Deskilling, Upskilling and the Dual Tendencies of Technology Conditioned by Uncertainty

Ken Archer

archerovi@hotmail.com

The debate over the deskilling effects of industrial capitalism has continued for 45 years since Braverman's *Labor and Monopoly Capitalism*. Case studies on each side present compelling evidence of, alternatively, the deskilling effects and the upskilling effects of innovations in work process and technology. This paper presents a deeper account of the deskilling hypothesis that accounts for the totality of this evidence, one indicated at times by Braverman and other historians of deskilling.

Deskilling and upskilling, it is argued here, are alternative technical responses to the primordial human condition of uncertainty. Humans accommodate uncertainty in one of two ways, through deliberation that accounts for uncertainty or through exact science that looks away from and conceals uncertainty. Technology is built in one of these two modes – upskilling technology empowers worker deliberation, often through information feedback, while deskilling technology removes the need to deliberate through process control and automation. The deskilling tendency is thus not unique to capitalism, as the dual tendencies of technology are present throughout human history.

The human condition of uncertainty is thus more primordial than technology itself, as the motivation to build is fundamentally a response to the burden of world-building in a condition of uncertainty. Technology must thus be analyzed from the inside to uncover these dual tendencies, in contrast to most philosophical analyses of technology in terms of its conditioning effects on human life. This paper presents a case study of industrial statistics that covers the same phenomena described by Braverman, but from the internal development of the technology involved in process control rather than from an external perspective of class struggle. This case study demonstrates these dual tendencies of technology from within and reveals these tendencies to have in common a response to the burden of uncertainty.

The Deskilling Hypothesis

The deskilling hypothesis was first advanced by Henry Braverman in his 1974 *Labor and Monopoly Capital*. According to this thesis, the prerogative of capital to reduce costs leads of necessity to a progressive deskilling of workers. Managers and engineers, as agents of capital, reduce operating costs by transferring craft knowledge away from the shop floor, thus separating head and hand and weakening the wage bargaining position of the worker.

The deskilling of workers proceeds, according to Braverman and others, in two overlapping and mutually reinforcing phases. The first phase is that of the progressive division of labor and the increasing specialization of jobs. This first phase is soon followed and reinforced by the second phase, automation of work using technology.

A common misconception, according to Braverman, about the transition from home-based craft work to factory work in the Industrial Revolution is that this transition was driven fundamentally by technical innovations, such as the division of labor and mechanization. In fact, this migration of the site of work from the home to the factory was driven primarily by the opportunity to situate the owner of a business between the worker and the market, thus realizing the surplus as profit. The division of tasks –

conducting one task across several units and then conducting a subsequent task across those same units – for the sake of efficiency was common artisan practice[1], and the first stages of industrialization simply organized artisans into subcontracting networks known as the “putting out system” and then into factories that were driven by the need for greater discipline within the putting out system.[2]

Once workers were organized into a single place of work, the new breed of capitalists realized the opportunity to increase surpluses by dividing tasks between workers, and by mechanizing the worker-specific tasks. This division of labor via specialization increased the surplus to the owner by deskilling the worker.[3]

This mediation between the worker and the market, and maximization of a surplus, required the transfer of craft knowledge to factory management and a corresponding deskilling and narrowing of autonomy for the worker to the technical execution of narrowly-defined tasks specified by

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[1] “Nor is the technical division of labor peculiar to capitalism or modern industry. Cloth production, for example, even under the guild system was divided into separate tasks, each controlled by specialists. But, as we have said, the guild workman controlled product and process.” “What do Bosses do?”, Stephen A. Marglin, p. 64

[2] In textile weaving, where factories were the first to arise, the power loom hadn’t even been invented at the time. In fact, “the handloom shed represented a transitional stage in the organization of cotton weaving between the true domestic system and the power driven factory”. Duncan Bythell, The Handloom Weavers, Cambridge University Press, Cambridge, England, 1969, pp. 33-34. Quoted in “What Do Bosses Do”, Stephen A. Marglin, p. 88.

