the time of Whitney, standardized people
had been an article of American faith. In the pre-Revolutionary period,
Crèvecoeur had made quite a point of the fact that there were no
extremes in America; it was a land of “middling competence.” Simplicity

and the lack of useless ornamentation had been an American ideal stemming from Puritan times, made an article of patriotism by the pre-Revolutionary crisis, and further intensified by the post-Revolutionary effort to achieve independence in manufactures.

Americans, in a word, had become accustomed to dressing alike and using the simplest implements available because of a whole complex of reasons including the necessities of frontier life, the political situation, a Puritan heritage, and an expanding population. When the age of mass production came, it merely confirmed long-existing tendencies in the population. The power loom, for example, was widely acceptable in America simply because there was a demand for the coarse, completely unaesthetic cloth which it could produce. As an 1832 report of the Franklin Institute advised, American manufacturers should produce “simple and neat” commodities because these were more popular. In short, Burlingame and others recognized a real tendency in American life, but it is no longer clear that they were correct in attributing it to our system of production. Rather, our system of production seems to have derived from long-standing attitudes of the population. To put it another way, the development of interchangeable parts and all the other characteristics of the American system may be due not so much to American ingenuity as to American preference.

And one can, I think, generalize on this point. If there is anything that seems clear at this point in our knowledge, it is that the preferences of people do have a lot to do with the development of their technology. If this recognition forces historians of technology to consider intangible factors and assign a somewhat lesser role to technology than they customarily do, if it forces them, even, to learn a little history, it will at least have the virtue of making unnecessary the futile game of trying to find direct, mechanically operating connections between a technological innovation and social change. If we stop misdirecting our work, we may one day find out how to direct it.