Technological discussions in iron and steel, 1871-1885

by Peter B. Meyer, U.S. Bureau of Labor Statistics, and
Carol Siri Johnson, New Jersey Institute of Technology
January 23, 2006
Preliminary and incomplete

Abstract Starting in 1871, *Transactions of the American Institute of Mining Engineers* (TAIME), a professional engineering journal, published papers which discussed improvements in iron and steel making, mining, engineering, and management. These documents recorded significant economic and technological changes as the industry crossed the frontier from small-scale to high-volume production processes. In 1871, most North American iron was locally produced, and steel was not mass-produced in Pittsburgh. By 1885, almost all U.S.-made steel came from big plants operating high-volume production processes centralized around Pittsburgh. The paper is an analysis of the journal's contents from 1871 to 1885. From a database of approximately 670 articles and metadata, we have recorded changes in article topics and technology, evolving modes of discussion, changes in the format of TAIME, and biographical information about the 270 authors. We test hypotheses about how these technological and business paradigms became established based on the journal's contents.

Introduction

Starting in 1871 a professional engineering journal, *Transactions of the AIME* (TAIME), published papers which discussed improvements in iron and steel making, mining, engineering, and management. We have scanned and digitized the journal's entirecontents, and categorized its approximately 540 articles from 1871 to 1885. We trace the article topics based on the changing technology used in the iron and steel making industry. We also trace modes of discussion based on word choices, article formats, and biographical information about the 270 identifiable authors. In 1871, most North American iron was locally produced, and steel was not mass-produced in Pittsburgh. By 1885, almost all U.S.-made steel came from big plants operating high volume production processes, around the edges of the Great Lakes and centrally in Pittsburgh. In this journal and during these years, the authors of TAIME constructed some of the new technologies and business practices of Big Steel. This paper is an analysis of hypotheses about how these technological and business paradigms became established based on the journal's contents.

One hypothesis is that the collective invention process, such as that seen in TAIME, is characteristic of technologically uncertain periods when new paradigms are being formulated and established. Or, put empirically, how can we define our underlying concepts and data so as to make some reliable findings of this kind which could make predictions possible?

The idea of technological uncertainty is that there is a divergence of views and knowledge about a new technology. There is not a common agreement about what will happen economically – it is not known what the invention is good for exactly, whether an industry will arise to make it, and whether a previously existing industry will decline. As a technology is developed and becomes stable, the uncertainty declines and regular processes like R&D manage ongoing improvement.

Technological uncertainty has been documented in several ways. One is the variation in financial forecasts, or their errors (Tushman and Anderson 1986). Another is in a rise in the variation in wages (Meyer, 2005). Another is in the rise of collective invention (Meyer 2003). Here we attempt to correlate technological uncertainty with changes in the collaborative discussion processes recorded in technical journals.

Three technological changes that contributed greatly to mass production processes were the three-high rail mill, Bessemer steel and open hearth steel. The three-high rail mill, invented by John Fritz in 1857, made faster rolling machines, used increasingly in large plants. The mass production product called Bessemer steel was invented in 1856, attempted first in the U.S. in 1864, and commercial production began about 1868. This became a high volume business. Open-hearth steel, a high quality steel production method, was first adopted in the 1870s. The TAIME has a written record of the collective invention and evolution of these processes.

The text data

we were able to get word counts of the articles overall, and of various terms. Some were topical, like mining, anthracite, Bessemer, and gas-fired. Others were meant to detect variations in technological uncertainty such as uncertainty, risk, doubt, perfection.

The overall size of these fourteen years of documents was about 5600 pages in the originals. We did not categorize front matter but rather the presented papers which were published in named articles. See Appendix A for a list of articles from one volume, and Appendix B to see how the data were pub into electronic form.

We have created two databases. One has data on the authors, listing their publications by volume, birth and death dates, educational level, professional role and areas of professional expertise. The other is organized by article, listing its date, topic, length, and presence or absence of citations. The modes of discourse are analyzed by searching and recording the frequency of expressions of uncertainty in the articles concerning the iron and steel industry.

The PDFs of the journals are now online at http://econterms.net/pbmeyer/research/ironwork/TAIME Once our research project is finished, we hope to make these available to other researchers in the long run.