The transition of the handloom from the home to the factory saw little change in technology, but rather a change in ownership of output and a desire for higher levels of output from the handloom weavers in the putting out system. Even so, the masters of these handloom factories still faced challenges in habituating weavers to a faster, more consistent pace of work, challenges which were solved by the power loom. The power loom solved the discipline problem by replacing human power with water power under the control of management. According to the important study of early industrial machinery by Maxine Berg, “It was quite clear to many that the productivity of the power loom was not its greatest asset. Consistent production time, and control and supervision over manufacturing processes in the factory were rather its most powerful attractions to the manufacturer”. Maxine Berg, The machinery question and the making of political economy, 1815-1848, Cambridge University Press, Cambridge, England, 1980, p. 241-242. According to the Committee of Manufacturers and Weavers of Bolton, “The chief advantage of power looms is the facility of executing a quantity of work under more immediate control and management, and the prevention of embezzlement, and not in the reduced cost of production.” ibid

A competing innovation to the power loom, known as the pendulum loom, was introduced at the time whereby a handweaver set into motion a pendulum so that one weaver could run two looms in his home. Such innovation which broadened the worker’s role and productivity struggled to find a market, however, as demand for technology was driven by factory owners, and the pendulum loom would not address issues of discipline in the factory. Berg, p. 267

[3] That this is the intention of deskilling is explained by 19th century industrial consultant Charles Babbage.

> [A]ny explanation of the cheapness of manufactured articles, as consequent upon the division of labour, would be incomplete if the following principle were omitted to be stated. *That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.*

Charles Babbage, *On the Economy of Machinery and Manufactures* (London, 1832; reprint ed., New York, 1963), pp. 175-76 management. Early industrial boosters such as Andrew Ure portrayed the skilled artisan as an obstacle to progress.

> *The more skillful the workman, the more self-willed and intractable he is apt to become, and, of course, the less fit a component of a mechanical system.*[4]

Ure maintained that "The principle of the factory system then is, to substitute mechanical science for hand skill."[5] While these boosters contrasted the skills of the artisan with the "applied science" that legitimized the new industrial order, numerous historians have made it clear that the applied science of the Industrial period was largely an appropriation of artisanal knowledge.[6]

Subsequent technical innovation, as a result, was driven not by workers, for whom the separation of head and hand had induced a generational deskilling of the workforce, but by the demand of industrial interests for machinery that would further maximize industrial surpluses by further reducing the required skills and market power of the worker. According to David Noble, another historian of deskilling, "the engineer designed his machines…with the aim of transmitting management authority into the work process (usually described as merely the 'transfer of skill' from craftsman to machine)."[7]

As a result, the second phase of the loss of agency and robust use of reason due to the degradation of work – mechanization and automation of work – was an extension and compliment of the first phase – hyper-specialization of jobs. Most industrial technology has merely transferred knowledge from workers to machines, resulting in a deskilling of workers and greater control to management. Thus, while hyper-specialization made jobs easier to automate, engineers in turn designed technology that automated these narrowly specialized jobs. Hyper-specialization created deskilled workers habituated to repetitive tasks, while automated technology relied upon such workers to operate machines which require no decision-making.

This is of course not to ignore the productivity advantages of technology driven since the Industrial Revolution, but to make a distinction between productivity predicated on reducing the autonomy of workers and productivity predicated on broadening the productivity and empowerment of workers. The former leads to deskilling of workers who employ ever narrower technical reason in their work, whereas the latter leads to greater agency of workers.

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[4] Andrew Ure, *The Philosophy of Manufacturers; or, an Exposition of the Scientific, Moral, and Commercial Economy of the Factory System of Great Britain* (London: Charles Knight, 1835; rpt., New York; Kelley, 1967), pp. 20, 23

[5] ibid

[6] Steven Shapin, "The Invisible Technician," *American Scientist*, 1989, 77: 554-563; Pamela H. Smith, "Art, Science, and Visual Culture in Early Modern Europe," *Isis*, 2006, 97:83-100; Charles F. Sabel and Jonathan Zeitlin, eds., *World of Possibilities: Flexibility and Mass Production in Western Industrialization* (Cambridge: Cambridge Univ. Press, 1997); Maxine Berg, *The Machinery Question and the Making of Political Economy* (Cambridge: Cambridge Univ. Press, 1980), pp. 154,250; and Berg, "The Genesis of 'Useful Knowledge'" *History of Science*, 2007, 45: 123-133

