Quantitative Cultures in the Associational State: A Forensic and Historical Analysis

Peter Ore (Queens College, CUNY)

Introduction

In 1923, Pittsburgh was a burgeoning city of nearly 600,000 people. An industrial hub surrounded by coal deposits, the city was a transitional zone between the extractive American west and south and the productive and financial northeast. It was also at the crossroads of engineering, medical, and chemical knowledges that formed the technical basis of American political and economic development in the interwar period. This was a period and a place in which elements of "the age of industrialization" and the "age of control" reticulated into an opportunity-rich (if labile) context for "associative" state action.[1] Pittsburgh's Carnegie Institute of Technology (CIT) was an important node in this system of associations. Here, a small group of academics, government scientists, and industrial engineers were busy defining the professional and technical organization of what would become the US system of air pollution control and, more than a century later, would define a substantial portion of the global response to climate change.

In this paper, I focus on one product of the intellectual-industrial milieu at CIT: a small dataset produced from a series of comparative tests of "dust counters." Over the previous three decades, a wide range of dust counters supposedly more effective than traditional methods had been developed to "determine" the dustiness of enclosed occupational atmospheres like mines, tunnels, grain elevators, and factories. The result was a cacophony of numbers. Federal Bureaus of Agriculture, Mines, the Public Health Service, and the American Society of Heating and Ventilating Engineers all recognized the incommensurability of these numbers as a threat to their campaign to rationalize American industry. So, in 1923, each organization sent a representative and their favored dust counter to the Federal Bureau of Mines laboratories on the CIT campus to establish "conversion factors" between their instruments.

Desrosierès' influential work on "four possible attitudes" toward the reality of statistics (2001) discusses four attitudes he thought prevailed among contemporary business statisticians in Europe. American engineers, chemists, and public health experts of the interwar period had their own, arguably related, distribution of possible attitudes. In full paper, I will make inferences about these attitudes by using my reanalysis of the dust counter

---

[1]Levy (2021) names the period between about 1979 to present the "age of chaos." The "age of control" is the period between the New Deal and the Volcker shock of 1979. The period before that he labels the age of industrialization, and the age of commerce spans the founding to about the Civil War. Associative, or associational, statecraft is originally from Hawley (1974).

study's computations, tabulattions, and interpretations of their atmospheric dust measurements. Preliminary results (discussed in part below) suggest implications for the social study of numbers, the cultures of quantification in the American state, and for the measurement technologies and regulatory devices still used to govern human atmospheres.

A Forensic Approach to Cultures of Quantification

In science studies, studying "laboratory life" usually implies ethnographic observation or hermeneutic readings of participant narratives. But no such artifacts remain for the dust counter study. Direct observation is out (it was 100 years ago) and the proverbial laboratory notebook — if it exists — is not archived with the rest of the Bureau of Mines Central Research Station papers.[2] All that remains is a report, with interpretive and justificatory text, numerical analysis, and tabular data.

This (largely) quantitative artifact of quantification, together with the paucity of more narrative forms of evidence, leaves careful examination of the data itself and the interpretive tools the authors applied to it as a primary means of studying this event. So circumstances force me to develop what I call a forensic approach to understanding this data's history; a way of using numbers and their relations to evoke the settings, characters, events, plot, and audience that produced them.

By "forensic," I mean the close examination of an artifact so its value as evidence can be debated. From the forensic perspective I develop here, the numbers tabulated in the report are interpretable as a stochastic impression of the social processes that produced them.

As always, this quantitative parsing cannot stand on its own. I join forensics to a historical and sociological interpretation of the larger body of technical knowledge cited in the report, and a detailed knowledge of the interorganizational politics put into play through these tests. This means bringing relevant archival documents into focus that have not yet entered the secondary literature on American political development, environmental history, or the scholarship on social measurement.

Small Data, Big Comparisons

The report is 95 pages long. It gives the results of 69 simultaneous measurements using six dust counters nested in 18 tests (12 high dust concentration and 6 low dust concentration). Observations were split across four types of dust: coal, grain, iron, limestone, and silica. Each dust was thought to be a significant atmospheric risk to the American industry that produced it, either by sickening workers or destroying fixed capital and raw materials in violent explosions. These interests mapped onto the technicians and dust counters involved in the tests, each of which tended to be a specialist in their sector's "dust problem." In short, the commensuration of dust counts was also part of an effort to harmonize the federal

---

[2]I spent five days looking for materials related to the study in the National Archives at Philadelphia and the Leonard Greenburg papers at Yale. All I found were some preliminary reports and a few vague references in Greenburg's early letters. These sources will be incorporated and discussed in the final paper.

bureaucracy and the American political economy itself; a small but significant moment in the "individualization of risk" (Krippner 2023).

