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Findings follow framings: navigating the empirical turn

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Abstract In this paper, I outline several methodological questions that we need to confront. The chief question is how can we identify the nature of technological change and its varied cultural consequences—including social, political, institutional, and economic dimensions—when our different research methods, using distinct 'levels' or 'scales' of analysis, yield contradictory results. What can we say, in other words, when our *findings* about technology follow from the *framings* of our inquiries? In slightly different terms, can we combine insights from the fine-grained "social shaping of technology" as well as from complementary approaches accenting the "technological shaping of society?" As a way forward, I will suggest conducting multi-scale inquiries into the processes of technological and cultural change. This will involve recognizing and conceptualizing the analytical scales or levels on which we conduct inquiry (very roughly, micro, meso, macro) as well as outlining strategies for moving within and between these scales or levels. Of course we want and need diverse methodologies for analyzing technology and culture. I find myself in sympathy with geographer Brenner (New state spaces: urban governance and the rescaling of statehood, 2004, p. 7), who aspires to a "theoretically precise yet also historically specific conceptualization of [technological change] as a key dimension of social, political and economic life."

Keywords Historiography of technology · Scale · Social constructivism · Agency-structure problem

Scholars, citizens, and policy makers all confront a need to understand the complex relationship between technological change and changes in society, politics, and

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culture. In the balance hangs the prospect for sensible policies about innovation and economic growth as well as for reasonable means to address such technology-laden issues as globalization, climate change, privacy, and security. One outstanding problem is that scholarship from varied disciplinary perspectives has yielded sharply divergent perspectives on how to understand this relationship. Work by philosophers of technology frequently emphasizes that technological changes lead to changes in politics, society and culture and, accordingly, has sought to specify the cognitive, normative, and policy implications of these technology-driven changes. This general emphasis continues even with those philosophers who reject the essentialist stance of figures such as Martin Heidegger or Jacques Ellul and are inquiring into the co-construction of humans and technologies. They are still likely to direct attention to "what things do."[1] By contrast, empirical studies of technology by historians and sociologists regularly embrace a contrary view: namely, that technology is best understood as a product of underlying social and cultural dynamics and is not—in itself—a compelling force for change. This second position is embodied in such popular approaches as the social construction of technology and the user heuristic. At the very least, we face an unsettling situation. As citizens of a "technological age" we know that technology in some way shapes our future, but we seem to lack robust insights into how it will do so and, crucially, whether and how we can exert significant influence over this future-shaping process.

Whether scholars conceptualize technology as an independent driver of social, cultural, and economic processes or alternately as a dependent outcome of such processes can be usefully correlated with the varied analytical levels at which research and analysis in our fields has been conducted. At least compared with most empirical researchers, philosophers of technology have often conducted their analyses and reflections at higher levels of abstraction, looking for generalizations and striving to identify broad characteristics from carefully chosen leading examples.[2] Conversely, most historians and many sociologists and anthropologists who study technology have typically examined the minutia or fine structure of empirical cases and in the main been wary of making overarching generalizations. These methodological differences have worked, invisibly yet perceptibly, to generate divergent perspectives on technology.[3] We have used different tools and, consequently, generated distinctly different views on technology and culture. For at least two decades, this methodological gap between fine-grained empirical work and broadly conceived analytical work has frustrated efforts to develop and refine grounded theories of technological change. Efforts at technology assessment foundered for much the same reason. Feenberg (2003) recently observed that we need means for "bridging the gap" between empirical studies of technology and philosophical analyses of modernity. More generally, I would say that we need ways of "navigating the empirical turn"—communicating across disciplinary boundaries and methodological divides.

[1] *What Things Do* is the title of Verbeek (2005). For reviews of recent philosophy of technology, see Achterhuis (2001) and Ihde (2004).

[2] Winner's (1980) classic account of Long Island's bus-blocking bridges as a case of "artifacts have politics" spawned rejoinders by Joerges (1999) and Woolgar and Cooper (1999).

[3] See especially the work of Misa (1988, 1994, 2004b), Brey (2003), and Edwards (2003).

This paper outlines several methodological questions that we need to confront. The chief question is how can we identify the "nature" of technological change and its varied cultural consequences—including social, political, institutional, and economic dimensions—when our different research methods yield contradictory results. What can we say, in other words, when our *findings* about technology follow from the *framings* of our inquiries? In slightly different terms, can we combine insights from the fine-grained "social shaping of technology" with complementary broad-gauged approaches accenting the "technological shaping of society?" As a way forward, the paper suggests conducting multi-scale inquiries into the processes of technological and cultural change. This will involve recognizing and conceptualizing the analytical scales or levels on which we conduct inquiry (very roughly, micro, meso, macro) as well as outlining strategies for moving within and between these scales or levels. To slightly recast the point of geographer Brenner (2004, p. 7) we should aspire to a "theoretically precise yet also historically specific conceptualization of [technological change] as a key dimension of social, political and economic life."

1 Do machines make history?

This section discusses how differences in analytical scales or levels yield divergent views on how and whether technology is an independent force for historical change. I develop my general argument starting with a controversy in business history concerning the timing, nature and dynamics of the industrial revolution. This case illustrates common aspects of the analysis of technology and culture; it is in no way anomalous or oddball. Other examples from diverse periods and fields might equally illustrate these points (see Misa 1988, 1994). Finally, on a reflexive note, this controversy is of special interest to me since it prompted my notions on the importance of scale in conceptualizing social and technological processes.

