The Improving Mentality: Innovation during the British Industrial Revolution, 1651-1851

WORKING PAPER
(NB the final sample will be double the size, and extended back to 1551)

Anton Howes
anton_howes@brown.edu

Brown University
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What caused innovation to accelerate in so many different industries during the British Industrial Revolution? I present new evidence on the sources of inspiration and innovation-sharing habits of 677 people who innovated in Britain between 1651 and 1851. The vast majority of these people – at least 80% – had some kind of contact with innovators before they themselves started to innovate. These connections were not always between members of the same industry, and innovators could improve areas in which they lacked expertise. This suggests the spread, not of particular skills or knowledge, but of an improving mentality. The persistent failure to implement some innovations for centuries before the Industrial Revolution, despite the availability of sufficient materials, knowledge, and demand, further suggests that prior societies may have failed to innovate quite simply because the improving mentality was absent. As to what made Britain special, we cannot know for sure without constructing similarly exhaustive lists of innovators for other societies. But a likely candidate is that the vast majority of innovators – at least 83% – shared innovation in some way, while only 12% tried to stifle it. Just like a religion or a political ideology, the improving mentality spread from person to person, and to be successful required effective preachers and proselytisers too.

The Industrial Revolution began in Britain.[1] In the two centuries after 1651, Britain emerged from the carnage of the English Civil War to become the world's technological leader. By 1851 millions of people flocked to the Great Exhibition in Hyde Park, London, to celebrate the remarkable change. The transformation was brought about by an unprecedented acceleration in the rate of innovation, even if economic historians disagree on how much the economy grew. [2] A student of the historian T.S. Ashton famously called the transformation a "wave of gadgets",[3] though this does not capture the breadth of industries affected. James Watt developed the separate condenser for steam engines, and Richard Arkwright spun cotton with his water frame, but technological leaps occurred in nearly all industries, beyond the famous examples of cotton, iron, and steam. It was also the age in which Edward Jenner developed vaccinations against smallpox, and in which John Bennet Lawes used superphosphate of lime as a fertiliser. Innovation accelerated in agriculture, medicine, brewing, furniture-making, photography, and even gardening.[4]

Other societies had become unusually prosperous before the British Industrial Revolution, such as the Dutch Republic in the seventeenth century, or China in the twelfth. But they had experienced only efflorescences – short-lived and reversible episodes of prosperity with only occasional innovation.[5] Britain's experience was different. It began the same way as the others, with an initial spate of innovations: Thomas Savery and Thomas Newcomen, for example, exploited the vacuum created by rapidly condensing steam to pump water out of mines; Abraham Darby baked coal and used it to cast iron cauldrons; George Ravenscroft added lead oxide to glass to make it as clear as cystal; John Dwight found a way to imitate German stoneware pottery. Such innovations would have contributed to economic growth for a while, and stagnation might have set in again – there was no guarantee that the likes of John Theophilus Desaguliers, Henry Beighton, and John Smeaton would each tweak the old Newcomen

[1] I use "British" to refer to the British Isles: the geographical area that comprises today's United Kingdom and the Republic of Ireland.
[2] See: Deane and Cole, *British Economic Growth 1688-1959*; Crafts, *British Economic Growth During the Industrial Revolution*; Crafts and Harley, 'Output Growth and the British Industrial Revolution'; Berg and Hudson, 'Growth and Change'; Temin, 'A Response to Harley and Crafts'; Crafts, 'Productivity Growth in the Industrial Revolution'; Clark, 'Macroeconomic Aggregates for England'; Broadberry et al., *British Economic Growth, 1270-1870*.
[3] Ashton, *The Industrial Revolution, 1760-1830*.
[4] Mokyr, *The Enlightened Economy*.
[5] Goldstone, 'Efflorescences and Economic Growth in World History'.

engine, or that James Watt would eventually supersede it. There was no guarantee that the Cranage brothers or Henry Cort would build on Darby's work, finding new ways to make wrought iron, or that Henry Bessemer would work out a way to mass-produce steel. Unlike the other efflorescences, however, innovation in Britain continued, leading to sustained economic growth.

What caused Britain's acceleration of innovation? All innovations, whether they be changes to processes or products, consist of a series of smaller improvements. There is no clear point at which each small improvement should be distinguished from another. Just as the length of a rugged coastline increases as one measures it on smaller and smaller scales, the number of improvements involved in an innovation only increases as one examines it more closely. At the broadest level, Josiah Wedgwood improved ceramics. In greather detail, he developed new glazes, colours, forms, designs, tools, and marketing techniques. In even greater detail one might identify each subtle change of colour in the course of experimentation, or each reconfiguration of his workshop for greater productivity. Specifying a consistent level of detail with which to compare Wedgwood's innovations is impossible. And this is despite the fact that all such improvements were made to the same industry. Comparing improvements across different industries is even more nonsensical.