The study's design reflected the difficulty of orchestrating even local harmonies out of the macroscopic dissonance of American economic life in the 1920s. With each test, a known quantity (in milligrams) of dust was blown into 1,000 cubic feet of normal indoor atmosphere, sealed inside a cutting-edge airtight gas chamber in the Bureau of Mines building at CIT. After a brief settling period, the technicians simultaneously triggered their dust counters' sampling mechanisms, reset them, and sampled the same dust cloud again three times. This involved a considerable number of set changes within a few critical minutes. Glass bottles and filters had to be replaced without undue disturbances; hose bibs, fans, and belts cleaned; fittings checked; timing instruments and other metadata reset.

Once the dust was sampled, the measurement process could begin. "Dust counter" is a misnomer – the instruments were really dust *samplers*. Each instrument's sample required distinctive, sometimes laborious, procedures to make its particles visible under a microscope for counting and statistical projection into an average dust count per cubic foot of air. Where laboratory equipment and skills were available, "re-establishing the object" (air dustiness) was a multi-step process often involving specialized microscopy, chemical manipulation, and numerous statistical reductions.[3]

Beyond the commensurable value indicating the dust content of the experimental chamber, each data point also reflects idiosyncrasies in the labor processes, technicians, and instruments used to produce it. In my analysis, I consider this "systematic error" a historical artifact, and consider what it indicates about the practices and ideas that went into producing it.

Preliminary Results

I have completed a detailed replication of the reports' computations, surveyed the air pollution scholarship of the era, and examined most of the extant research materials in the Bureau of Mines Central Research Station's archives. Out of a wide range of preliminary results, here I choose to focus on the authors' non-parametric method for computing conversion ratios between instruments. This method evokes the authors' basic "attitude" toward the reality of their measurements and the statistical aggregates they chose to represent them. A fuller analysis of this attitude will be prepared in the full paper, which will be complete before the conference.

The first thing to note is the report's ambivalence about the conversion ratios. The authors represent this "paper tool" (Klein 2003) as a means to compare the air dustiness measurements taken by various government agencies. But sections devoted to each instrument — authored by technicians who were experts in their use — implicitly compete to make the instrument itself the standard. Authors give contradictory evaluations of their

---

[3]Analysis of physical measurements provide an interesting scaffolding towards a theory of social measurement (Duncan 1984); the problem of "re-stablishing the object" is from quantum measurement theory (Busch, Lahti, and Mittelstaedt 1996). Error analysis begins with insights about the limitations of symbolic systems for representing continuous phenomena and attempts to decompose error into its "systematic" and "statistical" elements (Taylor 1982).

instrument's advantages and the purported "efficacy" of its measurements, sometimes making explicitly invidious comparisons with other instruments. Thus the conversion ratios represented a general failure of the group to agree on a more reliable standard: a single measurement strategy. With standardization of tools out of the question, they resorted to the conversion factors, a more actuarial form of control.

How should such conversion factors be produced? Consider the relationship between measures taken by the "Palmer Apparatus," "Sugar Tube" and "Greenburg-Smith Impinger":

$$\frac{\text{Sugar tube}}{\text{Palmer}} \times \frac{\text{Palmer}}{\text{Impinger}} = \frac{\text{Sugar tube}}{\text{Impinger}}$$

The authors exploited this identity to adjust the standard conversion factors for every device. First, they computed the ratio of the median measures of (say) the three instruments given above:

$$med(\frac{\text{Sugar tube}}{\text{Palmer}}) \times med(\frac{\text{Palmer}}{\text{Impinger}}) = 1.685 \times 0.31 = 0.52$$

Then they compared this value with the *actual* median ratio found for the sugar tube over the impinger, which happened to be 0.28. Then they defined the adjusted ratio as the average between the modeled median ratio and the actual median ratio. General theory and particular realities merge to produce $\frac{0.52+0.28}{2} = 0.4$.

Including a fourth instrument adds another theoretical ratio that the authors add to the adjustment (since $\frac{a}{b} \times \frac{b}{c} = \frac{a}{d} \times dc$). In total, then, three ratios combine to make the adjusted conversion ratio between each instrument-pair: two theoretical and one empirical ratio.