It is a commonplace that coal was closely bound up with broad social, economic and technological changes that historians once confidently labeled the "industrial revolution." Two generations ago, historians conceptualized the industrial revolution as a technology-driven process of wrenching economic change and social dislocation. First in Britain, then soon enough across Europe and North America, modern industrial society took form in and through coal-fired steam engines, iron that was smelted with coal and then refined using steam power, and the coming of the factory system. For these authors, the industrial revolution brought a revolution in work, leisure, consumption and wealth across the Western world and profoundly influenced the West's relations with the rest of the world through imperialism and development. "The Industrial Revolution marks the most fundamental transformation of human life in the history of the world recorded in written documents," wrote Eric Hobsbawm in his classic *Industry and Empire* (1968, p. 13). At the time, sociologists of diverse theoretical orientations sought to understand the genesis of "industrial society" and the even broader process of "modernization."

But by the 1970s, economic and social historians were reassessing whether the industrial revolution constituted such an abrupt change after all. Once they started actually counting steam engines and large factories, even in rapidly industrializing

Britain, there simply were not enough of them to drive the lock-step social and economic changes that the earlier models and theories had presumed. During early industrialism, perhaps only one British industrial worker in 10 ever saw the inside of a proper large-scale factory, with the majority laboring instead in small-scale industrial sites or even in backyard shops. In the United States the classic coal-fired, steam-driven factory was even less prominent, owing to the plentitude of wood that could be made into charcoal for fuel and the abundance of rivers that could be harnessed to provide waterpower for industrial activity. Waterpower remained the dominant industrial power source for many decades. In Sweden, like the United States, charcoal remained a vital industrial fuel for far longer than could be predicted by the coal-centered models inspired by Britain. The Netherlands conspicuously lacked any domestic supply of coal yet enjoyed substantial economic growth. These empirical findings challenged the prevailing assumptions about the centrality of coal. Either these economically successful countries suffered worrisome "lags" behind Britain—or the underlying models that focused on coal and steam were flawed. It gradually became clear that "modern industrial society" had diverse origins and was not a monolithic historical entity or certain "stage" or "phase" of development.

Given this backdrop historians debated the timing, nature, and causes of the industrial revolution from many angles. One way or another, coal was regularly at the center of things. In 1972 Alfred Chandler, a preeminent figure among business historians, published a broadly argued article in *Business History Review* that posited a new, overarching model for U.S. industrialization that returned coal to historical center stage. Chandler contended that the industrial revolution in America began not with New England's cotton textile mills, a favored site of historical attention ever since colorful stories were unearthed of Samuel Slater and his clandestine industrial espionage, but with the anthracite coal mines of northeastern Pennsylvania (see Fig. 1). The argument was a classic instance of Chandler's distinctive style of structural-functionalist analysis, where the analyst relates the "structures" of a business or industrial organization to the "functions" they perform. Only later did I come to see that the consequent Chandler-Winpenny controversy revealed an underlying—and unspoken—methodological divide.

In his essay, "Anthracite Coal and the Beginnings of the Industrial Revolution in the United States," Chandler (1972) argued that anthracite coal triggered a major structural change in American industry. While charcoal derived from wood had earlier been the country's principal industrial fuel, beginning in the 1820s anthracite coal generated fundamental changes in many sectors of industry and across the entire country. Not only was anthracite a particularly hard and clean-burning coal, which proved ideal for use in oversize iron smelting furnaces that would have crushed charcoal or softer coals. The anthracite fields in northeastern Pennsylvania were also attractively near to urban markets up and down the Atlantic coast. Consequently a rash of canal-building ventures to ship anthracite to these markets created an efficient transportation network that moved coal, other raw materials, and finished goods from mine to factory to warehouse. Houses were warmer, iron mills grew larger, cheap iron flooded onto the market, factories using this iron emerged for large-scale production of many diverse goods. Soon enough railroads completed the development, at once using iron for rails, locomotives, and rolling stock as well as providing quicker and more regular transport.

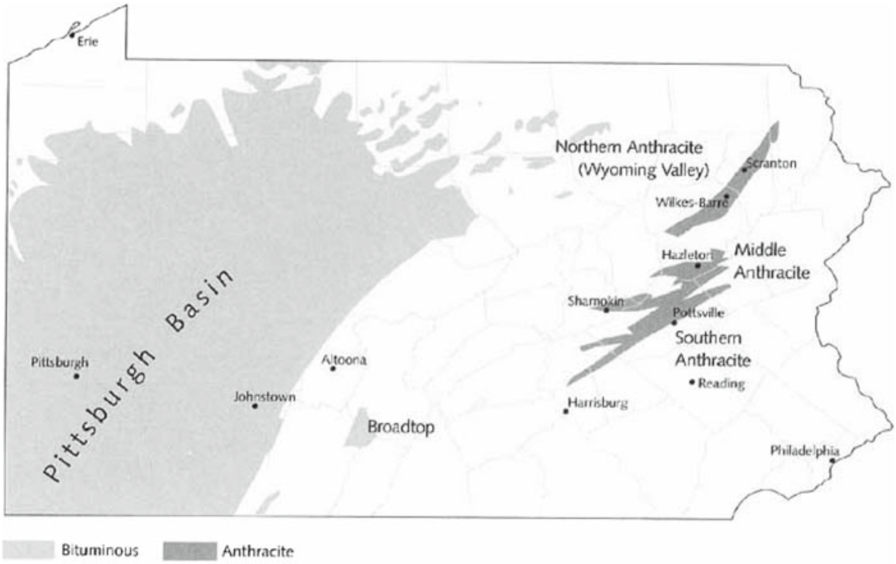

Fig. 1 Coal fields in Pennsylvania

In short, the factory system at the center of the industrial revolution could be traced to dynamic forces unleashed by anthracite coal.