[7] Noble, America by Design, p. 260. In fact, the large-scale deskilling that resulted from changes that were lauded as innovation in turn sidelined the historic source of technical innovation – direct producers of products. According to one economist, "It would be surprising indeed if the workman's propensity to invent has not been diminished by the extreme specialization that characterizes the capitalist division of labor." Marglin, pp. 67-68. This same point is in fact made by Adam Smith in the same text in which he champions the division of labor – pp. 734-35.

The assembly line is an example of this distinction. Braverman, in his survey of industrial technology, writes the "chief advantage of the industrial assembly line is the control it affords over the pace of labor, and as such it is supremely useful to owners and managers whose interests are at loggerheads with those of their workers. From a technological point of view, it is extremely primitive and has little to do with 'modern machine technology'. Nevertheless, in such barbarous relics is found the seat of 'scientific knowledge' and the basis for technology."[8]

The assembly line formed the basis for technology because it framed the direction of technical innovation: "the progressive elimination of the control functions of the worker, insofar as possible, and their transfer to a device which is controlled, again insofar as possible, by management from outside the direct process".[9]

Critiques of the Deskilling Hypothesis

While Braverman's hypothesis has generated significant debate, the deskilling hypothesis today has receded in discussions of technology largely as a result of case studies describing the more ambiguous potential of technology to deskill or to upskill workers.[10] The ubiquity of computers and of the Internet in daily work has made is less plausible to argue that industrial technology proceeds deterministically in the direction of deskilling and degradation of work.

The potential of computers to upskill work in fact emerged from the automation of the production line. The progression of machines on production lines moved in two phases.

In the first phase, the machinery evolved from general purpose tools used by craftsmen to special purpose machines which transferred knowledge of craftwork from the worker to the machine. Artisan tools became industrial machines once they were given a "fixed motion path by the structure of the machine itself".[11] With the addition of further controls, such as gears and cams, a machine mechanizes a specific function, further specializing the machine. The final step in the specialization of the machine is the addition of a control that sequences through a series a functions, such as the home washing machine, or the automatic turret lathe, "which carries its series of tools in a turret that revolves to the next tool as the previous one completes its cycle".[12]

The effect of this hyper-specialization of machines was the complete transfer of skill and agency from workers to machines, and the consequent deskilling of a generation of workers.

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[8] Braverman, p. 160

[9] Braverman, p. 146.

[10] For a review of such case studies and an excellent overview of the deskilling debate, see Peter Meiksins, "Labor and Monopoly Capital for the 190s: A Review and Critique of the Labor Process Debate", Monthly Review, Nov 1994, 46:6

[11] So, "the drill press, the lathe fitted with a slide rest, and the sewing or knitting machine all move cutting tools or needs along grooves cut into the machine frame or parts." Braverman, p. 130

[12] Braverman, p. 130

The second phase of innovation in industrial machinery was a reversal of the first phase, as the control of machines again became external to the machine itself. The cost of machines that were specialized to the production of specific products could only be justified for large runs of mass market products.[13]

The transfer of control of a machine to external media holds out both peril and promise for the empowerment of workers.

On the one hand, due largely to demands from the U.S. military for smaller runs of specialized, non-commercially viable aircraft, innovations such as the numerical control of machines and computer-aided manufacturing (CAM) completed the transfer of knowledge of production from the site of production offsite to the office of the engineer and the manager.[14]

On the other hand, the transfer of control from capital-intensive machines, such as the automatic turret lathe, to more broadly accessible computers that control general-purpose machinery, obviously holds out the possibility of innovation that empowers and broadens the scope of responsibility of workers and professionals.[15]

This potential of technology to empower workers, while not denying the deskilling practices of large parts of capitalist enterprise, is the subject of numerous responses to Braverman calling for a more nuanced account of the effects of deskilling and upskilling.