Consider the adjusted ratios for all instrument pairs, shown in Figure **??**. Each instrument pair is denoted by the first letter of the instrument's name in the numerator (in caps) and denominator (lower case). See the table below for full instrument names. The position of the plotted letters on the Y axis is the value of the adjusted median. Behind the letters are bars with three points. The bars and letters are ordered on the X-axis by the percentile rank of their adjusted median. The plot is taller than wide to emphasize the trends in the differences between ratios as percentile rank for the adjusted median ratio increases.

Three ratios are given for three points: the theoretical median furthest from the empirical median is the triangle pointing up; the theoretical median closest to the empirical median is the triangle pointing down; the empirical median is a circle. The dotted lines connect values from each median distribution to its value in adjacent ranked adjusted ratios. The tangling in these lines shows how the order of the theoretical and empirical medians alone contrasts with the ordering of the adjusted median.

With "true" ratios between ideal-typical measurements (rather than those given with our sample medians and theoretical ratios), the equation above implies that the rank ordering should give symmetrical positions to inverse ratios, so (for example) the most similar instruments converge at the 50th percentile. The rank ordering requirement is satisfied only in the distribution of adjusted medians: Pi is first, Ip is last, Pt second and Tp second-to-last, Ts and St are right next to each other in the middle, and so on.

This stipulation would be broken if the authors of the report had relied on any of the other three ratios alone. For example, the largest estimated ratios for the Impinger/thimble and Impinger/sugar tube would switch positions if they were ranked by this set of ratios.
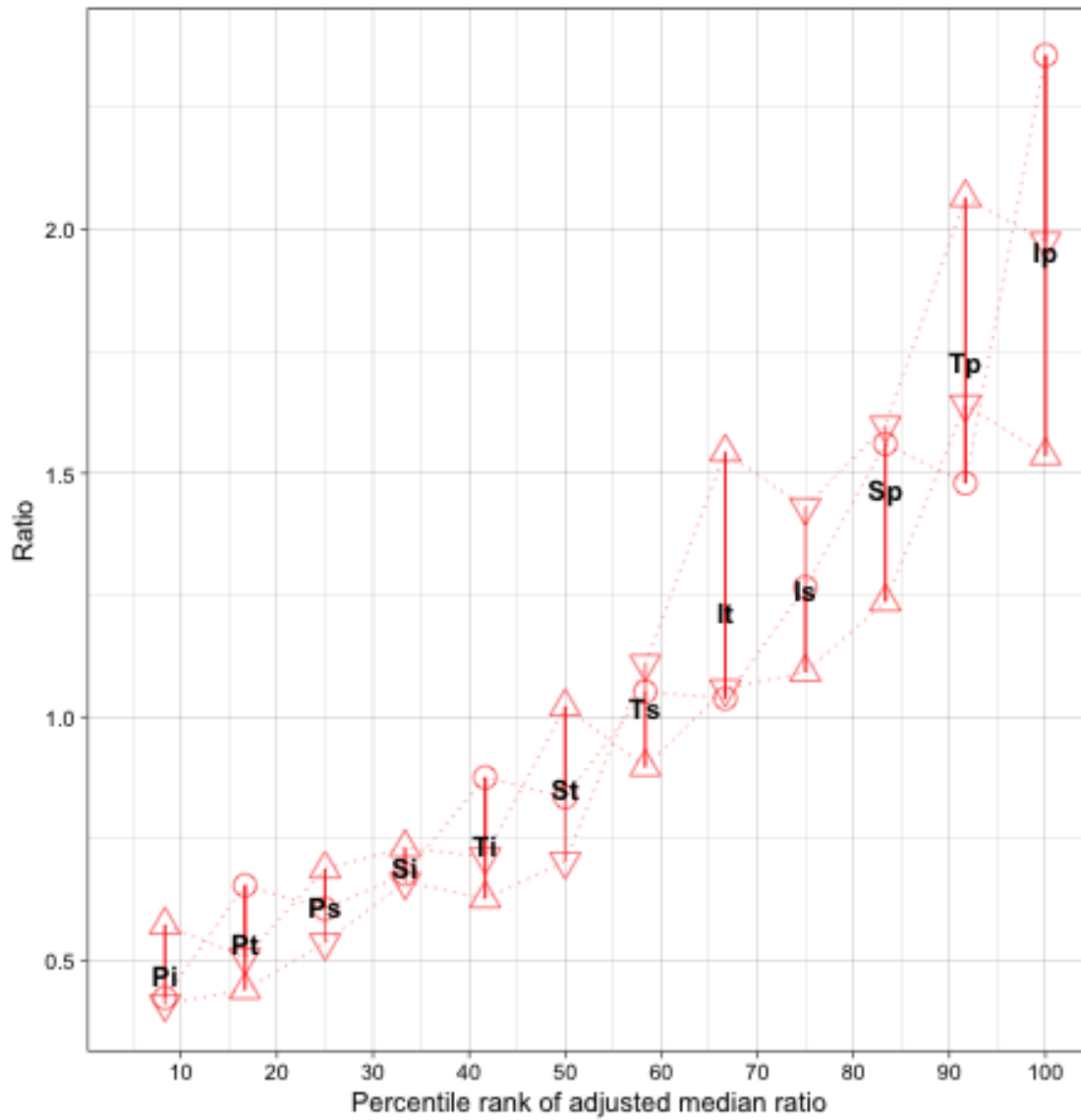
4