The new anthracite regime brought major changes. No longer were industrial enterprises limited by the imperative to harvest trees and make them into charcoal, or by the finite size and seasonal uncertainty of industrial water power; these limits to industrial and economic growth simply vanished with the provision of a cheap, readily mined mineral-based fuel. In Lewis Mumford's terms, anthracite pushed the U.S. from the earlier water-and-wood based Eotechnic era into the coal-and-iron based Paleotechnic era. In Chandler's terms, anthracite from Pennsylvania triggered the industrial revolution, a nation-wide economic and institutional change. Soon enough, after railroads crossed the Allegheny Mountains running through central Pennsylvania, the huge bituminous coal fields of the western Pittsburgh region came onto the market and into play as an historical explanatory factor.

In several tightly argued books, Chandler elaborated his characteristic style of analyzing economic and institutional change. Gone were the robber barons whose colorful buccaneering and financial chicanery had captivated an earlier generation of business historians; rather, Chandler placed foremost the emergence of orderly patterns, large-scale institutions, and a new class of managers that presided over economic growth. Chandler sidelined such figures as Andrew Carnegie and Henry Ford, who may have been brilliant, if impulsive entrepreneurs, stressing instead that economic growth and institutional change were the result of progressive managers and systemic rationalizers such as Pierre S. du Pont and Alfred P. Sloan. The multifarious technologies of mass production also played a crucial explanatory role, especially in his *Visible Hand: The Managerial Revolution in American Business* (1977). Capping a symposium discussion of this Pulitzer-Prize winning book, Chandler (1988, quote

p. 460) argued that two factors were principally responsible for fundamental change in American industry: “technology and markets [were] basic determinants of the size of firms and of concentration in industry.” Across his many scholarly works, Chandler showed a decided preference for identifying large-scale patterns, seeking functional relationships, abstracting lessons from carefully selected case studies, and accenting the actions and attainments of far-seeing rational actors. With his focus on patterns and functions, Chandler simply skipped over topics that business historians had earlier favored such as the nation’s recurrent economic panics, the grinding working conditions, the play of politics, and the essential uncertainty of economic change.[4]

Chandler’s work was immensely influential in business and technology history.[5] Yet, curiously, few historians directly tested Chandler’s bold hypotheses and striking generalizations. Two years after *The Visible Hand* appeared, Thomas Winpenny published an essay, also in *Business History Review*, that openly challenged Chandler’s thesis about anthracite and industrialization. In “Hard Data on Hard Coal” Winpenny (1979) sharply critiqued Chandler’s suggestions about anthracite’s catalytic role in the American industrial revolution. Drawing on his own detailed research on one industrializing community in eastern Pennsylvania, Winpenny (1984) flatly denied Chandler’s predictions of dramatic and wrenching changes driven by anthracite, such as might be reasonably expected near the epicenter of a “revolution.” Winpenny’s community developed industrial activities and even a factory-based textile industry, but these activities did not seem to be greatly influenced by anthracite. And, remember, this was in the very shadow of the anthracite region.

Eventually, I came to see that Winpenny’s arguments did not so much disprove Chandler’s overarching thesis, but rather presented findings at a different scale or level of analysis. Chandler and Winpenny were simply not on the same page, methodologically and conceptually, much like today’s scholarly communities that offer divergent interpretations of technology and change. There are several reasons why this was so. While Chandler focused on broad causal patterns that he believed to be valid across time and space—where some identified event or factor causes something else to happen, often hundreds of miles away—Winpenny was telling a tightly focused story that accented complexity and diversity. His industrializing community in the 1850s utilized a variety of fuels, including wood for making bricks, pottery and bread; soft bituminous coal for blacksmiths and the gas company; charcoal for the town’s iron forge; and anthracite coal for the cotton and iron mills. And where Chandler pointed to the systemic economy-wide effects of dramatically cheaper anthracite fuel, Winpenny computed the actual fuel savings, using detailed mill-by-mill data, and found that using anthracite saved each mill only a few pennies on the dollar in overall costs.

Factories came to Winpenny’s community all right, but anthracite had surprisingly little to do with it. Winpenny saw a local story with its own dynamism. The community’s entrepreneurs, swayed by the “gospel of steam cotton mills,” mobilized their

[4] These themes have returned in the new post-Chandler business history pioneered by Scranton (1997). For a resume of Chandler’s impact on business history, see John (1997) available at www.thebhc.org/publications/rjbhr.html.

[5] See appraisals by John (1997) and Usselman (2006).

local financial resources to build factories in the first place and then employed the town's surplus female labor in operating them. Local leaders were also mindful of the rising nation-wide demand for cotton and took good advantage of protective tariffs that, for a time, kept foreign imported cotton off the U.S. market. Winpenny (pp. 254–255) allowed that his complex multifactor explanation for his town's industrialization was not "elegant and tidy." Chandler, he concluded, had simply failed to "establish a cause-and-effect relationship" between anthracite and the factory system.

In his pointed reply to Winpenny's charges, Chandler appeared to rebut the points of disagreement one after the other. For years, it puzzled me whether anthracite really did—or did not—cause the industrial revolution in the United States. Then I began noticing numerous instances where historians and philosophers examining technology and culture similarly "talked past" one another and where the divergent *scale* of their research and analysis seemed to be a crucial but often-hidden problem. To understand the underlying methodological and conceptual issues, there were abundant clues in Chandler's original 1972 essay and especially in his 1979 rejoinder. Although Winpenny evidently took Chandler's anthracite hypothesis to be universal—for the economy as an aggregated whole as well as for individual towns and even particular cotton mills—Chandler wrote explicitly that he "did not intend" his essay "to explain changes in manufacturing in one specific town" (p. 255). Chandler certainly presented numerous instances where early industrial enterprises used anthracite coal, mobilizing evidence that was consistent with his hypothesis. He finally reiterated his core claim that "the coming of anthracite coal altered the technology of production and the ways of work in the nation's leading industries" (p. 258). One might say that Chandler gave a functional description of the relationship between anthracite coal and the industrial revolution. After all, it is not surprising that some relationship existed between the discovery and development of a cheap high-quality industrial fuel such as anthracite and the growth of industrial enterprises that consumed this fuel. He did not, however, establish a rigorous, linear "cause-and-effect" relationship between them. Just one step further: it's far from clear that anthracite was a necessary and sufficient condition for the industrial revolution.

