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Comment

David C. Mowery

This chapter by Meisenzahl and Mokyr addresses an important issue in the economics of technological change—the contributions of incremental innovation to technological change and economic growth. This topic was addressed in the original *Rate and Direction* volume, which included the chapter by John Enos (1962) on the contributions of incremental innovation to performance in petroleum refining during the so-called "beta phase" that followed the introduction of major innovations.

Meisenzahl and Mokyr argue that incremental innovation was an impor-

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tant contributor to technical advance during the Industrial Revolution, and further assert that Great Britain enjoyed a comparative advantage in such "tweaking." Much of the evidence for their arguments draws on a novel data set describing the activities of "tweakers" during 1660 to 1830 that includes information on the sectoral distribution of these tweakers, their educational and training background, and the role of selected incentive mechanisms (prizes, patents, "first-mover advantages") in tweaking activity. The authors conclude that tweakers were active in a wide range of sectors, including textiles, the engineering industries, instruments, and so forth. The sheer breadth of incremental technological innovation during the British Industrial Revolution, the authors argue, supports a characterization of this economic transformation as one that operated on a broad front, rather than being limited to a few key sectors such as textiles or steam power.

The data set assembled by Meisenzahl and Mokyr is a rich one, and the authors should be congratulated for amassing this extensive set of measures of the activities of individuals who contributed to technical progress during the Industrial Revolution. Nevertheless, like all such data, the tweaker data set has some shortcomings that undercut the inferences of the authors. First, and most important, these data are limited to successful tweakers, those whose activities were of sufficient importance to result in entries in the *Dictionary of National Biography* and other published sources. Indeed, one can argue that the sources used by the authors mean that only the most successful tweakers are included in their database. No information exists in this data set on the size (and critically, the intersectoral distribution) of the overall population of aspirant tweakers. Among other things, a finding that tweaking was more successful in textiles or steam power (based on a comparison of the size of the aspirant and successful populations of tweakers in these and other sectors) might corroborate Allen's argument (2009) that innovation was more productive in these sectors than elsewhere, benefiting Great Britain to an unusual extent.[1] The lack of information on the relative "productivity" or success of tweaker activities in different sectors, as well as an absence of data on the contributions of such educational and training institutions as apprenticeships to tweaker productivity, mean that at least some of the conclusions in the chapter need to be qualified.

A second challenge associated with these data is the distinction between tweakers and inventors who contributed the major innovations that were the focus of the modifications and improvements undertaken by tweakers.

1. See Allen (2009), especially his concluding chapter: "It is important that the British inventions of the eighteenth century—cheap iron and the steam engine, in particular—were so transformative, because the technologies invented in France—in paper production, glass, and knitting—were not. The French innovations did not lead to general mechanization or globalization. One of the social benefits of an invention is the door it opens to further improvements. British technology in the eighteenth century had much greater possibilities in this regard than French inventions or those made anywhere else" (275).

This distinction is conceptually clear, but empirically cloudy in the data set in this chapter. The authors do not describe the specific criteria used to distinguish tweakers from inventors, making it difficult for the reader to evaluate the credibility of these distinctions and ascertain that the data set does not include inventors as well as tweakers. Indeed, the authors note that the distinction between "invention and implementation" (the latter activity presumably consisting mainly of tweaking) is not a sharp one. For example, many of the individuals included in this data set may well have made contributions as both inventor and tweaker over the course of their careers, perhaps developing important incremental improvements to their major inventions, or learning from tweaking activities in ways that eventually enabled them to undertake inventive activity. The inventive "stars" examined in table 9.7 of the chapter are all drawn from the authors' sample of tweakers, further blurring the distinctions between "great inventors" and tweakers. A clearer articulation of the criteria distinguishing tweakers from inventors and some discussion of the longitudinal stability of these distinctions would be useful. Among other things, such a discussion might support more of the cross-national comparative work that is needed to establish a key conclusion of this chapter; that is, that Great Britain enjoyed a comparative advantage in tweaking.

These empirical challenges notwithstanding, this chapter provides a fascinating portrait of innovation during the Industrial Revolution, one that underscores the importance of technological diffusion for innovation. After all, the incremental improvement of innovations that constitutes the definition of tweaking implies that tweakers had access to these major inventions. The extensive diffusion of key inventions within Great Britain therefore may have contributed to the incremental innovation that the authors examine. This interaction between diffusion and innovation, of course, is by no means limited to the Industrial Revolution or to the process innovations in petroleum refining examined by Enos (1962). For example, technological change in information technology during the last quarter of the twentieth century, especially in technologies such as desktop computers, computer networking, and Internet applications, all relied on the inventive and tweaking activities of users who benefited from easy access to a large "installed base" in the United States and other industrial economies. The contributions of tweaking to innovation thus appear to have been important in more than one historical epoch, and Meisenzahl and Mokyr deserve our thanks for highlighting these contributions in an era in which the contributions of incremental innovation all too often have been overlooked.

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