But we can count the *individual men and women* who innovated – an exercise for which there is ample precedent.[6] I compiled a sample of 677 people who became innovators between 1651 and 1851.[7] Among the innovators are familiar names like Richard Arkwright, James Watt, and Isambard Kingdom Brunel. But the sample also includes lesser celebrated innovators like the timber merchant George Smart, who invented a device to clean chimneys, replacing the use of climbing boys; Hugo Meynell, who pioneered the practice and business of fox hunting; and William Moon, who devised books for the blind – a precursor to Braille.

It is tempting, when considering innovation, to think only of ingeniously contrived machines, or of novel products. But innovation is, at root, the act of

[6] See: Allen, *The British Industrial Revolution in Global Perspective*, 242–71; Khan and Sokoloff, 'Institutions and Democratic Invention in 19th-Century America'; Khan, 'Knowledge, Human Capital and Economic Development'; Khan and Sokoloff, '"Schemes of Practical Utility"'; MacLeod and Nuvolari, 'The Pitfalls of Prosopography'; Meisenzahl and Mokyr, 'The Rate and Direction of Invention in the British Industrial Revolution'.

[7] Unless otherwise stated, details about innovators are taken from their respective entries in the online *Oxford Dictionary of National Biography*, or the *Biographical Dictionary of Civil Engineers in Great Britain & Ireland*.

improvement. And improvement can take many forms. Some civil engineering projects, such as John Smeaton's rebuilding of the Eddystone Lighthouse, were particularly ambitious, and stand out as innovations. Some projects were more mundane: John "Blind Jack" Metcalf, for example, built over 120 miles of high-quality road, gradually devising new methods to build at unprecedented gradients and over marshy ground. Metcalf, however, was as much an innovator as Smeaton – both engaged in improvement, though one was more immediately discernible than the other.

Innovators are sometimes distinguished by their significance, labelled "macro-" and "micro-inventors", or "stars" and "tweakers".[8] But this sample does not do so. Assigning significance is heavily biased by prevailing narratives about the Industrial Revolution, and done with the distorted lens of hindsight. George Smart saved the health and lives of countless children with his chimney-sweeping device, but until recently he did not even feature in the *Oxford Dictionary of National Biography*. His impact was different, but was he any less of an innovator than Richard Arkwright?

Of course some innovators were more financially successful than others, or have since received longer-lasting recognition. Some were more prolific, or were better at advertising their achievements. But all of the people in the sample improved things. The aim is to understand why they became innovators, rather than passing judgement on their eventual impact. Innovation is a process with many steps, from noticing an opportunity for improvement, to designing a solution, implementing it, and then adjusting it further. Many more people likely only noticed opportunities and never bothered to record or exploit them – they might arguably be innovators too, in the sense of coming up with novel ideas, but they very rarely, if ever, become known to us (happily, such people did sometimes invent other things and so we thus hear about the inventions they did not pursue too). The men and women in the sample were those who at the very least put pen to paper, or voiced their ideas to others, even if not all of them implemented their designs, or went even beyond that and actively promoted their use. The designers, the implementers, and the tweakers were all still innovators.

Note, however, that innovators were not scientists (then known as natural philosophers). Science is the practice of advancing our *understanding* of the world, whereas innovation is the distinct activity of *improving* it. William Herschel is included

[8] Allen, *The British Industrial Revolution in Global Perspective*, 239–42; Meisenzahl and Mokyr, 'The Rate and Direction of Invention in the British Industrial Revolution'.

in the sample for his improvements to telescopes, not for his identification of a new planet, which he called the *Georgium Sidus* (George III's Star) but is now called Uranus. James Prescott Joule is included not for his work to uncover the laws of thermodynamics, but because he invented electromagnetic engines, improved barometers, developed a thermoscope, and applied his understanding of heat to brewing.

Britain's acceleration of innovation was not just a wave of innovations; it was an increase in the number of people who innovated. As Figure 1 shows, in the first quarter of the eighteenth century fewer than 30 people became innovators; in the last quarter more than 130 did. And as Figure 2 shows, even small increases in the number of people becoming innovators meant more pronounced increases in the total number of innovators. The number of innovators grew faster than the population, and faster than the urban population too.