Reflecting on this debate and its wider echoes in the literature, I began to see that the "scale" or "level" on which scholars posed their questions and sought their explanations was just as fundamental as the raw evidence they cited. Many other authors followed an explanatory method similar to Chandler's, which we can term macro-level analysis. These authors frequently study "large" things such as a national economy or a generalized mode of production (e.g. industrial revolution, information revolution, post-Fordist economy). While often presenting individual case studies, authors using a macro-level approach deploy them to draw general lessons, to trace the emergence of structural features, or as instances for higher-level abstractions. Their chosen historical actors are prototypically rational problem-solvers that confront challenges and in the end get the right answers; they are almost never driven by emotions or raw power or greed. These actors typically create order in the form of large business institutions or technological systems.

There is clearly an elective affinity between these macro-level accounts that accent order and rationality and the modernist era's drive for control, order, and predictability. Such authors as Chandler, James Beniger (1989), David Landes, many macro-level sociologists and modernity theorists, and for a time most philosophers of technology, adopted macro-level methods of research and analysis and generated results that followed from these methods (Brey 2003; Misa 2004b). These authors focused on the large-scale processes of ordering, rationalizing, disciplining, standardizing, and modernizing that they saw as self-evident in the modern world around them. (They did not pay much attention, however, to the countercurrents of protest, struggle, conflict, and contestation that become visible at the micro-level of analysis and that became the special passion of postmodern critics.) Very often, some concept of technology was at the center of these macro-level explanatory accounts. Ultimately, essentialist abstractions such as Heidegger's "enframing" or Weber's science-laden "rationalization"—which posit transcendent forces or inherent properties of the technical world that have certain and definite impacts on the human condition—are exemplary instances of macro-level analysis.

By contrast, empirical accounts that focus like Winpenny's on individual situated case studies employ a distinct explanatory method, which can be termed micro-level analysis. Frequently enough, the macro- and micro-level analysts are not aware of the methodological divide between them. This can be amusing as well as painful. Instead of using the macro-level strategy of "generalizing upward"—using chosen case studies to elaborate a more general or abstract observation—micro-level analysts often "dig downward" and plumb the depths of their specific cases' complexity. Often they can point out the shortcomings of order-driven macro-level patterns by emphasizing the variety of historical experiences, the persistence of varied forms of disorder, and the contingency of historical processes. Social constructivist accounts of science and technology frequently claim to explain the emergence of scientific facts and technological artifacts through micro-level accounts of the attendant controversies and disagreements. In this view, science and technology are thoroughly social processes (contested and contingent), not the end result of some overarching process of rationalization or modernization. Once again, for micro-oriented social constructivists as well as for macro-oriented theorists of technology, the "nature" of technology depends crucially on the framings of their inquiry.

Factories, supposedly, were the essence of the industrial revolution. Yet in micro-level historical accounts of the industrial revolution, factories were by no means the only mode of production: recent historical accounts of the industrial revolution emphasize such alternative modes as household production, independent artisans, central workshops, and diverse forms of "sweated labor." And, where they truly existed, large-scale factories might take form for a variety of reasons: the desire of mill owners to discipline their labor force through long working hours, to control the quality of the goods they produced, to take full advantage of accessible water power or cheap steam power, or to provide an advantageous site to deploy special production technology. In the older historical accounts in which machines made history, Richard Arkwright's famous "water frame" spinning machines required the factory mode of production; but when you look carefully, at the detailed micro level, the decisive moment was the decision by Arkwright and his business partners to license the required patents only to large mills (1,000 spindles or more) so that cases of patent infringement could be easily spotted and quickly suppressed. Each of these highly detailed and locally situated accounts undermined the historical grounding of explanatory appeals to transcendent rationalization or modernization processes.

Actors in micro-level accounts may or may not behave rationally. They are frequently motivated by a wide variety of emotions, interests, and inspirations. For example, Winpenny's industrialists considered such varied factors as local labor supply, prevailing notions of gender, protectionist public policies, and economic demand for cotton, not solely a strict calculus of fuel costs. Often, as the above discussion of Arkwright's factories illustrated, micro-level analysts can significantly modify or undermine rational reconstructions of complex processes. These discussions on the industrial revolution played out against the backdrop of the wider debate on technological determinism. In general, many scholars embraced the social construction of technology to confront technological determinist accounts that presented a tidy technology-driven portrait of change. Thus, whereas older accounts of the industrial revolution once approvingly quoted Karl Marx's technological determinist aphorism that "the handmill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist," historical accounts of the industrial revolution now point to such varied explanatory variables as social structure, land-tenure practices, gender norms, access to markets, patent laws and strategies, as well as technological factors such as steam mills. The state-of-the-art historiography on the industrial revolution—namely, that macro-level accounts generate one view of technological and cultural change, whereas micro-level accounts generate an opposite view—is an apt if frustrating instance of the general scholarly debate on technology and culture. Are there ways of bridging this gap and navigating the empirical turn?

2 Micro and macro

Much more than an accurate account of the historical coal economy is at issue here. Indeed, many penetrating critiques of technology have effectively used macro-level methods. Among the notable examples are Heidegger's notions about "enframing," the Frankfurt school's critiques of rationalization, and Jacques Ellul's omnipotent "technique" that structured and constrained modern society. Such contemporary writers as Bill McKibben and Bill Joy also posit worrisome trends in technology and society, suggesting that technology is dangerously out of control.[6] These critiques place the issue of technological determinism front and center. Commenting on McKibben's *Enough: Staying Human in an Engineered Age* (2003) Wendell Berry, the noted critic of technological society, writes "Your book [raises] the now inescapable question: Are we willing to submit our freedom and our dearest meanings to a technological determinism imposed by the alignment of science, technology, industry and half-conscious politics?" Posed in these terms, this is hardly a question on which Berry expects a neutral and detached debate.

