
Do Patents Encourage or Hinder Innovation? The Case of the Steam Engine

BY MICHELE BOLDRIN, DAVID K. LEVINE, AND ALESSANDRO NUVOLARI

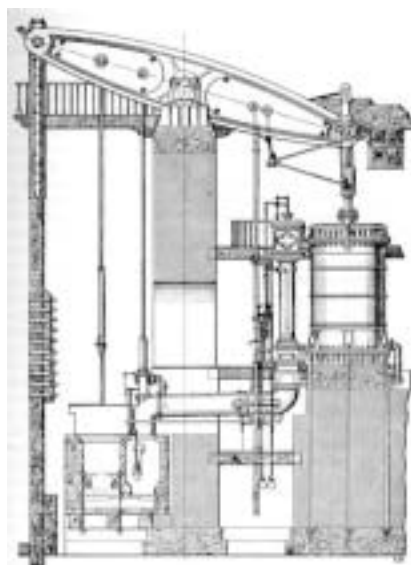
Many economists are in love with the idea of a natural experiment. A natural experiment is a turn of events that enables a clean comparison between two different economic-policy alternatives. For many economic policies we do not have the good fortune of a natural experiment. In these cases economists must fall back on other less-reliable modes of econometric analysis. Fortunately for other economic policies nature has been kind enough to provide us with the laboratory we need.

The Patent Controversy

Today one of the most controversial issues in economic policy is that of patent law. Is a patent just an extension of property rights to the realm of ideas? Or is it an unwarranted interference by the government into the rights of individuals who have purchased goods and services to use them as they see fit? Should the Western system of patents be extended worldwide? Or should we get rid of patents entirely? Is the patent system responsible for modern miracle drugs? Or is it to blame for the millions dying of HIV in Africa? Do patents lead to greater innovation and economic growth? Or do they kill the goose that lays the golden egg?

The issue of whether patents are genuine property rights or unwarranted government interference cannot of course easily be answered by a natural experiment. We will leave that discussion to philosophers. The

impact of patents on innovation does have an objective answer. In this case history instead of nature has been kind enough to provide us with a wonderful natural experiment. This experiment took place in the county of Cornwall, England, between 1772 and 1852. It was there, in the extreme southwest of England, in the wet depths of the Cornish copper and tin mines, far removed from the supply of coal in Wales, that the steam engine was pioneered.