Figure 1
Number of New Innovators in Britain 1651-1851

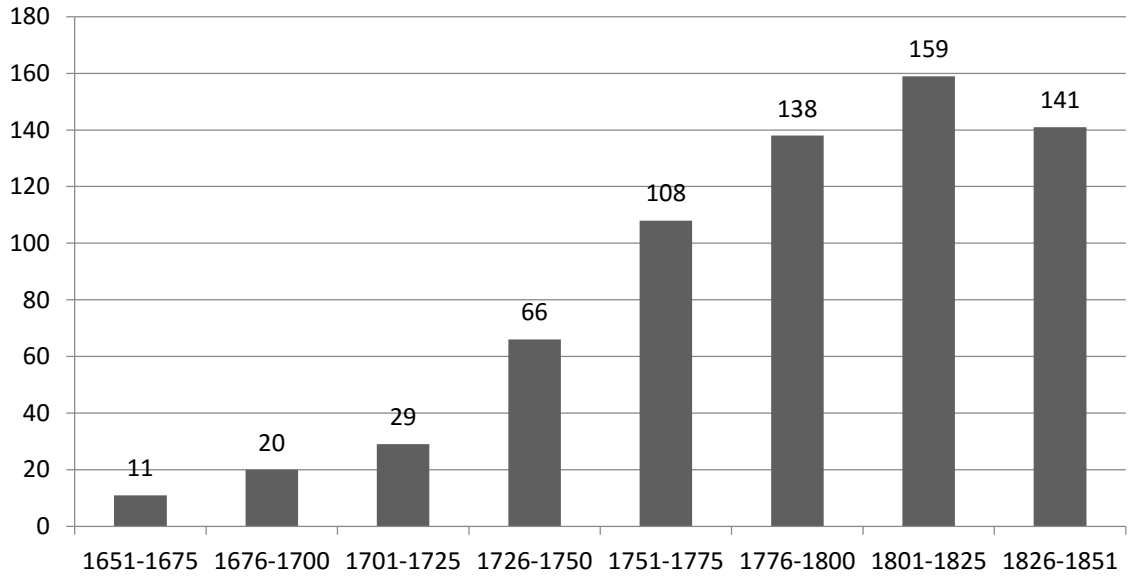

Figure 1: n=672, excluding innovators for whom there is no indication of when they first innovated.

Figure 2
Innovators in Britain 1651-1851

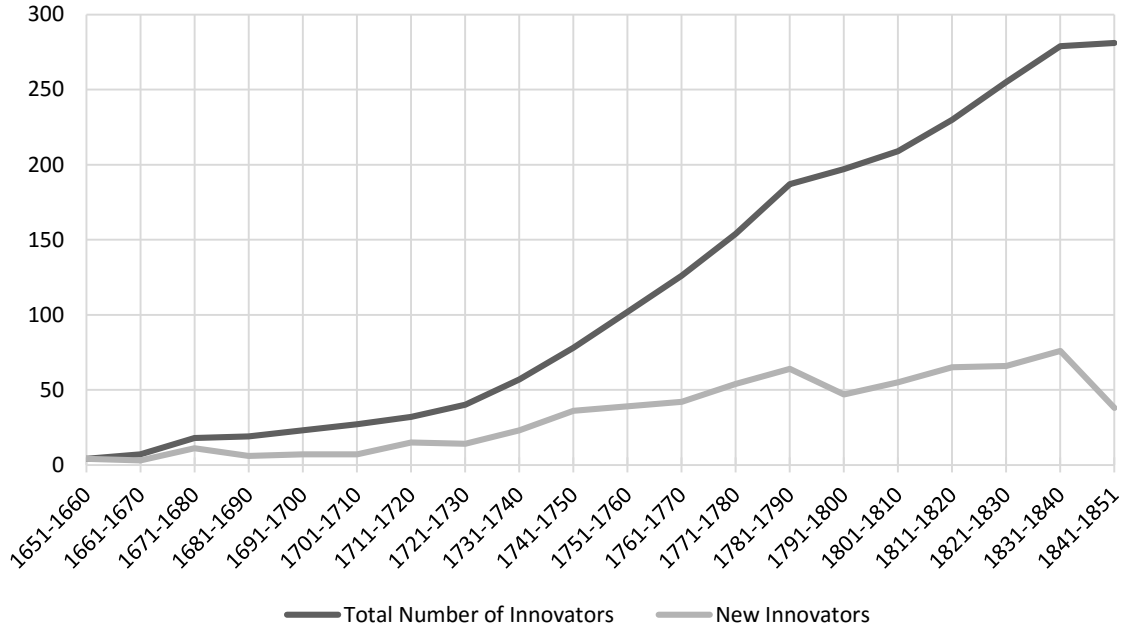

Figure 2: n=672, excluding innovators for whom there is no indication of when they first innovated. The total number of innovators shows the number of people who had become innovators, until the date of their death. Where dates of death were unknown, the last known date alive was used.