Whether or not they agree with these critical perspectives on technology, empirical researchers often experience discomfort or dismay with Joy and McKibben's overarching and schematic analysis, weak argumentation, and problematic presumptions about

[6] Winner (1977).

the nature of technology. McKibben obviously flirts with an overarching essentialist stance on technology, with provocative illustrations carefully chosen from genetic engineering, robotics, and nanotechnology, and mixed together with the wild and wooly claims of technological enthusiasts. His technical world is all of a piece, and its inexorable spread threatens humanity. And, yes, you've heard it before: "Agriculture is now the mechanized food industry, in essence the same as the manufacturing of corpses in gas chambers and extermination camps, the same as the blockade and starvation of nations, the same as the production of hydrogen bombs," as Heidegger phrased the essentialist critique of technology in 1949.[7] Here, then, is the dilemma: how can we combine the sweep and vision of macro-level accounts with the detail and bite of micro-level accounts? A realistic diagnosis of the problems and possibilities of technology and society hangs on this question. Developing effective technology assessment strategies and feasible steering modalities—and the political support for their realization—also demands engagement with these analytical issues.

Before proceeding to discuss three bridging strategies, let me summarize the points made so far. The key point is that the distinct analytical scales or levels on which scholars conduct their analyses correlate strongly with divergent views on whether and to what extent technology drives change. Authors who portray technology or technology-driven processes like rationalization or modernization as a powerful, even autonomous agent in historical change often use macro-level analyses, whereas authors who repudiate the varied claims of technological determinism typically use micro-level analyses. The micro-level literature is particularly strong in recent agency-centered STS work, such as Bijker and Pinch's social construction of technology, Latour and Callon's actor-network theory, the new (post-Chandler) business history, and most work in history of technology and science. Macro-level accounts embracing technology as a key agent of change include structural accounts like Landes' *Unbound Prometheus* and Beniger's *Control Revolution*, the tradition of modernity studies represented by such authors as Anthony Giddens and Ulrich Beck, and even Karl Marx's summaries and aphorisms.

These distinct methods are powerful tools that do different things. Accordingly, they lead to divergent perspectives on technology. Micro-level methods are effective at critiquing technological determinism and examining controversies in technology and science, often showing underlying political, economic, or cultural dynamics that are at play (possibly in addition to rationalistic arguments about agreed-upon evidence). This method is also the choice when scholars wish to embrace variety of experience and to demonstrate "messy complexity" and thereby to critique over-ordered accounts. In sum, micro-level accounts show the "nature of technology" as contingent, constructed, and contested. But micro-level accounts obscure as much as they reveal. In focusing closely on a set of actors, micro-level accounts often conceal the wider context; they make it difficult to understand background conditions, including pre-existing structural constraints. Asymmetrical power relations are difficult for micro-level accounts to properly visualize and carefully analyze (Klein and Kleinman 2002).

[7] Heidegger quoted in Feenberg (2000, p. 297, note 3).

Likewise, macro-level accounts are powerful tools for distinct purposes. Macro-level accounts naturally lend themselves to examining larger or aggregated units of analysis. As noted with Chandler's account of the industrial revolution, macro-accounts are useful for inferring or deducing overarching patterns and for fashioning accounts of increasing order and stability. If macro accounts are "order-driven," micro-level accounts can be described as "disorder-respecting." By passing over instances of conflict, macro-level accounts can leave the impression that large-scale patterns of industrialization or modernization unfolded without conflict. Such a perspective also shows the "nature of technology" as rational or even inevitable instead of contingent and contested. Macro-level accounts can also be a potent tool for critique of technological society and culture; by showing the negative consequences of industrialization or rationalization or modernization they call into question society's commitments to such processes.

3 Multi-level analysis

If my intuition is correct that "findings follow framings," micro-level accounts as well as macro-level accounts can each give us valid if partial insight into the nature of technology and society. Can we take the next step, then, of recognizing these varied scales or levels, analytically moving between them, and combining their perspectives and insights? The remainder of this paper outlines three promising strategies for doing so. I am not searching for some Grand Theory but rather seeking promising avenues for further exploration. The first two of these strategies were suggested by colleagues confronting methodological problems, while the third came from my efforts to write a long-span history of technology and culture while avoiding the conceptual trap of remaining at any single analytical scale or level.

Methodological concerns were unavoidable in the *Modernity and Technology* volume. This project began with the pressing need to understand the complex construct of "modern technology" but we quickly realized that the scholarly communities that were ideally situated to do so did not speak the same language, they preferred distinct styles and scales of research, and they even held divergent background assumptions about the nature of technology. I remember distinctly the challenge we faced in bringing a group of philosophers of technology together with a group of STS scholars in a seminar we convened at Twente University. In an early meeting someone suggested, innocently enough, that each group simply share a broad thematic question that might serve as a common point of departure. "What is technology doing to us?" was the philosophers' characteristic question. The STS scholars visibly squirmed at the implicit technological determinism of this question, quietly puzzled how to shift the question to recognize the social shaping of technology, then eventually replied "What are we doing to ourselves through technology?" Here then was the dilemma in native terms: how to reconcile the macro-level approach that viewed technology as an independent agent impinging on humans, with the micro-level approach that viewed technology as a result of underlying social and cultural and political processes. While we never reached a tidy resolution, we did need to recognize disciplinary differences and methodological issues and to grapple with them.