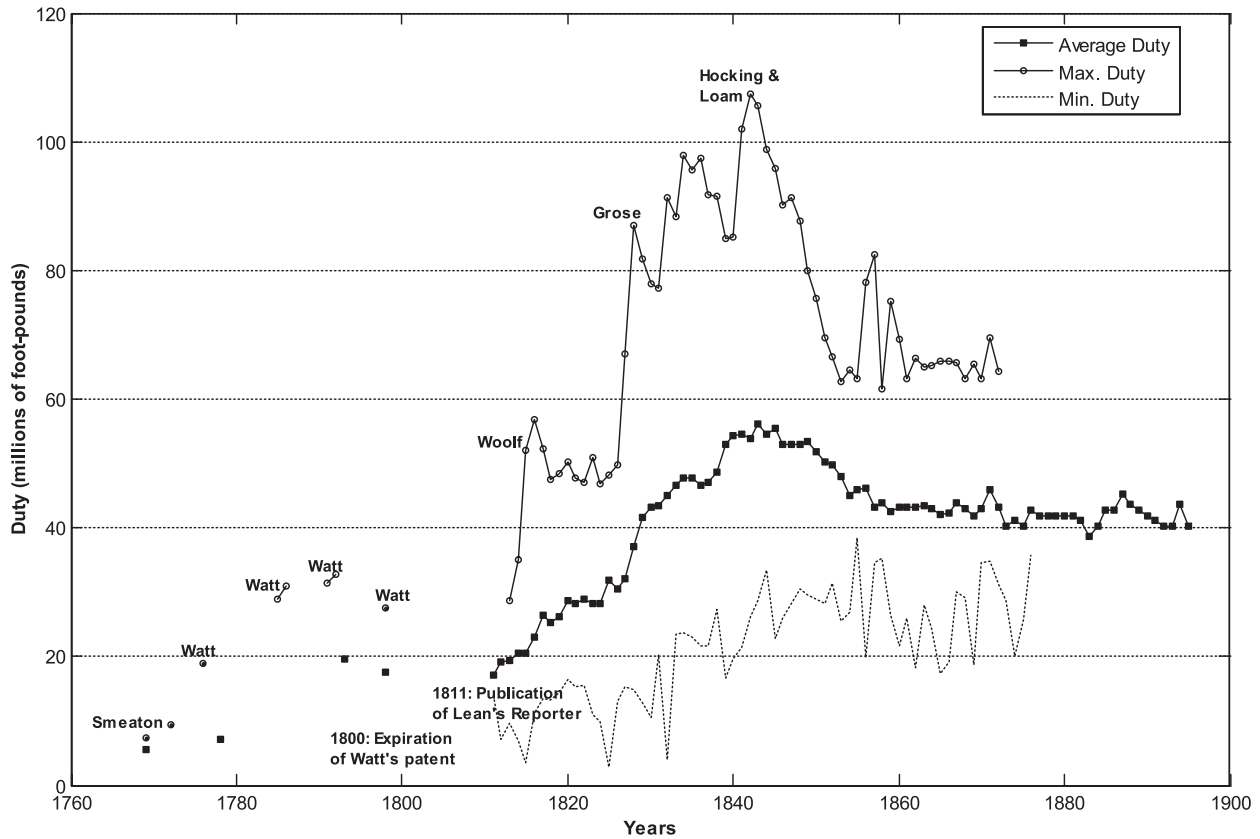


A nineteenth-century drawing of a Cornish steam engine

To examine innovation in steam technology, we need a measure of how good a steam engine is. One important measure is the amount of work delivered by a given amount of fuel. This can be measured by the *duty* of a steam engine: the number of pounds of water that can be lifted one foot for each 94 pounds of coal consumed.

In 1772 steam engines were of the so-called Newcomen design of which the best had a duty of 10 million foot-pounds (10M). In 1777 Matthew Boulton and James Watt began selling the first steam engines with a separate condenser. These initially had a duty of 18M, rising

Michele Boldrin (micheleboldrin@gmail.com) and David Levine (david@dklevine.com) are professors of economics at Washington University in St. Louis. Boldrin is co-editor of the Review of Economic Dynamics. Levine is president of the Society of Economic Dynamics. Alessandro Nuvolari (A.Nuvolari@tm.tue.nl) is an assistant professor of the economics of science and technology at Eindhoven University of Technology in the Netherlands.



by 1792 to a peak of 26M. These things rested until 1814 when the use of the high-pressure design of Richard Trevithick led to engines with a duty of 55M. The duty then rose relatively continuously until it reached a peak of 110M in 1852.

To summarize: During the 42 years from 1772 to 1813 duty rose 3.8 percent per year; during the 38 years from 1814 to 1852 duty rose more than twice as fast—8.5 percent per year. The evolution of the duty is charted in the figure. The state of innovation is best represented by the best engine currently being produced, but for completeness the average and minimum duty of constructed engines is reported. The decline in duty growth after 1852 reflects both the general decline of the Cornish mining industry and the more difficult conditions in which steam engines were forced to operate due to the deepening of the mines.

As it happens there is one critical difference between the earlier period and the later period. By patenting the separate condenser Boulton and Watt, from 1769 to 1800, had almost absolute control on the development of the steam engine. They were able to

use the power of their patent and the legal system to frustrate the efforts of engineers such as Jonathan Hornblower to further improve the fuel efficiency of the steam engine. By way of contrast, and fortunately, Trevithick did not patent his equally innovative high-pressure design.

Ironically, not only did Watt use the patent system as a legal cudgel with which to smash competition, but his own efforts at developing a superior steam engine were hindered by the very same patent system he used to keep competitors at bay. An important limitation of the original Newcomen engine was its inability to deliver a steady rotary motion. The most convenient solution, involving the combined use of the crank and a flywheel, relied on a method patented by James Pickard, which prevented Watt from using it. Watt also made various attempts at efficiently transforming reciprocating into rotary motion, reaching, apparently, the same solution as Pickard. But the existence of a patent forced him to contrive an alternative less-efficient mechanical device, the sun and planet gear. It was only in 1794, after the expiration of Pickard's patent, that Boulton

and Watt adopted the economically and technically superior crank. The impact of the expiration of Watt's patents on his empire may come as a surprise as well. Far from being driven out of business, Boulton and Watt for many years were able to charge a premium over the price of other steam engine manufacturers.

Here we see clearly the upside and the downside of the patent system in action. The upside is that it may be the case that the prospect of a 31-year monopoly induced Watt to spend three and a half years of his life—between late 1764, when he first was asked to repair a steam engine, and mid-1768, when he applied for patents on his improved design—working to improve steam technology.

The downsides are two. The first is that the reward to success bears no relation to the cost of invention. In what respect is it necessary, reasonable, or fair to grant a 31-year monopoly and make a man fabulously wealthy because he spent a few years working on a project that benefited his fellow man? Certainly this kind of inducement was not needed for Trevithick, whose contribution to steam technology raised the duty 110 percent as against Watt's contribution, which raised the duty only 80 percent.