From a variety of sources we collected biographical information about the authors.

Questions to be addressed to the data

When defining scientific paradigms and revolutions, Kuhn (1962) made a couple of predictions about the pre-paradigmatic and later scientific work of various fields. It was predicted that before a paradigm is clearly established and well known to the scientists doing work in a relevant field, the authors are likely to write longer articles, in which they try to define their scope and tools. In later works, articles would be shorter, and take more as assumed. We plan to test whether articles on novel topics were longer than those which were not. It may also be possible to identify clearly which articles cite previous work and which ones do not. Articles in established paradigms should have more references to previous work. We think articles in pre-paradigmatic, or uncertain, areas are more likely to cite the author's personal experience, and will test this if possible.

Kuhn posited that in a pre-paradigmatic phase a scientific field includes people with a wide variety of educational backgrounds. This narrows once a paradigm is established, and education in that paradigm becomes sharply defined and is taken to be a prerequisite of work in the field. Therefore we are gathering educational information about those who published. A few articles were written by people who did not reach high school, since experience iron managers were not likely to have much academic background. At the same time, many were by PhD's in chemistry, physics, or other fields. A number were by managers of mines or plants, or by consultants. This diversity suggests a kind of pre-paradigmatic look to the population which we will attempt to quantify.

Kuhn hypothesized that the early authors of a new paradigm are younger than the authors in established paradigms, for a series of interrelated reasons which include their incentives. The young authors have less to lose and more to gain by trying something radically new, whereas older authors have a comparative advantage in prestige, legitimacy, and experience. We shall test this proposition if we can get ages of enough of the authors, and define technological paradigms sharply enough.

Litterer (1961) describes this period as the one in which a literature on management consulting first appeared, and in engineering journals. We shall attempt to categorize the articles addressing management issues. Did they help generate Big Steel? Were they experimenting with the issues which in retrospect have been treated as central by Chandler (1990) and the related literature?

Meyer (2005) shows that inequality of earnings for workers within the iron and steel sector went up while it did not appear to change in other sectors. Can we see any discussion of this, or of the forms of compensation to labor such as inside contracting, which made jumps in earnings possible?

Appendix A. Example contents from TAIME.

This is the list of contents of Volume II of the TAIME.

Article ID	Meeting Year	Meeting Month	Start Page Original	End Page Original	Word Count	pages	Author 1	
201	1873	May	17	28	3703	12	ELLSWORTH	DAGGETT
202	1873	May	28	31	1462	4	DR. THOMAS	M. DROWN
203	1873	May	31	43	4864	13	HENRY	ENGELMANN
204	1873	May	43	57	3535	15	PROF. B. W.	FRAZIER
205	1873	May	57	57	131	1	J. HENRY	HARDEN
206	1873	May	58	59	626	2	T. STERRY	HUNT
207	1873	May	59	60	535	2	B. C.	PECHIN
208	1873	May	61	65	1684	5	R. W.	RAYMOND
209	1873	May	65	78	4178	14	T. F.	WITHERBEE
210	1873	October	79	81	981	3	J. J.	BODMER
211	1873	October	81	83	663	3	J. J.	BODMER
212	1873	October	83	84	234	2	J. J.	BODMER
213	1873	October	85	89	1566	5	J. J.	BODMER
214	1873	October	89	101	3142	13	W. M.	COURTIS
215	1873	October	101	102	496	2	A.	EILERS
216	1873	October	103	105	1028	3	FRANK	FIRMSTONE
217	1873	October	105	116	4004	12	OSWALD J.	HEINRICH
218	1873	October	116	122	3048	7	A. L.	HOLLEY
219	1873	October	123	131	3846	9	T. STERRY	HUNT
220	1873	October	131	140	3840	10	R. W.	RAYMOND
221	1873	October	140	143	980	4	R. W.	RAYMOND
222	1873	October	143	144	461	2	R. W.	RAYMOND
223	1873	October	144	158	5975	15	RICHARD P.	ROTHWELL
224	1874	February	159	171	5996	13	J. M.	ADANS
225	1874	February	172	175	1436	4	W. S.	AYRES
226	1874	February	175	199	11049	25	THOMAS S.	BLAIR
227	1874	February	200	203	1507	4	PROF. W. P.	BLAKE
228	1874	February	203	207	1518	5	WILLIAM P.	BLAKE
229	1874	February	208	215	2760	8	JOHN F.	BLANDY
230	1874	February	215	219	1951	5	A. J.	BROWN
231	1874	February	219	224	1539	6	ECKLEY B.	COXE
232	1874	February	224	225	486	2	THOMAS M.	DROWN
233	1874	February	226	240	6328	15	BOLESTON	PROF. T.
234	1874	February	241	263	7806	23	J. OSWALD	HEINRICH
235	1874	February	263	272	1263	10	HOLLEY	A. L.
236	1874	February	273	278	2592	6	T. STERRY	HUNT
237	1874	February	279	295	5856	17	T. STERRY	HUNT
238	1874	February	295	299	1967	5	LOCKE	J. M.
239	1874	February	300	310	3034	11	ARCHIBALD	MACMARTIN
240	1874	February	306	309	1421	4	E. C.	PECHIN
241	1874	February	310	314	717	5	D. PETERS	EDWARD
242	1874	February	314	326	6738	13	PROF. J. C.	SMOCK