Figure 1: Adjusted conversion factors for four instruments

Letter	Instrument name
I (i)	Greenburg-Smith Impinger
P (p)	Palmer Apparatus
S (s)	Sugar Tube
T (t)	Thimble

The adjusted medians soak up a great deal of the information available within the two-way system of relations among measurements, and — by the logic of the order inverse ratios — seems to provide a fairly reasonable set of standards. The authors' supervisors seemed to think so, at least. The conversion factors were promptly adopted to commensurate dust measurements across the federal government.

What does all this say about the culture of modeling that prevailed in this laboratory? First, it highlights how, for these technicians, data was precious. A serious amount of labor and negotiation was required to carry out the tests and conduct their analysis. To the authors, every data point represented the sum of work it took to set and reset instruments under severe time pressure, peer into microscopes, dry out dusts and instruments on an open flame, and argue for the relevance of their or their mentors' favored system of measurement.

Instead of appealing to theoretical distributions or principles of long-run probability, the researchers muddled their way to a non-parametric standard based on what they regarded as the best available information — their own data. The authors remained agnostic about the "true" distributions of phenomena like measurement ratios (though this was a vague concern). Instead, their goal was to give themselves reasonable grounds for establishing the "true" (i.e. standard) distributions by fiat. Consistent with the US style of government in these years, this approach rejects the imperialism of theoretical distributions in favor of the small-scale republican despotism of the industrial laboratory.

In Desrosierès' (2001) terms, the attitude toward numerical measure suggested by the adjusted conversion factors is neither "constructivist" nor "metrological" but a variant of the actuarial attitude. As in accounting, these conversion factors have a direct and self-conscious role in *making* reality. They are declarative; true because high-level federal bureaucrats say so. They are also actuarial in intent. As in conversion across monetary systems, the authors are after a *general equivalent* for translating across measurements (that in fact vary locally). More fundamentally, the reality test for the factors relies on "balancing the books," only here the balancing act is divisive rather than subtractive.

References

Busch, Paul, Pekka J. Lahti, and Peter Mittelstaedt. 1996. *The Quantum Theory of Measurement*. Vol. 2. Springer Sciencie Business Media.

Desrosiers, Alain. 2001. "How Real Are Statistics? Four Possible Attitudes." *Social Research* 68(2): 339-355

Duncan, Otis Dudley. 1984. *Notes on Social Measurement: Historical and Critical*. Russell Sage Foundation.

Hawley, Ellis W. 1974. "Herbert Hoover, the Commerce Secretariat, and the Vision of an 'Associative State,' 1921-1928." *The Journal of American History*: 116-140.

Klein, Ursula. 2003. *Experiments, Models, Paper Tools: Cultures of Organic Chemistry in the Nineteenth Century*. Stanford University Press.

Krippner, Greta R. 2023. "Unmasked: A History of the Individualization of Risk." *Sociological Theory* 41(2): 83-104.

Latour, Bruno, and Steve Woolgar. 2013. *Laboratory Life: The Construction of Scientific Facts*. Princeton University Press: Princeton.

Levy, Jonathan. 2021. *Ages of American Capitalism: A History of the United States*. Random House: New York.

Mosteller, Frederick, and John W. Tukey. 1977. *Data Analysis and Regression: A Second Course in Statistics*. Addison-Wesley Series in Behavioral Science: Quantitative Methods.

Taylor, John R. 1982. *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements*. University Science Books.