These dual possibilities of technology – to upskill and to deskill - are the basis for many alternative accounts of technology that incorporate both possibilities. Andrew Friedman argues that there are in fact two workplace control strategies: "direct control" (referring to scientific management) and "responsible autonomy".[16] Shoshana Zuboff and Andrew Feenberg distinguish between two modes of information technology – information technology that automates worker processes, in the mechanical model of technology, and information technology "informates" these same workers.[17]

While both tendencies of technology appear from numerous case studies to be real effects of technology itself, the Braverman deskilling hypothesis struggles in its determinism to account for both. While many critics call for a social constructionist understanding of technology in which the power relations between labor and management, different in different times and places, are reflected in the

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[13] "A lathe", for example, "can be controlled even more efficiently by a punched paper or magnetic tape, and be immediately adaptable to work of every kind suitable to its size and power." Braverman, p. 132

[14] Noble, Forces of Production

[15] In fact, several inventors of the first personal computer, especially Lee Felsenstein, were inspired by Ivan Illich's description of convivial tools, tools which are not specialized to serve a proprietary machine or process, but which "can be easily used, by anybody, as often or as seldom as desired, for the accomplishment of a purpose chosen by the user." Illich went on to say, "Science and technology are not bound to the peculiar notion, seemingly characteristic of the last 150 years of their application to production, that new knowledge of nature's laws has to be locked into increasingly more specialized and highly capitalized preparation of men to use them." Ivan Illich, Tools for Conviviality, pp. 22, 33. See "Convivial Cybernetic Devices, From Vacuum Tube Flip-Flops to the Singing Altair, and Interview with Lee Felsenstein", from *The Analytical Engine*, Computer History Association of California. 3(1), November 1995.

[16] *Industry and Labor: Class Struggle at Work and Monopoly Capitalism*, Andrew Friedman (MacMillan Press: London, 1977)

[17] Zuboff, S. (1985). Automate/informate: The two faces of intelligent technology. *Organizational Dynamics, 14*(2), 5-18

deskilling or upskilling mode of industrial technology, we will see below that the deskilling thesis, with its intuitive appeal, need not be abandoned altogether.

Uncertainty and the Dual Tendencies of Technology

Empirical research seems to call for a deeper account of industrial technology than one based on the material interests of capital, one which incorporates its dual tendencies to deskill and to upskill workers. Why does industrial technology proceed in one of the directions or the other? This deeper account is in fact indicated in places by Braverman and his colleagues.

The notion of skill offered by Braverman and other historians of deskilling moves between two notions - one based on application of theoretical knowledge and another based on judgment. The latter notion emphasizes the tacit skill and knowledge of the worker that is applied in uncertain situations. Braverman mentions at one point, "The overall purpose of all administrative controls is, as in the case of production controls, the elimination of uncertainty".[18]

If the worker's skill is one of judgment in the face of uncertainty, the response of management as the elimination of uncertainty through process control and process-based automation entails the elimination of judgment. Braverman quotes Taylor, according to whom scientific management "involves the establishment of many rules, laws and formulae which replace the judgment of the individual workman".[19] With numerical control of machining tools, writes Braverman, the machinist, "is now definitively relieved of all the decisions, judgment and knowledge which Taylor attempted to abstract from him by organizational means".[20]

Noble, too, at times describes deskilling in terms of removal of uncertainty from the labor process.

> Above all, engineers want to eliminate not particular human beings but the more abstract possibility of "human error". So they design systems that preclude as much as possible any human intervention…This engineering mentality betrays a rather cynical view of human beings (not to mention an elitist and derisive view of subordinates) in which any chance for human intervention (by workers) is negatively assumed to be a chance for error rather than, more positively, a chance for creativity, judgement, or enhancement.[21]

These indications serve as a clue to a more fundamental condition that explains both the deskilling and upskilling effects of technology. Throughout the history of philosophy, uncertainty has played a central role in articulating the human condition out of which technical thinking arises, as well as the different modes of such technical thinking that account for uncertainty.