The sample was compiled from some existing lists of innovators, and corrects for biases by adding innovators from other sources. It fully incorporates a list compiled by Allen, and a list compiled by MacLeod and Nuvolari from the nineteenth century *Dictionary of National Biography* and its modern descendant, the *Oxford Dictionary of National Biography*.[9] MacLeod and Nuvolari point out that their list perpetuates the biases of the Dictionary of National Biography's compilers, neglecting innovators in industries such as food processing, consumer products and the decorative arts.[10] To correct for the bias, the sample includes all innovators mentioned in works by Maxine Berg and by Kristine Bruland, which emphasise innovations in neglected industries.[11] The sample also includes all innovators mentioned in Joel Mokyr's *The Enlightened Economy*, which names people who improved an especially broad range of industries. [12]

[9] Allen, *The British Industrial Revolution in Global Perspective*; MacLeod and Nuvolari, 'The Pitfalls of Prosopography'.
[10] MacLeod and Nuvolari, 'The Pitfalls of Prosopography', 775–76.
[11] Berg, *The Age of Manufactures, 1700-1820*; Berg, *Luxury and Pleasure in Eighteenth-Century Britain*; Bruland, 'Industrialisation and Technological Change'.
[12] Mokyr, *The Enlightened Economy*.

MacLeod and Nuvolari point out that other lists of innovators use patent records to inform the compilation of samples, potentially over-representing patentees. To correct for the bias toward patentees, the sample includes all innovators mentioned in the "Manufactures" and "Agriculture" categories of *A History of the Royal Society of Arts*.[13] The work is a rich source of non-patentees: between 1765 and 1845 patented innovations were not allowed to win the Society's prizes. And it generally emphasises industries where patenting was uncommon, such as agriculture, agricultural machinery, horticulture, telegraphy, brewing and textile design.[14] It also emphasises innovators with humanitarian aims, such as George William Manby, who developed lifeboats, portable fire extinguishers, and a means of preventing accidents on ice.

Though the sample includes innovators from a few older lists, some innovators who feature in those lists were omitted because they only started innovating after 1851. Their decision to become innovators would have been influenced by factors what were not present before 1851 (such as significant reforms to the patent system that took effect from 1st October 1852). Similarly, though they appear in some other lists, the sample excludes hoaxes and frauds like a mysterius C.M. who wrote to the Scots Magazine with a proposed telegraph in 1752 – I have followed the *Oxford Dictionary of National Biography*'s judgement that he was merely the "offspring of credulity and wishful thinking". The aim is to understand why people innovated, rather than why people pretended to innovate. And the sample includes immigrants like the Belgian-born John Joseph Merlin, inventor of various mechanical automata and the rotisserie oven, but excludes British-born innovators who never innovated in Britain. John William Draper and Hugh Orr are mentioned in other lists of innovators, but only became innovators after they moved to the United States.

To understand why innovation accelerated, we must understand why more and more people decided to become innovators. For innovation to have affected so many industries, from agriculture to watchmaking, the reason was likely ideological or cultural.[15] Few other factors could have affected people from such diverse backgrounds, and with such diverse interests. Among the sample of innovators we find engineers and

[13] Wood, *A History of the Royal Society of Arts*.
[14] Textile design is a particularly interesting area, especially as compared to the prominence usually given to textile machinery. Pioneers in this industry include the tapestry and pile carpets producers Thomas Moore and Thomas Whitty.
[15] Mokyr, 'The Intellectual Origins of Modern Economic Growth'.

gentlemen, surgeons and farmers, the urban and the rural, the rich and the poor, the Anglican and the dissenting, the university graduates and the school leavers. Many innovated for money or glory, and still others sacrificed both in the pursuit of improvement. If there is a single factor to explain why such varied became innovators, only habits of thought – ideas – could have affected such different people in the same way.

