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Gaining Steam: Incumbent Lock-in and Entrant Leapfrogging

Based on BFI Working Paper No. 2024-54, "Gaining Steam: Incumbent Lock-in and Entrant Leapfrogging," by Richard Hornbeck, University of Chicago; Shanon Hsuan-Ming Hsu, University of Chicago; Anders Humlum, University of Chicago; and Martin Rotemberg, New York University

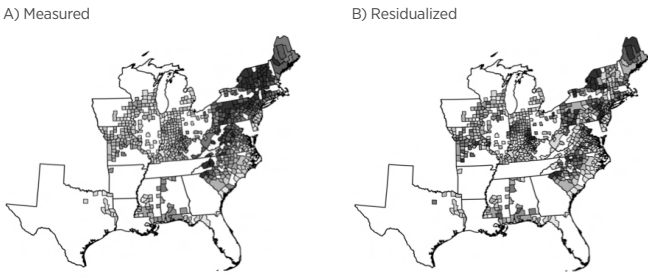
The adoption of new technologies can be slowed if companies become locked into alternatives that are cheaper at the outset. During the mid 1800s, small mills used waterpower because of its low fixed costs; their failure to switch to steam power slowed its adoption overall.

In the mid-19th century, the American landscape was dotted with mills powered by the flow of rivers. Waterpower dominated, providing an essential energy source for flour and lumber mills, which were vital to local economies. However, a new technology was emerging—steam power—that promised to free manufacturing from the constraints of riverbanks.

Mills were slow to adopt steam, despite its advantages. In this paper, the authors uncover the forces that delayed the transition to steam, as they have important implications for encouraging more rapid adoption of future technologies.

The authors digitize records from the US Census of Manufactures to create a rich panel dataset showing the name, industry, location, and power source over 80,000 lumber or flour mills between 1850 and 1880. They use these data to explore which mills were using steam or waterpower and how mills switched over time. The authors find the following:

Figure 1 • County Waterpower Potential



Note: This figure shows the authors' county-level estimates of waterpower potential, with darker color corresponding to greater waterpower potential. The sample is restricted to the authors' main balanced panel of 690 counties. Panel A shows the measure of county waterpower potential: the sum across all river segments in the county of the flow rate of each river segment times its fall height (and a gravitational constant), per square mile, and Panel B shows the residual county waterpower potential, after controlling for total county water flow and terrain ruggedness; the presence of a navigable waterway, distance to the nearest navigable waterway, and county market access in 1850; the presence of coal in the county, the share of county area covered by coal deposits, and market access to coal deposits.

- Waterpower was attractive to less productive, often smaller mills because of its relatively low **fixed costs**. As these mills aged into established businesses, they faced significant **switching barriers** to adopting steam, namely

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Fixed costs: Expenses that remain constant, regardless of changes in a business's production volume or sales levels

Switching barriers: The costs or obstacles a business faces when altering its operational processes, suppliers, or systems

sunk costs in the form of their investments in waterwheel infrastructure.

- In counties with less waterpower potential (those with fewer powerful rivers), new mills adopted steam and manufacturing grew more rapidly. New mills were roughly four times more likely to use steam power than incumbent mills.
- Waterpower potential substantially slowed steam adoption: If the average county had one **standard deviation** lower waterpower potential, the share of mills using steam would have reached one-half 31 years earlier and been 18 percentage points greater at full capacity.
- Absent any switching barriers, the share of mills using steam would have reached 30% a decade earlier. This delay was mainly caused by relatively low productivity entrants, initially attracted to the lower fixed costs of water, who then faced barriers in switching to steam power. Switching barriers were sufficiently large that incumbent firms suffered overall from the introduction of steam power, because the increased competition from new entrants outweighed the benefit from the option to switch to steam.
- The authors explore several policies aimed at overcoming these barriers to adoption. They consider a "cash for clunkers" style policy, where the government subsidizes the removal of old waterwheel systems. This subsidy generates a positive social surplus by accelerating steam adoption among directly affected incumbents and fostering technological spillovers that benefit later entrants. In addition, the authors show that new technologies with lower upfront costs, akin to the waterwheel but without its operational inefficiencies, enable rapid adoption and prevent newer entrants from becoming locked into older technologies.

This research offers critical lessons for the adoption of future technologies. It illustrates how initial conditions, economic incentives, and market structures can dramatically influence the pace and spread of innovation. For policymakers and industry leaders, understanding these dynamics can help design interventions that mitigate technological lock-in, encouraging more rapid adoption of new technologies and maximizing their economic benefits.

Sunk costs: Expenses that have already been incurred and cannot be recovered

Standard deviation: a statistic that measures the amount of dispersion from the average in a set of data

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