According to Aristotle, there are two parts of the rational soul, the scientific and the deliberative, with the deliberative part being concerned with what admits of being otherwise. *Episteme* (science) and *sophia* (understanding) are the two states of the scientific part of the rational soul, while *techne* and *phronesis* are the two states of the deliberative part of the rational soul, distinguished according to the

[18] Braverman, p. 184
[19] Braverman, p. 79
[20] Braverman, p. 139
[21] David F Noble, *Progress Without People* (Between the Line Press: Toronto, 1995), p. 80

activities with which they are concerned – *poeisis* (production) and *praxis* (action).[22] Deliberation is thus the response to uncertainty in one's objects.

Heidegger's early work was deeply engaged with Aristotle, and in particular with the intellectual virtues. With the publication of his Aristotle lectures throughout the 1920s, there is now consensus among Heidegger scholars that *Being and Time* is largely a phenomenological hermeneutics of *techne*, in Division One, and of *phronesis*, in Division Two. Deliberation in the face of uncertainty, then, was central to everyday living for Heidegger.

A central concern, perhaps the central concern, for Heidegger is the facticity of human existence. Heidegger and subsequent thinkers developed a method of phenomenological hermeneutics that sought to account for everyday thinking in its facticity in a way that modern philosophy could not, and that in turn rediscovered premodern concepts such as *phronesis*, phenomenologically understood as the stance one takes towards one's facticity, that had been discarded by modern thinkers. Heidegger aimed to return philosophy from the abstractions of metaphysical conceptuality to this concern for everyday factical existence. Western *techne* was viewed by Heidegger as derivative of such abstractions, as it is oriented, in contrast to *phronesis*, entirely by formal ideas of one's finished product and is limited to narrow deliberation about the instrumental means to bring formal ideas into being.

Here we see in Heidegger the dual tendencies of world-making, the tendency to turn away from one's facticity towards exact science and reliance upon socially given rules, and the tendency to bear up to one's facticity and appropriate it as one's own. Circumspective concern for the world, for the early Heidegger, is drawn in these two directions, either in the direction of conscience (*phronesis*) or of things, understood via science (*episteme*). This is initially indicated in Heidegger's 1924-25 lectures, in which Heidegger translates *phronesis* as both circumspection and conscience. In Heidegger's Aristotle lectures, *episteme* is characterized by "fallenness" and "forgetting", as what was disclosed sinks back into concealment, while *phronesis* "is in each case new" such that "there is no possibility of falling into forgetting". Thus, the everyday circumspection of active involvement in the world can be "woken up" by the call of conscience, by *phronesis*, or alternatively can be reflected upon, in a secondary mode, by *episteme*, in terms of the outward properties of its tools conceived no longer as essentially tools but as present-at-hand entities.

Subsequent thinkers, such as Gadamer, would develop this hermeneutic relationship in which particular situations can be interpreted in light of a horizon of practical, factical knowledge. The school of philosophical hermeneutics that followed Heidegger sought to de-ontologize man's hermeneutic situation as given by Heidegger, and instead explore how *phronesis* develops out of one's hermeneutic dialogue with one's facticity. Central to man's response to the uncertainty of action in the world, according to the philosophical hermeneutic tradition, is the need to apply incomplete practical knowledge towards uncertain situations and in turn interpret uncertain situations within the horizon of incomplete practical knowledge.

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[22] "For production has its end in something other than itself, but action does not, since its end is acting well itself". All quotes from Nicomachean Ethics (NE) are from the translation of Terence Irwin. Aristotle, *Nicomachean Ethics*, (Hackett Publishing, 1999), NE VI, 5, Sec 4, 1140b7. This recalls the same distinction made at the opening of NE, "the ends appear to differ; some are activities, and others are products apart from the activities". NE I, 1, Sec 2, 1094a4

A particularly interesting work in the philosophical hermeneutics of technology, one which demonstrates the two modes of technical thinking in response to uncertainty, is that of Donald Schon. According to Schon, one enters into "a reflective conversation with a unique and uncertain situation" through experiments that he classifies as exploratory experiments, move-testing experiments and hypothesis tests. Through these reflective experiments, one applies incomplete knowledge of a practice to an uncertain situation, and through the action itself and its consequences one adds to one's practical knowledge.