Margaret Jacob, Deirdre McCloskey, and Joel Mokyr all make the case for culture or ideas, and each offer their own interpretations of exactly what kind of ideas made the difference. McCloskey emphasises the role of rhetoric in casting commerce and innovation in a more positive light, thereby giving encouragement to the bourgeois classes.[16] Jacob emphasises the role of scientific knowledge, in particular of Newtonian mechanics, which some innovators adopted through education and engagement with scientists.[17] And Mokyr emphasises the role of other practices associated with the scientific community, which were applied to industry and commerce. He suggests that innovators emulated Isaac Newton in experimenting systematically, and followed the lead of Francis Bacon in cataloguing and sharing useful knowledge[18]

I suggest, however, the emergence of an idea that was even simpler and more fundamental than systematic experimentation or Newtonian mechanics, though it was implicit to each of them: the idea of improvement itself. It was the idea of breaking with tradition, and imagining something better. It involved envisaging new products to better satisfy consumers, or new manners in which to make one's work easier or cheaper. Once adopted, the idea of improvement changed the way that people saw the world. Improvement became a *mentality*.

And it could become something of an obsession. Henry Bessemer, who invented the process to mass-produce steel, after contriving some initial innovations, noted that "the love of improvement, however, knows no bounds or finality", compelling him to make further adjustments.[19] Henry Dircks, who improved steam engines and designed optical illusions, expressed the new mentality thus:

[16] McCloskey, *Bourgeois Dignity*; McCloskey, *Bourgeois Equality*.
[17] Jacob, *Scientific Culture & the Making of the Industrial West*; Jacob, *The First Knowledge Economy*.
[18] Mokyr, *The Enlightened Economy*.
[19] Bessemer, *Sir Henry Bessemer, F.R.S.*, 10.

> No work of art appears perfect to an enterprising mind. However simple its purpose, it may possibly be made lighter, stronger, more efficacious, or be done away with altogether. The man whose mind is thus constituted becomes an Inventor.[20]

Once possessed of the improving mentality, people of all walks of life and experience imagined new possibilities for material progress. They inhabited a new ethos – that of the innovator – and everywhere saw room for improvement.

Once they saw the world in this new way, it could even become difficult to switch off. Henry Bessemer described how, when trying to focus on other professional pursuits, "it was my misfortune that inventions sprung up in my mind without being sought".[21] An inventor of the screw propeller, Francis Pettit Smith, after impoverishing himself in the implementation of his innovation explained, when asked if he still innovated, that "if anything comes into my head, I give it a tap and say, 'Be off with you! I've suffered too much by such intrusions'".[22] His friend Edward Lyon Berthon, another inventor of the screw propeller, described how "in an instant, without any previous thought, [the screw propeller] came like a flash of lightning into my mind".[23]

All innovators in the sample, almost by definition, were possessed of the improving mentality. Crucially, however, the mentality appears to have spread from person to person. nearly all of the 677 people in the sample began to innovate after coming into contact with other innovators **[NB: the precise figure is still being researched but so far looks to be about 85%]**. In other words, innovators were among their teachers, colleagues, employers, employees, neighbours, friends, family, and acquaintances. Others have investigated the spread of knowledge, in particular of techniques, designs, or blueprints.[24] But the spread of the improving mentality was something altogether different. It was not a skill or a set of facts, but a frame of mind – a lens through which they suddenly perceived the status quo as being imperfect, and then sought to rectify those imperfections. They said, in essence, "this could be better" – and then did something about it.

[20] Dircks, *Inventors and Inventions*, 9.
[21] Bessemer, *Sir Henry Bessemer, F.R.S.*, 128.
[22] Berthon, *A Restrospect of Eight Decades*, 69.
[23] Ibid., 45.
[24] For a recent example see Squicciarini and Voigtländer, 'Human Capital and Industrialization'.

The improving mentality was usually spread through direct contact with innovators, as evidenced by the sheer number of innovators who had such prior connections. The fact that so many of these connections were noted by biographers or in memoirs, and for so many innovators, hints at their formative importance in their careers. Beyond the evidence of a prior connection, we do not usually have direct documentary proof that so-and-so was an important influence on such-and-such an innovator. But when such evidence does exist, usually recorded in an innovator's memoirs, it can be unambiguous about how the mentality spread. In 1766, at an exhibition of mechanical toys in Chester, an Irish aristocrat named Richard Lovell Edgeworth struck up a conversation with the curator:

> In the course of conversation . . . [the curator] spoke of Dr Darwin, whom he had met at Lichfield. He described to me a carriage, which the Doctor had invented. . . . I determined to try my skill in coach-making, and to endeavour to obtain similar advantages in a carriage of my own construction.[25]