Philip Brey's strategy of *interlevel analysis* for bridging the gap between micro- and macro-level accounts reflects his training as a philosopher. Brey (2003) argues forcefully that technology has a pervasive role in the making of modernity, even terming it a "necessary condition" for the functioning of modern institutions. Understanding technology as a defining feature of modernity is necessary, he reminds us, since not only do modern institutions depend on technology but also many modern functions and practices are crucially mediated by modern technologies. Modern culture, to take just one example, is a thoroughly technological culture. Brey notes that technologies are not the passive material base or inert substrate for cultural forms but rather an active medium through which cultural forms emerge. Whatever one makes of the "information technology" revolution, its cultural consequences have been just as profound as its economic or political ones. Pretty clearly the cultural consequences of email, instant messaging, chat rooms, and various social networking sites have allowed new communities to form while at the same time disrupting other communities.[8]

Brey notes that despite much sound and fury there has been little progress connecting and relating the micro- and macro-levels of analysis. (Work proceeds fitfully on the closely-related agency-structure problem, too.) He observes that "micro" and "macro" are only rough distinctions that can hamper recognition of the variety of levels that are typically present. In a more analytical vein he argues that there are two, distinct dimensions on which the micro and macro levels differ: size of the unit of analysis, and degree of abstraction. Sometimes, macro-level analysis deals with phenomena that are both "large" and "abstract" (such as modernity or the post-Fordist economy) but there are many counter-instances that confound any one-to-one mapping between these dimensions. For one such counter-instance, the "modern self" is more abstract, yet smaller, than a "group of college students at their graduation." "The locations of capital cities around the globe" is a second counter-instance, both large and concrete. Furthermore, Brey reminds us that size can equally be a problematic category. An absolute metric of size is not crucial, he argues, but rather a set of part-whole relations. A social system is "larger" than a particular social group, since a social system can contain that social group; likewise an economic system is "larger" than a single individual, whether or not there is any exact measurement.

In these terms, Brey replaces a dichotomous view of micro and macro, offering instead twin hierarchies (degree of size and degree of abstraction) that are each continuous in themselves and that can point toward several different types of inter-level analyses.[9] Brey suggests four possibilities. In a *decomposition* or reductive analysis, larger units are analyzed in terms of smaller ones (for instance, financial markets at the

[8] In the 1990s, our young family lost a valued baby-sitter to a chat-room romance that blossomed into marriage and prompted a 1,000-mile move.

[9] Even though Brey does not stress the point, I believe the intermediate "meso" level also can offer a way of moving along a continuum from micro to macro. For instance, "financial markets" at the macro level comprise not merely micro-level "individuals" but also intermediate actors and institutions such as stockbrokers, government regulators, mutual funds that aggregate investors' capital, and an entire world of financial reporters, financial databases, and financial backroom activities (increasingly outsourced to India and China).

macro level can be analyzed through the behavior of individuals at the micro level).[10] A *subsumptive* analysis moves in the opposite direction. One examines smaller units by setting them into some larger structural or functional pattern of which they are a part. Examining a modernistic research and development laboratory, one might expect to find standardization or rationalization or some other "modern" characteristic. Similarly, in examining a postmodern "edge city" one might look for fluid networks or the lack of central control characteristic of a post-Fordist economy or postmodern society. In a *deductive* analysis, one examines a concrete unit as a revealing subclass or token of a general phenomenon. One can try to deduce features of a particular bureaucracy by using a general theory of modern bureaucracy, working in this case from the general to the specific. The direction is inverted in *specification*, where one examines some general or more abstract phenomenon through studying one or more specific types or tokens. Social science research involving the interplay of theory and case studies is a common instance of specification.

Historian Edwards (2003) echoes many of Brey's observations on the interweaving of modernity and technology, but develops a distinct strategy of *multi-level analysis*. He highlights the crucial dimension of time. Time is particularly vexing because while technologies may be designed, constructed, and put into use in the relatively short term of months or years, their broad consequences might become evident only after decades or even centuries (Kranakis 2005, p. 809). The concepts of (physical) force and social organization, when added to time, allow Edwards to create a continuously varying set of criteria for evaluating phenomena at widely varied scales: macro, meso, and micro. Edwards suggests that differences in scale result in radically different views of technical infrastructures. For instance, large technological systems such as railroads, electricity networks, and telephones display a life cycle of innovation and system building, diffusion across geographical and political boundaries, and finally stability and resistance to change, "a developmental pattern *visible only on historical time scales*" (decades to centuries). Edwards echoes the point that large technical systems are not merely hardware but they also meaningfully incorporate legal, organizational and political elements. Instances of the "capture" of government regulatory agencies by the large technical systems they were supposed to control can be interpreted as the systems gaining control over their environment.

Large technical systems are best understood in the medium-term historical timespan, and Edwards suggests a medium-term or "meso" scale on which they operate. Just as certain developmental dynamics can only be seen in this medium time span, so too do other characteristics of technology—and hence alternate views of its "nature"—become visible on shorter as well as on longer time spans. Turning to the micro level, where typical time spans are on the human scale of hours to years, Edwards summarizes the well-known work in the social construction of technology and with the "user heuristic" in technology studies. Here he gives particular attention to how close attention to the micro-level can alter what we take to be the "nature" of modernity. Accounts of modernity that stay at the aggregated macro level typically portray individual humans

[10] While suggesting a reductive analysis, Brey is careful to express his wariness about reductionist analysis, where the higher level is held to be nothing more than the lower level.

trapped in systems of dominance and control, whereas it is difficult for these accounts to recognize instances of conflict and protest that may undermine these systems of control. “At the micro level, ‘modernity’—as subjection, control, dominance of systems, panopticism—becomes slippery and difficult to locate,” Edwards suggests.[11] His point is emphatically not that one level or another is any privileged window into truth, but that infrastructures embody complex and even contradictory characteristics (e.g. disciplining as well as protest) and that attention to multiple scales is necessary to reveal and understand this complexity and contradiction. Inquiry at any *single* scale will simply fail to produce the desirable multi-scale perspective.