The central challenge to what Schon calls "reflection-in-action", however, is that it cannot account for itself. When confronted with demands for explanations for its decisions, it is silent and, as a result, apparently irrational. In response, practitioners in every field codify insights that are common across many reflections and put this forward as the scientific foundation for the field.[23]

Heidegger's approach to technology is widely considered to be inhibited by technophobia in contemporary philosophy of technology. However, Heidegger's technophobia was at play in his interpretation of Western *techne*, not in his phenomenology of *techne* and *phronesis* as are found in Divisions One and Two of *Being and Time*. Western *techne*, for Heidegger is a particularly deep falling into things as present, a falling that conceals man from himself to a devastating degree.

Verbeek, in his critique of Heidegger's technophobia, acknowledges the lack of such technophobia in Heidegger's early work. Verbeek interprets Heidegger's early work as concerned with artifacts as actively mediating the disclosure of being to humans, and then develops a phenomenology of artifacts as radically conditioning human thought and activity.[24] His interpretation of Heidegger contrasts Heidegger's early concern with artifacts with his later, post-*Kehre* concern with the conditions of the possibility of technology itself.

Missing from this account of the early Heidegger is his concern with Dasein. Equipment, for Heidegger, does not disclose a world – rather, one's world discloses equipment in its referential significance given the pre-existing context of a world. World comes first and is factically constituted for Dasein given one's particular history. The two modes in which one responds to one's facticity – falling into the factical world of the "they" already given for Dasein or appropriating one's facticity as one's own under the call of conscience (Heidegger's phenomenological account of *phronesis*) – are the central concern of *Being and Time*. Verbeek doesn't mention Division Two of *Being and Time* or the development of the themes of *Being and Time* in his lectures and limits his analysis of the early Heidegger to the sections of *Being and Time* on equipment.

The primordial condition of work, of building a world, is thus uncertainty. Humans accommodate uncertainty in one of two ways, through deliberation that accounts for uncertainty or through exact science that looks away from and conceals uncertainty. Technology is built in one of these two modes – upskilling technology informs worker deliberation while deskilling technology removes the need to deliberate. Deskilling and upskilling are alternative technical responses to the primordial human condition of uncertainty.

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[23] Donald Schon, *The Reflective Practitioner* (Basic Books, 1984)

[24] In Being and Time, according to Verbeek, things "play an active role in the way in which human beings have access to reality". Peter-Paul Verbeek, *What Things Do* (Pennsylvania State Univ Press, Pennsylvania: 20015), p. 92

The ideology which manifests the tendency towards deskilling, then, is not capitalism, but managerialism, described by Noble's account of engineering ideology above. One of the central objections to Braverman is that the profit incentive is often best met by empowering the worker to reduce overhead costs. This presumes that cost reduction, and not uncertainty reduction, is the true aim of management.[25] Managerialism aims not at cost reduction, but at eliminating uncertainty in the work process through process control and through automation.

Case Study: Industrial Statistics

The human condition of uncertainty is thus more primordial than technology itself, as the motivation to build is fundamentally a response to the burden created by uncertainty. Technology must thus be analyzed from the inside to uncover these dual tendencies, in contrast to most philosophical analyses of technology in terms of its conditioning effects on human life. Only such internal account of technology can avoid technical determinism and account for the dual tendencies of technical development.

This section presents a case study of industrial statistics that covers the same phenomena described by Braverman, but from the internal development of the technology involved in process control rather than from an external perspective of class struggle.

The role of statistics in the first phase of the narrowing of agency and rationality within work through hyper-specialization and centralization described by Braverman is important to explore in depth, as it reveals fundamental developments of statistics to be responses to the primordial condition of uncertainty in work, as well as the dual modes in which industrial statistics develops in response to the condition.

Central to scientific management was the creation of centralized planning departments that conducted stopwatch and motion studies to dictate the precise bodily steps required by each process, in order to eliminate wasteful steps and then control each process through functional foremen and a separate inspection department. While the separation of hand from brain was central to capitalist production, scientific management took this separation to new lengths, treating the worker's body as the cogs and levers of the industrial process.