The second downside of the patent system is the devastating effect it has on incremental innovation. From 1786 to 1800 there was no increase in the duty of steam engines at all, as Boulton and Watt successfully sought to prevent competition by suppressing innovation. This should be a cautionary note for people who think that the current wave of patent litigation triggered by a system of software patents created by the courts is likely to have a beneficial impact on software innovation.

Collaborative Innovation

For the 11 years following the end of the Boulton and Watt monopoly, Cornish mining activities underwent a period of slackness, as the mine adventurers were content with the financial relief coming from the cessation of the premiums they had paid to Bolton

and Watt. As a consequence they neglected the maintenance and the improvement of their engines. This situation lasted until 1811, when a group of mine captains decided to begin the publication of a monthly journal reporting the relevant technical characteristics, the operating procedures, and the performance of each engine. Their explicit intention was twofold. First, the publication of the reports permitted the rapid individuation and diffusion of best-practice techniques. Second, it introduced a climate of competition among the engineers entrusted with the different pumping engines, with favorable effects on the rate of technical progress. Joel Lean, a highly respected mine captain, was appointed as the first engine reporter. The journal would later be called *Lean's Engine Reporter*. During the

31 years after 1811 this collaborative competitive effort at innovation raised duty by more than the great "breakthrough" of Watt ever did.

It is worth remarking another important feature of the process of technical change in Cornish engines during the collaborative period. Most engines were single-cylinder, high-pressure, single-acting engines, with a plunger pump of the type originally erected by Trevithick in 1812. Interestingly enough, however, alternative designs were never completely ruled out. For example, in different peri-

ods, engineers such as Arthur Woolf and James Sims continued to experiment with compound engines. Throughout this period, the development of the Cornish engine remained a fluid state and this facilitated a more thorough exploration of alternative designs.

The astute reader will no doubt notice that the collaborative innovation occurring after the expiration of the Watt patents resembles nothing so much as modern open-source software development. Like with open-source software, altruism and socialism played no role—just good old-fashioned capitalist incentives. Engineers were recruited by captains of the mine on a one-off basis to build and design an engine. Engineers were in charge of the design and they supervised the erection of the engine that was commissioned to them. They also

The collaborative innovation occurring after the expiration of the Watt patents resembles nothing so much as modern open-source software development.

provided directions for day-to-day working and maintenance of the engines they were entrusted with. Thus the publication of technical information concerning the design and performance of different steam engines permitted the best engineers to consolidate their reputation and improve their career prospects. Over time, this practice gave rise to a professional ethos favoring sharing and publication of previous experiences.

Much of the free/open-source-software industry operates this way today, with software engineers competing for future business through the quality of their current innovations. Sharing of information is a key part of this competition. If Linus Torvalds, creator of the Linux kernel, is not nearly so rich as Bill Gates, he is nevertheless richer than most of us. (See Michele Boldrin and David K. Levine, "Open-Source Software: Who Needs Intellectual Property?" *The Freeman*, January 2007, <http://tinyurl.com/6hnyxf>.)

Even the modern controversy over the current effort of the Free Software Foundation to limit software patents through the General Public License Version 3 finds reflection in the earlier Cornwall experience. Familiar with the negative impact of the Watt patents on innovation, Cornwall mine engineers were reluctant to patent their inventions. From 1781 to 1852 Cornish residents took out a grand total of 15 patents on steam

technology—against 994 patents on steam technology in all of England during that period. Will it surprise you to learn that the area with the fewest patents also was the area that contributed the most to the innovation and development of steam technology?

One may wonder why development in an obscure corner of England should draw our attention. As it happens, the design of fuel-efficient high-pressure steam engines did not only serve to improve the efficiency of pumping water out of mines in one small region. It is the fact that efficient high-pressure engines can be made light and compact and do not require much weight of fuel that made possible such modest advances as . . . the steam train, the steam boat, the steam jenny, and the steam just-about-everything-else. In short—the steam engine that we imagine as the centerpiece of the Industrial Revolution, the key link that took us from riding horses to being frequent fliers—was not the product of the inventive genius of James Watt. When the Boulton and Watt monopoly expired in 1800 steam engines were used only to pump water out of mines. The earth-shattering innovation of widely usable steam engines was the product of the efforts of Joel Lean and dozens of other equally anonymous Cornwall mining captains and engineers. It is equally a tribute to their steady innovation without making use of patents. **FEE**



Checking your holiday gift list?

Give a year of *The Freeman*!

It's a thoughtful way to remember that special teacher, student, business associate, or friend.

Just \$40 per year.

Call 1-800-960-4FEE for further information.