The Dr Darwin in question was the polymathic Erasmus Darwin, grandfather of Charles Darwin, who in 1758 designed a carriage-steering mechanism. He was very much possessed of the improving mentality, and eager to share it, being the principal founder of Birmingham's celebrated Lunar Men society. Inspired, Edgeworth started a correspondence with Darwin, which resulted in an obsession with improving more than just coachbuilding: he went on to design sailing carriages, an improved phaeton, a one-wheeled chaise, some kind of velocipede, and an early caterpillar track; but also a wide range of agricultural tools, a signal telegraph system, and (along with his second wife Honora Sneyd and his daughter Maria) applied his ideas to the improvement of education, systematically testing hypotheses on his 22 children.

As a mentality, separate from any particular skill or understanding, its emergence and spread can account for how improvement accelerated simultaneously in industries as different as gardening, surgery, and engineering – anything, after all, could be better. Lancelot Brown looked out over the gardens of the wealthy and declared them "capable" of improvement, earning him the nickname Capability Brown. The ingenious architect Robert Salmon got a hernia, but unlike most sufferers he contrived

[25] Edgeworth and Edgeworth, *Memoirs of Richard Lovell Edgeworth, Esq*, 68.

and patented a surgical truss to treat it. William Cecil, a country vicar who developed telescopes, ear trumpets, and a tool to draw teeth, even tried to apply the improving mentality to his work as a clergyman. He systematically categorised the quality of hymns, and constructed a "mechanical apparatus for teaching psalmody, to large assemblies of children", which consisted of a sort of sing-along chart suspended from the wall, to which he could pin notes and symbols of painted tin.[26]

And the improving mentality could be applied to areas where innovators lacked expertise. Darwin was a physician but improved carriages; Edgeworth was an unskilled aristocrat but improved agricultural machinery. Henry Bessemer described how when he struck out on his own as a teenager he "laboured under the great disadvantage of not having been brought up to any regular trade or profession". He felt, however, that he had "an inventive turn of mind", and became the most prolific innovator in the sample, taking out at least 119 patents.[27] Regarding his work on steel in particular, he admitted:

> My knowledge of iron metallurgy was at the time very limited . . . but this was in one sense an advantage to me, for I had nothing to unlearn. My mind was open and free to receive new impressions, without having to stuggle against the bias which a lifelong practice of routine operations cannot fail to more or less create.[28]

Training then, according to Bessemer, might sometimes have been a disadvantage.

Many innovators of course stuck with what they knew best: many potters stuck with improving pottery, and many surgeons stuck to improving surgical techniques. But the lack of skill was no limitation so long as innovators had a certain degree of persistence – they simply branched out into the unfamiliar, teaching themselves as they went, or relied upon the expertise of others. The lawyer William George Armstrong became a leading hydraulic engineer and developed artillery, having spent all his leisure time devoted to experimentation. The art dealer John Watkins Brett sold his collection to lay the first under-water electric telegraph line. Patrick Bell, a farmer's boy, noted that when he invented his widely-adopted reaping machine "no man could have been less slenderly furnished with books calculated to instruct him in the science and history

[26] Yule, 'In Memory of the Rev. William Cecil, M.A., Sometime Fellow of Magdalene College and Fellow of the Cambridge Philosophical Society', 10–11.
[27] Bessemer, *Sir Henry Bessemer, F.R.S.*, 9.
[28] Ibid., 136.

of mechanical invention".[29] Though he was able to do his own experiments and make his own working models, creating the original full-sized machine required him to outsource the construction of certain parts to a foundry, a wheelwright, and two blacksmiths.[30]

To modern ears, it sounds almost ridiculous that something as simple as improvement could ever have been absent. Yet the historian Paul Slack suggests that the very word for improvement emerged with its current meaning, of making *any* kind of thing better, only over the course of the seventeenth century, and at first only in England – continental Europeans failed in their attempts to find a direct synonym even into the eighteenth century.[31] Innovation in modern society is a pervasive and unspoken assumption, but we must guard against *assuming* its existince – to do so would be to engage in presentism, uncritically transplating our own expectations onto the past. We today expect that every year our products will become both cheaper and better, that life expectancies will rise, and that our economies will grow. The slowing of material progress, let alone its absence, is labelled stagnation.[32] Yet such progress is a feature of accelerated innovation – we take it for granted that someone, somewhere, will do the improving. Before the eighteenth century such progress was rare and halting, and so was the innovation that causes it – the possibility should be entertained that before the Industrial Revolution people simply did not think about improvement.