The use of statistics to inspect and control industrial processes led to profound debates over the role of statistics in relation to worker autonomy and agency, a debate that continues into the present day. Before the rise of the factory, the autonomous workman inspected his own product, and this practice continued in the early factories. Scientific management changed this, creating independent inspection departments in line with the sharp separation of management functions and labor activities (or, head and hand activities).[26]

One of these independent inspection departments, at Bell Laboratories, was faced with the massive engineering challenge of building and inspecting a universally accessible telecommunications network. Inspection, both before and after the rise of industry, was traditionally full-lot inspection, which

[25] Braverman quotes Seymour Melman, in response to the question why corporation absorb such heavy management costs, "The explanation of the rather homogenous increase in the administrative type of overhead will be found, we suggest, in the growing variety of business activities which are being subject to controls…as administrators have sought to lessen the uncertainty of their prospects." ibid

[26] "The Taylor System and Quality Control", Dr. Joseph M. Juran, p. 5

imposed significant costs as well as delays for large-scale industrial operations based on extreme specialization. The inspection department of Bell Laboratories accounted for 12 percent of the plant workforce.[27]

In the 1920s there was rising interest in the use of probability theory to manage problems of risk and uncertainty in industry. Walter Shewhart and Harold Dodge, two leaders of the Bell Labs inspection department, transitioned inspection from full lot inspection to random sampling between 1923 and 1927, an innovation that significantly reduced the cost and time required for inspection at Bell and across industry over the subsequent decades.[28] However, the specific application of sampling-based inspection proceeded in two distinct directions.

In the context of the antagonistic relationship between labor and management into which sampling-based inspection was introduced, the most common approach was use of acceptance sampling *tests*, which applied statistical significance testing to reject work from vendors (in the case of inputs) or workers (in the case of outputs).

Concurrent with the rise of sampling-based inspection was the development of statistical significance tests by statisticians such as Ronald Fisher and, subsequently, Egon Pearson and Jerzy Neyman. Significance tests such as p-values, f-values and R^2 values use arbitrary thresholds of statistical significance to infer the presence of an effect in any object of study or to select from competing statistical models of an effect, and have been applied across dozens of fields from agriculture to psychology to industrial acceptance sampling.

This application of statistics has been criticized as having impeded as much as it advanced scientific and technical progress, by moving substantive domain expertise "out-of-the-loop" of scientific and technical work in favor of tests of statistical significance. These arbitrary tests of an effect replace substantive significance, which is concerned with the magnitude of an effect, with statistical significance, which sets magnitude aside and makes binary assertions of the presence or absence of effects based on thresholds of statistical significance.[29]

Shewhart, at Bell Labs, and his younger colleague Edwards Deming, were early critics of the displacement of workers' domain expertise with the use of arbitrary significance tests to judge quality of work. For them, variations in industrial output quality help workers' better understand the processes themselves, and inform new hypotheses into how to improve these processes. Deming consistently critiqued the application of statistical significance to management, countering that "Statistical theory shows how mathematics, judgment, and substantive knowledge work together to the best advantage.[30]" Deming had this to say in his, *Out of the Crisis*.

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[27] Juran, *Architect of Quality,* p. 75

[28] Paul J. Miranti, "Corporate Learning and Quality Control at the Bell System, 1877-1929", pp. 55-57

[29] *"If you yourself deal in medicine or psychiatry or experimental psychology, …we would recommend that you focus on clinical significance. If you deal in complete life forms, environmental or ecological significance. If you deal in autopsies or crime or drugs, forensic or psychopharmacological significance. And so forth…An arbitrary and Fisherian notion of "statistical" significance should never occupy the center of scientific judgment." The Cult of Statistical Significance: How the Standard Error Costs us Jobs, Justice and Lives, by Deirdre McCloskey and Stephen Ziliak (Univ of Michigan, 2008), p. 20*

[30] *Sample Design in Business Research*, by Deming, W. Edwards, (John Wiley & Sons, 1990), p. v

