

Steam power, establishment size, and labor productivity growth in nineteenth century American manufacturing [☆]

Jeremy Atack ^{a,*}, Fred Bateman ^b, Robert A. Margo ^c

^a *Department of Economics, Vanderbilt University, Nashville, TN 37235, USA*

^b *Department of Economics, Terry School of Business, University of Georgia, Athens, GA 30602, USA*

^c *Department of Economics, Boston University, 270 Bay State Road, Boston, MA 02215, USA*

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Abstract

We use establishment-level data from the 1850–1880 censuses of manufacturing to study the relationships among establishment size, steam power use, and labor productivity. Large establishments, measured here by employment, were much more likely to use steam power than smaller establishments. By 1880, slightly more than half of all manufacturing workers were employed in establishments using steam power, compared with 17 percent in 1850 and we show that, after controlling for various establishment characteristics, steam-powered establishments had higher labor productivity than establishments using other sources of power. Moreover, this productivity differential was increasing in establishment size.

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1. Introduction

The vast majority of manufacturing establishments in early nineteenth century America were what Sokoloff (1984) has called “artisan shops”. These were very small establishments, usually consisting of the entrepreneur and perhaps an assistant or two who fashioned the final product from start-to-finish using only their skill and a few hand tools. There were other establishments that still relied on hand tools and had no inanimate sources of power but which employed more workers who were less skilled than those in the artisan shops. However, their productivity was higher by virtue of the division of labor.

[☆] Atack is Professor of Economics and of History, Vanderbilt University, and Research Associate, National Bureau of Economic Research. Bateman is the Nicholas A. Biddles Professor of Economics, University of Georgia. Margo is Professor of Economics and of African-American Studies, Boston University, and Research Associate, National Bureau of Economic Research. This is a heavily revised version of a paper originally written by Robert Margo for the conference on “The Development of the U.S. and European Economies in Comparative Perspective”, held at the University of California, Berkeley, in September 2004. Comments from Bart van Ark, Richard Steckel, seminar participants at Berkeley, Harvard, the NBER, and Northwestern, and two referees of this journal are gratefully acknowledged.

* Corresponding author. Fax: +1 615 343 8495.

E-mail addresses: jeremy.atack@vanderbilt.edu (J. Atack), fbateman@uga.edu (F. Bateman), margora@bu.edu (R.A. Margo).

Labor productivity could also be increased through the use of powered machinery such as lathes, power looms, and drill presses. Power had long been supplied by falling water but steam technology increasingly caught the attention of contemporaries. The diffusion of light, simple, and cheap high pressure engines along the lines pioneered by Oliver Evans fit well with relative factor prices in America (Habakkuk, 1967). These had a voracious appetite for fuel and a relatively short-life expectancy but were relatively cheap and easy to manufacture, ship and set-up (Atack, 1979; Hunter, 1985). Consequently, establishments using steam power could be much more “footloose” than those relying upon water especially after fuel prices fell. The wide variety of applications and scales to which these engines could be adapted also qualifies them as a “general purpose technology”—that is, a technology that is adaptable to a wide range of uses and for which there may be external economies.¹ Manufacturing establishments using water power, on the other hand, had to locate at one of the limited suitable sites and their potential power was limited by the stream flow and the height of the water’s fall.²

Although economic historians have written extensively about the diffusion of steam (Temin, 1966; Atack, 1979; Atack et al., 1980; Hunter, 1985) surprisingly little attention has been paid to the role played by establishment size and attendant productivity effects.³ To this end, we use data for individual manufacturing establishments to examine the use of steam power and its impact on labor productivity in American manufacturing between 1850 and 1880, paying particularly close attention to differences by establishment size. We focus on the period from 1850 to 1880 because it is during this period that steam power began to diffuse in earnest, whereas, after 1880, electrical power increasingly became an alternative (Atack et al., 1980; Devine, 1983). Furthermore, excellent data are available at the establishment level for this period unlike for later in the nineteenth or early in the twentieth century.

We have three principal findings. First, the likelihood of adopting steam power was increasing in establishment size. This is consistent with the hypothesis that the availability of steam power was a factor behind the growth of large-scale enterprises which played a central role in the United States’ ascendancy as the leading industrial nation by World War One (Wright, 1994; Broadberry, 1994, 1997; Broadberry and Irwin, 2006). Second, plants using machinery that was powered by steam or water had higher labor productivity than non-powered establishments, although most of these differences were due to higher capital intensity in powered establishments rather than the source of power itself. Third, even after controlling for capital intensity, steam-powered “factories”—a label which we apply to establishments with 16 or more employees (see Sokoloff, 1984, 1986)—had significantly higher total factor productivity than steam-powered plants with fewer than 16 employees.⁴

2. The economics of the diffusion of steam power: the role of establishment size

There is an extensive literature on the choice of power (Temin, 1966; Atack, 1979; Halsey, 1981; Hunter, 1979, 1985) but none of these directly address whether the diffusion of steam varied with establishment size. Our explanation of why this should be the case has two parts. The first emphasizes the division of labor associated with mechanized production and is not (theoretically at least) specific to steam. The second part argues that the cost advantages of steam relative to water were increasing in establishment size. Taken together, the two parts imply that the diffusion of steam should have been positively related to establishment size.

¹ Rosenberg and Trajtenberg (2004) suggest that diffusion of steam may have promoted urbanization in the United States, which is assumed to have promoted external economies. See, however, Kim (2005) who argues that any such effect of the diffusion of steam was small in magnitude. For a general discussion, see David, 1990; Crafts, 2004; van Ark and Smits, 2004.

² These sites were quickly appropriated by first settlers who restricted and controlled entry to manage the scarce resource. For example, the Proprietors of the Locks and Canals at Lowell controlled the waterpower resources there while the Essex Company controlled the rights at Lawrence. See U.S. Census Office, 1991.

³ A recent paper by Crafts (2004) examines the impact of the diffusion of stationary steam engines, steam-powered railways, and steamships on aggregate total factor productivity growth in the British economy during the nineteenth century. He finds that steam’s impact was much larger after 1850 than before but overall the contribution to productivity growth was modest. The scope of our paper is narrower and different; it is narrower because we examine the use of steam and its impact on labor productivity by establishment size solely in manufacturing (and not the other sectors considered by Crafts) and it is different because it derives from econometric estimation of production functions in which we directly compare differences in labor productivity between steam, water, and hand (or animal) powered establishments.

⁴ Here, the idea is that steam might have enhanced the division of labor. We elaborate on this point in Section 2.

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