Appendix B. The text data

The contractor Digital Divide Data did this. Pages from the journal were scanned. Images of the pages were then cropped and cleaned up in the Photoshop software. Tables, pictures, diagrams and some equations were copied elsewhere as images. DDD then ran a optical character recognition (OCR) software on the text, and a spell check on the results. The resulting PDFs are stored as text with font and format information, so they are re-rendered to look like the original pages although the text does not look exactly the same. On each page the images have been pasted back in. The reason to store the contents as text is that the resulting PDFs are not binary images but searchable text.

References / bibliography

Allen, Robert C. Collective invention. *Journal of Economic Behavior and Organization* 4 (1983): 1-24.

Chandler, Jr. Alfred D. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Harvard University Press.

Dosi, Giovanni (1988), Sources, Procedures, and Microeconomic Effects of Innovation. *Journal of Economic Literature* 26:3 (Sept.), 1120-1171.

Fishlow, Albert. 1966. Productivity and technological change in the railroad sector, 1840-1910. In *Output, Employment, and Productivity in the United States after 1800*, vol. 30 of the Studies in Income and Wealth, pp. 583-646. National Bureau of Economic Research and Columbia University Press, New York.

Gordon, Robert B. 1996. *American Iron: 1607-1900*. Johns Hopkins University Press.

Hirsch, Paul M. 1986. "From ambushes to golden parachutes: Corporate takeovers as an instance of cultural framing and institutional integration." *American Journal of Sociology*, 91: 800-837.

Kuhn, Thomas. *The structure of scientific revolutions*.

Litterer, Joseph A. 1961. Systematic Management: the Search for Order and Integration. *Business History Review*. Winter. 461-476.

Meyer, Peter B. 2003 "Episodes of collective invention." U.S. Bureau of Labor Statistics Working paper WP-368. Online at http://www.bls.gov/ore/abstract/ec/ec030050.htm.

Meyer, Peter B. 2005. Turbulence, inequality, and cheap steel. BLS Working paper 375. Online at http://www.bls.gov/ore/abstract/ec/ec050010.htm

Misa, Thomas J. 1992. Controversy and Closure in Technological Change: Constructing "Steel". Chapter 4 of *Shaping Technology / Building Society: studies in sociotechnical* change, edited by Wiebe E. Bijker and John Law. MIT Press.

Misa, Thomas J. 1995. *A Nation of Steel: the making of modern America 1865-1925*. Johns Hopkins University Press.

Rosenberg, Nathan, and Birdzell. *How the West grew rich*.

Swank, James M. 1883. Statistics of the iron and steel production of the United States. In vol. 2 of the 1880 U.S. Census.

Tushman, Michael L., and Philip Anderson (1986), "Technological Discontinuities and Organizational Environments." *Administrative Science Quarterly* 31 (Sept.): 439-465.

Warren, Kenneth. 1973. *The American Steel Industry, 1850-1970: A geographical interpretation*. Clarendon Press, Oxford.