And it is easy to not think about it. The agricultural pioneer Arthur Young, extolling improvement's virtues, railed against the natural state that prevailed in its absence: "that dronish, sleepy, and stupid indifference, that lazy negligence, which enchains men in the exact paths of their forefathers, without enquiry, without thought, and without ambition".[33] A correspondent of Young's, labelling the vast majority of farmers "boorish barbarians", exhorted him to deliver agriculture from those who showed "a vacant brow and ideot grin at any novel, however ingenious or useful invention".[34] It has been noted before that innovations frequently encounter opposition,

[29] Bell, 'Bell's Reaping Machine', 186.
[30] Ibid., 191.
[31] Slack, *The Invention of Improvement*, 5–6.
[32] See, for example: Cowen, *The Great Stagnation*.
[33] Young, *Annals of Agriculture and Other Useful Arts*, 1791, 16:546.
[34] Young, *Annals of Agriculture and Other Useful Arts*, 1786, 5:439.

be it from workers or intellectuals.[35] But before they produced something worthy of opposition, innovators had to do a remarkable thing – break from tradition.

In the face of such natural inertia, one often finds among the sample of innovators a sort of stubborn optimism. William Clowes, a pioneer of improvements to printing, had only derision for anyone who questioned the necessity of improvement: "I see you are a *difficulty*-maker: you will never do for me".[36] In addition to his "inventive turn of mind", Bessemer remarked upon the necessity of "more than the usual amount of persistent perserverance".[37] And Berthon regretted that despite having come up with the idea for a screw propeller, and even submitted a model to the Admiralty, he "had not the pluck to follow it up against the advice of friends, and the ignorant opposition of the 'powers that be'".[38]

The prevailing absence of innovation was not for want of opportunity. Easy solutions to technological problems went unexploited for centuries, possibly millennia. Take John Kay's flying shuttle, which is today famous for improving the efficiency of weaving cotton. But it was originally intended to speed up the weaving of wool and linen, as shown by John Kay's patent: "shuttle for weaving broad-cloths, broad-baize, sail-cloths, or any other cloths, woollen or linen".[39] It was first adopted in the woollen industry too. Woollen textiles had been one of England's major exports since at least the thirteenth century, and by the sixteenth century they were its principal export. Linen textiles served a similarly prominent role in Scotland and Ireland.[40] The flying shuttle would thus have been a welcome improvement for centuries. And it required no new-fangled materials or sophisticated scientific knowledge. It consisted of a piece of string to propel the shuttle across the loom, and two wooden boxes to catch it on either side. It was a remarkably simple improvement to an already-complex technology, the horizontal broad loom, which had been largely unchanged for centuries: weaving shuttles are even mentioned in the Book of Job.[41]

[35] Mokyr, 'Technological Inertia in Economic History'; Nuvolari, 'The" Machine Breakers" and the Industrial Revolution'.
[36] Emphasis in the original: Samuel Smiles, *Men of Invention and Industry*, 219.
[37] Bessemer, *Sir Henry Bessemer, F.R.S.*, 9.
[38] Berthon, *A Restrospect of Eight Decades*, 45.
[39] Woodcroft, *Alphabetical Index of Patents*, 315.
[40] Broadberry et al., *British Economic Growth, 1270-1870*, 144.
[41] Bigwood, *Cotton*, 37.

Rather than asking why the flying shuttle was invented in 1733, we should ask why it was not invented centuries earlier. One of the most revolutionary innovations of the Industrial Revolution was a minor adjustment to an ancient industry, applied to an ancient technology, using ancient materials, and applying no new scientific knowledge. And Kay's flying shuttle is not alone in this. The same is true of Lewis Paul's carding machine, of Richard Arkwright's water frame, and of many of Edmund Cartwright's improvements to textile machinery. Though famous for their later effects on the cotton industry, their patents often list applications to silk, linen, hemp, hair, and wool, not just cotton.[42] They again involved simple additions, using no new materials, to ancient technologies. How many hundreds of thousands of people must have carded, spun, and weaved, before Paul, Arkwright, Cartwright and their ilk were inspired by others to see room for improvement?