At the largest, “macro” scale Edwards identifies yet a third distinct set of phenomena. Here he suggests how and why it can be revealing to adopt a functional analysis such as Chandler’s or Beniger’s. At the macro level, stretching even beyond historical time spans, what matters most is not the particular form of a technical system but rather its broader function. Telegraphs grew rapidly in the nineteenth century because they were a fast if expensive alternative to the slower but cheaper postal system. Yet in January 2006 Western Union, the once-powerful commercial telegraph monopoly, sent its final telegram. On the historical time scale, infrastructures like telegraphs can and do die. But while the specific form of the commercial telegraph industry is gone, the function of communication is obviously alive and well in the form of email, fiber optic cables, satellite links, and wireless phones. Similarly, our present fascination with the “information age” has spawned a wide-ranging body of scholarship that locates the roots of the information age at various points stretching back into the eighteenth century. In *When Information Came of Age*, Headrick (2000) points to the emergence of science and statistics, new forms of maps and graphs, the spate of encyclopedias and dictionaries, and the profusion of postal and telegraphic systems. All were important ways of creating and organizing information. On this time scale, spanning several centuries, the function of managing information is important—not its specific technical or organizational form.

The third and final strategy for bridging the gap between these analytical levels and their distinct perspectives on technology comes from grappling with the conceptual problems of writing a long-span history of technology. *Leonardo to the Internet* (2004a) spans a bit more than five centuries, from the early Renaissance through to present-day globalization. Although I began this book as a survey of the field, I also wanted it to grapple with the conceptual issues regarding the technological shaping

[11] Edwards here refers obliquely to authors who have taken a certain view of modernity (as subjection, control, dominance of systems, panopticism), such as Heidegger and Foucault. One can certainly find “evidence” that supports their view that modern large-scale technical systems can be oppressive or dominating. Yet I believe Edwards is raising a more subtle point, namely, that such modern technical systems are not inherently or necessarily—let alone in essence—oppressive or dominating. They do appear to be so on certain scales of analysis (meso). Alternately, if you examine large technical systems at the micro level (see e.g. the ‘user heuristic’ advocated by Fischer (1992) in analyzing the early U.S. telephone system) one finds a very different picture: at the micro-level, users are not coerced into accepting a given system, but they can and often do exercise agency to alter or change the technical system. This user agency is difficult to see if one frames and conducts an inquiry at the meso-level, and probably impossible to see at the macro level. Edwards, then, argues a specific instance of the general claim that “findings follow framings.” For user agency, see Fischer (1992); Kline and Pinch (1996); Borg (1999); Kline (2000); Blaszczyk (2000); Oudshoorn and Pinch (2003); Nye (2006); Yates (2006); Edgerton (2007).

of society and the social shaping of technology. The dilemma was how to do this, and yet write an accessible book that was not crippled by analytical jargon. I believe the word “meso” appears nowhere in the entire book, yet it is suffused with this intermediary concept. The book creates fine-structured (micro-level) narratives about specific people and technologies that embodied and expressed social, cultural and political aspirations while also showing how those technologies concurrently shaped subsequent social and cultural developments. I stick as close as possible to individual people and specific institutions that are characteristic of eight distinct historical “eras.” (Looking back one can see instances of each of Brey’s four types of inter-level analysis.) Yet I also readily generalize to bring out broader (macro-level) patterns and developments.

Conceptually, the chapter on the industrial revolution was by far the most difficult. I started out intending that chapter to have a traditional “agents of change” structure with sections on coal, iron, steam, and cotton, the principal technological sectors in the older model of the industrial revolution. When I began working on this chapter, however, I discovered a much more complicated picture and a fiendishly complex historiography. How was I to discuss the key technologies of the industrial revolution while adequately acknowledging the social and economic historians whose research severely critiqued the very idea of an industrial revolution? Social historians were finding that surprisingly few industrial workers ever saw the inside of a factory building (as mentioned above), while economic historians studying the aggregated statistics found evidence only of slow and measured growth—but again no revolution. The Chandler-Winpenny controversy echoed in my head. With a functional (macro-scale) approach like Chandler’s I could still stress the transformative power of the key industrial technologies. Alternately, with a closely focused (micro-scale) approach like Winpenny’s on individual industrializing communities, I could show that there was no such thing as an industrial revolution. Neither option seemed entirely satisfactory.

As a way forward, I decided to confront the variety of industrial experiences head-on while exploring the distinctively industrial character of the time through comparative analysis. I first looked for the largest geographic site of industry in Britain, and was both surprised and pleased to find that it was London. London had somehow been passed over in historians’ rush to examine the industrializing textile towns, but it was Britain’s leading shipbuilding and engineering center well into the nineteenth century. It was also the site of the industrial-scale porter-brewing industry, about which there were many colorful stories as well as rigorous business histories. Next I wanted to examine a classic cotton textile town, and settled quickly on Manchester. Again it proved a good choice. The historical record was rich in both the basic story of technology and factories (with several recent business histories) as well as the large-scale social and political protests that erupted in Manchester. Everyone it seemed came to Manchester and wrote about their impressions; Friedrich Engels stayed longer than most visitors, working in his father’s Manchester textile mill and using his paycheck to bankroll one Karl Marx. For the third and final region I wanted a non-traditional site of industry, one where factories were not the key. I might have chosen elsewhere but I liked Sheffield, and again its distinctive history as a network of smaller shops making world-competitive steel goods seemed a counter-current and yet compelling story.

