Haris Kitsikopoulos, *An Economic History of British Steam Engines 1774-1870: A Study of Technological Diffusion*, Springer 2023.

The introduction and spread of steam engines enabled the production and distribution of goods and services to break free – for the first time – from the constraints of muscle, wind or water. The technology thus eventually shaped some key aspects of Britain's industrial revolution. This monograph picks up the story of the installation of James Watt's engine in Matthew Boulton's Soho factory in 1774, when the only practical steam competition came from Newcomen engines.
The study begins with the updated Kanefsky database (https://coalpitheath.org.uk/engines/) being used to revise the dissemination of engines, distinguishing between the total installed horsepower (HP) and the horsepower actually in use. By 1800, engines in use accounted for around one quarter HP more than earlier estimates recorded by Crafts (2015). Before 1774 engines were largely limited to pumping water from mines, and colliery installations remained the main sector of use

[22] C. Tilly, *Big Structures, Large Processes*, Huge Comparisons, Russell Sage Foundation, London, 1984, p. 14.

of steam engines until the last quarter of the eighteenth century. Delays in delivering orders suggest that the supply of engineers able to construct and maintain these steam engines failed to match demand. Kitsikopoulos measures the deviation of actual fuel efficiency of individual engines from the ideal to show how variable were engineers' skills, especially in the early years of a new engine design.

Kitsikopoulos calculates an average Newcomen fuel rate (measured in pounds of coal per hp per hour) of 25.25 compared with only 9.65 for Watt engines. Coal was costly to move to any great distance from the coal mine, which gave Watt engines a competitive advantage, but this could be offset by their higher capital cost. Newcomen engines were thus likely to be preferred for pumping coal mines and when they were only required to work part time, for example in textile industries. Newcomen engine success accelerated at the same time as Boulton and Watt engines were spreading; different techniques for the same purpose can coexist profitably within a national economy when there are relevant regional and industrial differences in demand.

Steam was of minor importance in energy supply by 1800 because water-power was so competitive. The Breast waterwheel introduced starting from the 1750s greatly improved the efficiency of undershot wheels: at the end of the eighteenth century, in the range of 1-30 HP the capital costs of water wheel power were lower than those of both types of steam. Where more power was required, Newcomen engines offered lower capital costs and Watt engine capital costs matched those of water-power.

The first section of the monograph ends chronologically with the expiry of the Watt patent in 1800 while the second part introduces the Cornish high pressure engine innovations. Richard Trevithick took a high-pressure steam patent in 1802. His engine was simple and cheap but in practice it was considered dangerous and inferior to Watt's. More successful was his 1812 Wheal Prosper engine. Though it gave irregular movement, it was the first of a series of Cornish engines. Kitsikopoulos takes issue with the claim that this was a period of collective invention in Cornwall. There was no new ethos averse to patenting in Cornwall. Every major innovation from Trevithick's to McNaught's was tied to patenting. In 1804, Arthur Woolf took a patent for a compound engine with twice the thermal efficiency of the Watt engine. Trevithick was keen on patenting, but he went bankrupt in 1812 and so he could not afford to patent the Wheal Prosper engine because of the expense. There was not enough relevant material for Lean's Engine Reporter (1811) publication to spawn collective invention, Kitsikopoulos maintains; it was merely a record of efficiency standards not a technological compendium to provide the information necessary for further innovation. This phase of technological innovation lasted through to the mid 1840s, followed by stagnation till the 1870s, a cyclical pattern explained by the early dominance of Cornish mining in world copper and tin markets and the later contraction of market share and rise of production costs.

According to Kitsikopoulos, the initially slow success of high-pressure engines beyond Cornwall was due to their irregularity of motion which was bad for textile manufacturing. Subsequently regional prices of coal for high price areas were more likely to favour the more fuel-efficient high-pressure engines. Temin (1966) noted that the high-pressure steam engine was introduced simultaneously in Britain and America but thirty years later almost all stationary steam engines in Britain were low-pressure engines whereas almost the totality of those in America used high pressure. He suggested that in practice the range of efficiencies of different engine types may not have differed. Anyway, steam engine diffusion accelerated in the 1840s so that by 1870 steam power accounted for slightly over 89% of total power output.

Preparing the ground for steam engines in railways, Kitsikopoulos discusses the introduction of wooden rails in the early seventeenth century. Much of the early railway story is well known, such as Stephenson's work for coal haulage and the fixed steam engine phase. Progress with locomotives depended on progress in other fields, as by the mid 1830s wrought iron boilers and wheel rims replaced cast iron, and brass boiler flues replaced those in copper. Reduction in operating and fixed costs of rail locomotive freight haulage is compared with costs of roads and canals, as well as of stationary engines. It is no surprise that in the first half of the nineteenth century railways spread much faster than the one percent a year growth of canals and turnpikes because they offered much cheaper ton mile rates and a faster service. Though a surprise at the time was the importance of rail passenger traffic, which additionally set a new challenge for cost allocation on most rail routes. By 1870 horse haulage cost was 7-12 p per ton mile and canal rates accounted for one third of land carriage. In 1842-1856, the average receipt for railways was 1.71 pence per ton mile.

In his steam cars 'Dead ends' chapter Kitsikopoulos is more impressed by the supply of entrepreneurship than the quality. Principal practitioners Goldsworthy Gurney and Walter Hancock went bankrupt. While available technology and discriminatory road tolls undoubtedly reduced the viability of these vehicles and their services, he claims that road steamers could have been profitable if managed competently. He calculated that in the 1830s road steamers could achieve two thirds of the costs of stage coaches and in the 1870s steamers could haul goods at two thirds the cost of horse haulage. Hostile tolls would have been avoided if the entrepreneurial focus had been on goods haulage, especially agricultural goods, rather than passengers. The quarter century delay in road steamer investment from the mid1830s was an entrepreneurial and managerial failure, apparently less fundamental for other uses of steam power over the preceding half century.

This is an extremely thorough achievement considering the literature and sources available for the study of steam engines in Britain. Each chapter begins with a summary quite similar to an abstract. There is no index and references follow each chapter. A few diagrams to elucidate the technologies would have been helpful.

James Foreman-Peck
Cardiff University

References

Crafts N.F.R. (2015), "Steam as a General Purpose Technology: A Growth Accounting Perspective", in *Economic Journal*, 114, April, pp. 338-351.

Temin P. (1966), "Steam and Waterpower in the Early Nineteenth Century", in *Journal of Economic History*, 26, 2, pp. 187-205.