There are many other books on so-called quality control. Each book has something good in it, and nearly every author is a friend and colleague of mine. Most of the books nevertheless contain bear traps, such as reject limits,…areas under the normal curve, acceptance sampling….The student should also avoid passages in books that treat confidence intervals and tests of significance, as such calculations have no application in analytics problems in science and industry.[31]

This school of thought has generally been overshadowed by the more dominant school of Fisher, whose followers have argued for the use of tests of statistical significance as a more objective approach to model selection that eliminates the subjectivity inherent in human model building and decision making. Statisticians such as Shewhart and Deming, however, reject this elimination of subjective judgment. For them, science and technology are essentially model building activities, the ongoing refinement of mental models, before statistics enters the scene. This view of technology, as a mental modeling activity that is natural to man's practical life, has a long history in the philosophical reflection on technology and is known as practical reason. The value of statistics, on this view, is the measurement of variation for improved model building.

This tension that runs through the history of statistics is present at its founding. Prior to statistical models, there was a prejudice against the variation of particulars in favor of mental models. In all fields, researchers "took simple averages of nearly perfectly replicated determinations of the same quantity; but the idea that accuracy could be increased by combining measurements made under different conditions was slow to come. They feared that errors in one observation would contaminate others, that errors would multiply, not compensate"[32].

The achievement of statistics was to measure variation, thus learning from particulars by introducing models that diverged from mental models. The Shewhart & Deming school of thought envisioned statistical and mental models checking and modifying each other, such that statistical models would be tools to be used to enhance our understanding of processes used in production. This same school of thought is found in present-day Bayesians such as Gelman and Kruschke.

However, this school was not to win the day. The Fisher school of thought was an overreaction that denied the value of mental models, analogous to the previous denial of the value of particulars, which has plagued statistics from the beginning. The Fisher school is rooted in a positivist view of science which seeks to remove any trace of subjectivism from objective science, a bias which when applied to modern industry seeks to remove the need for a workers' skill, knowledge and judgment in favor of objective processes specified by management. The positivist view of social science which was ascendant as the turn of the 20th century, by limiting evidence to that which is 'theory-neutral' and objective, is largely responsible for the central place given to statistics in social science.[33]

Implications

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[31] *Out of the Crisis*, by Deming, W. Edwards (MIT, 1982), p. 369

[32] *The History of Statistics: The Measurement of Uncertainty before 1900*, by Stigler, Stephen (Belknap Press, 1986), p. 4

[33] "So the positivist conception of empirical data provides an important rationale for the role of statistics in positivist social science." "Positivism and Statistics in Social Science", Keat, Russell, in *Demystifying Social Statistics*, London: Pluto Press, 1979, p. 80.

This positivist mission of Fisherian statistics presages the subsequent application of predictive models in AI as autonomous from human interference. The central dilemma raised by both AI and applied tests of statistical significance, the displacement of substantive decision-making by practitioners with instrumental calculation by technicians, is the same, and is bad for both technical progress as well as for technical ethics. When viewed in this way, AI is a continuation of contemporary technology rather than something fundamentally new from an ethical perspective. What is new about AI in the history of applied statistics is that statistics is now the product, rather than a control on the process that delivers a product consistently to a specification.

The positivist founding flaw in the history of applied statistics is its vision of the worker and practitioner as technicians, merely applying models rather than building them.[34] This vision ultimately ends in the autonomy of statistical models. The attempt to move the activity of model building from the practitioner, the professional, to the scientist and manager, slows the progress of technology while also removing ethical agency from the practitioner.

This understanding of what is at stake in technology – judgment – also serves to ground an ethics of technology that sidesteps the debate over ethical frameworks. When deskilling is understood in terms of its elimination of judgment, then it is appropriately understood as moral deskilling, a term coined by Shannon Vallor. Ethics of technology, when considered in this way, is not something separate from technology itself. The call to be more ethical is no different than the call to be better engineers – to respond to uncertainty with innovations that acknowledge uncertainty rather than wish it away.

[34] "When our gaze turns to the technical intricacies of these computational systems, it sets the stage for technical experts to become the architects of society." (Katz, p 16)