By pitching my analysis at the micro level, I could easily show the varieties of industry and the varied paths that distinct regions took in industrializing. I might have stopped here. But I was interested in exploring "industrial society" and began looking for commonalities among the three different city-regions. I had often read about the dire working and living conditions in industrializing towns, but I was really shocked to read the actual mortality statistics. Industrializing Sheffield, especially, suffered a sharp deterioration in living conditions. The region had at first industrialized using waterpower, which resulted in a markedly decentralized pattern of industry (more than 100 water power sites were distributed along the four rivers that flowed into the town) and a great deal of part time and seasonal work. This was important in the grinding trades—in which skilled workers finished the edges of needles, knives, forks, scythes, and other steel tools—since the workers might have a chance to clear their lungs between bouts of grinding.

When steam came to the grinding trades, however, the outlying water mills closed up and the seasonal pattern of work ended. Steam-driven grinding mills ran year around, and workers' 12-h shifts never gave them time to fully clear their lungs. "Till steam-power was introduced in the trade, towards the end of the last century, the grinders' disease was scarcely known," stated an employment report in the 1860s. Death rates for grinders soared. Death rates for small children also soared due to the extreme crowding that resulted when employment as well as residences were centralized in the most densely packed districts of the town. Foul air, unsanitary water, filthy privies, and shamefully high death rates—Sheffield had this deadly steam-driven concentration in common with London and Manchester.

4 Conclusion

This essay started with a simple observation about a complex conceptual puzzle. The puzzle concerns the "nature" of technology and culture (specifically, the relationship between technological changes and the accompanying social, political, institutional, economic and cultural changes) and what we can know about it.[12] There is surprisingly little agreement in the scholarly literature about this key question, despite its obvious relevance to understanding the contemporary world. I have identified two broad traditions, which can give an overview or mapping of this contested intellectual terrain. Time and again, scholars that seek to demonstrate the transformative impact of a given technology, system, ensemble or network use a characteristic method. This method involves what I have termed "macro" level analysis. In part these scholars study "larger" units of study, but even more importantly they use carefully chosen examples to show the ordering, disciplining, rationalizing and modernizing processes that are associated with technology. Supporters of technology sometimes use this method to tell positive and optimistic stories about "the machine that changed the

[12] In my view, the key philosophical problems here are epistemological, i.e., questions about what we can know and how we can know. Postulates about ontology seem highly problematic since they appear to be trans-historical claims about the nature of existence and being. My sense is that for any ontological claim, a great variety of empirical evidence, pro and con, might be located. But see the explorations by Hecht (2002) and Mol (2002).

world." Yet critics of technology from Heidegger through to contemporaries such as Joy and McKibben also deploy similar, generalizing macro-level methods. The critics' diagnosis is that technology is responsible for many of the problems that humans face today, and they sometimes voice the prescription that the world would be better off with less technology (or possibly a suite of technologies carefully chosen to better sustain and support human values).

Conversely, scholars seeking to deny various forms of determinism, including what they consider to be a debilitating technological determinism, take up a distinctly different method. This method involves what I have termed "micro" level analysis. These scholars study locally situated developments with great attention to the underlying diversity and variation. Instead of asking a broad question such as what is the nature of the industrial revolution, they inquire into the detailed social and technological processes involved with individual industries, individual factories, or even individual workers or managers. Their analysis is typically fine-grained, with great awareness to detail and specificity, and can often show change processes as contested and contingent. These scholars, too, mount a critique of contemporary society and culture but it is not aimed at the "nature" of technology, inherently good or bad. These scholars focus at the importance of users' agency in shaping emerging technologies—where social and cultural choices can significantly alter the types of technologies that a society develops, adopts, and lives with.

It would be a mistake to see this discussion separate from the practical and policy realms. For example, technology assessment took institutional form in the early 1970s when the "impact" tradition was the dominant theory of technology. Scholars who showed the impact of technology on society, typically using macro-level analyses, generated social awareness and political justification for governmental efforts to monitor technical developments, to provide so-called early warning about potential issues and problems, and sometimes to attempt intervention (through regulatory, taxation, subsidy, or other incentive programs) in the process of technological development. The impact tradition grounded the technology assessment institutions that took form in the U.S. and in Western Europe.

The policy discourses and scholarly discourses about technology developed along two separate paths beginning sometime in the 1980s. Scholarship in technology studies flourished with the lively debate on technological determinism, the rise of contextual studies in history of technology, and the excitement about the social construction of technology (Bijker et al. 1987; Staudenmaier 1990; Bijker and Law 1992; Smith and Marx 1994). Academic work in technology studies might have been institutionally connected with technology assessment, but with several exceptions (see Rip et al. 1995; Schot 2003) it was not. In the early 1990s low ebb was reached in the U.S. There the pioneering Office of Technology Assessment was under fire from powerful political enemies. Many U.S. academics were, I believe, insufficiently concerned with its fate in some measure because its methods and outlook seemed outmoded and irrelevant. Congress closed down the OTA in 1995.[13] Meanwhile technology assessment

[13] See the 'legacy' site at www.wws.princeton.edu/ota/

in Europe developed in close connection to national parliaments (Vig and Paschen 2000; Decker and Ladikas 2004).

Our efforts to “bridge the gap” or “navigate the empirical turn” should be mindful of the cultural and political field that is at play. Macro-level studies that can show the impact of technology on society and culture are, it seems, necessary in the practical realm to generate political legitimation for technology assessment efforts. Equally important are the micro-level studies that can show contingency and the role of agency in technology developments. If they are separate, these two traditions will each have only partial insight into the complex process of technological change. Bringing these two traditions together might well result not merely in a better theory of technological change but also the practical and conceptual tools for better managing technology in society.

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