The extraordinary persistence of such unpicked low-hanging fruit is further demonstrated by the number of British innovations that had been anticipated elsewhere, sometimes by hundreds or thousands of years. Chinese innovators had developed multispindle spinning wheels and treadle looms as early as the eleventh century, and in 1690 even a "proto-Bessemer converter".[43]And in the fifteenth century Europeans were terrified to cross Inka suspension bridges made of reeds (a principle of bridge construction not tried in Britain, using iron, until the early nineteenth century).[44] The seed drill of 1701, for which Jethro Tull would become famous (and have a rock band named after him), was another remarkably simple improvement to civilization's foundational industry: agriculture. It, too, had been anticipated in China before the third century; and it was even used in Mesopotamia in the 3rd millennium BC. The technology did not appear in Europe, let alone Britain, until the sixteenth century.[45]

Even in the mid-nineteenth century, when Britain's technological prowess was widely lauded, innovators found it difficult to get low-hanging fruit accepted. The "powers that be" Berthon regretted succumbing to were the Admiralty, who in 1836 rejected the screw propeller as "a pretty toy, which never would and never could propel a ship". The Admiralty was resistant, even despite the spirit of the age, and despite the fact it wanted such an invention – well over a hundred vessels used in the Crimean War

[42] Woodcroft, *Alphabetical Index of Patents*, 11, 94, 431.
[43] Mokyr, *The Lever of Riches*, 220–21.
[44] Mann, *1491 (Second Edition)*, 95.
[45] Needham and Bray, *Science and Civilisation in China*, 258–71.

were kitted with it. It was only when a farmer, Francis Pettit Smith, brazenly drove his screw-propelled *Archimedes* up to the Lords of the Admiralty on the Thames and towed them that they finally took it seriously.[46]

That the improving mentality was rare ought not to surprise us. Innovators are probably more common today than ever before, but they are still rare. The vast majority of people go about their work according to tradition, getting on with their jobs the way they have always done, not even considering the innumerable opportunities for improvement. They may have the incentive, the knowledge, and even skill. But it simply doesn't occur to them to innovate – they lack the improving mentality.

Many innovations of course pre-date Britain's Industrial Revolution. But improvement is not always designed, or even actively pursued. Technology can develop gradually, the product of an evolutionary process without purposeful direction. Joseph Henrich describes how indigenous Tukanoans of the Colombian Amazon developed a way to remove cyanide from manioc, one of their staple crops. It could take years or even decades before the effects of chronic cyanide poisoning began to take effect, so they would have had no way of experimenting individually with how to process manioc. Instead, traditions built up over time, each of them seemingly obscure and none of them understood, but all essential to avoid chronic poisoning. When Portuguese colonists tried to transport manioc to West Africa without also adopting the traditions, cyanide poisoning became a problem there.[47] Like a language, technology can evolve without purposeful innovators, spontaneously. As Alfred North Whitehead put it, "change was slow, unconscious, and unexpected".[48]

There were of course pre-eighteenth century societies with their own purposeful innovators: the Hellenistic Mediterranean had its Archimedes, the Medieval Islamic world its Banu Musa brothers, Song Dynasty China its Su Song, the Italian Renaissance its Leonardo da Vinci, Edo-era Japan its Hiraga Gennai, and the Dutch Republic its Christiaan Huygens. Even pre-1651 Britain had the likes of John Napier, inventor of logarithms. Why then did Britain seemingly have so many more of such innovators?

[46] Berthon, *A Restrospect of Eight Decades*, 65–66.
[47] I am grateful to the anonymous blogger "Pseudoerasmus" for bringing this example to my attention. Henrich, *The Secret of Our Success*, 97–99.
[48] Whitehead, *Science and the Modern World*, 96.

One plausible answer is that it didn't. Mokyr, for example, suggests that Britain simply had a comparative advantage in the adoption of other European innovations, as well as having some capacity to create its own.[49] It had already attained a reputation for improving (albeit not yet originating) by 1700.[50] Alternatively, people possessed of the improving mentality in other countries may simply have directed it toward less productive ends. [51] Without constructing exhaustive samples of innovators in other countries, however, and then comparing them with the sample presented in this paper, we cannot say for sure.

Assuming, however, that Britain did in fact have more innovators, the evidence from the sample suggests a reason: British innovators were almost all committed in some way to advancing, proselytising, or disseminating improvement further. Table 3 shows that at least 49% of innovators in were members of societies committed to the diffusion of knowledge, and about 60% authored books, published in journals, or otherwise published their work. These figures are much higher than those identified by Meisenzahl and Mokyr for their list of innovators: they found that only 39% of innovators were members of societies for the diffusion of knowledge, and only 38% published. As they readily admit, however, their "absence of evidence is not necessarily evidence of absence".[52]

[49] Mokyr, 'Editor's Introduction: The New Economic History and the Industrial Revolution', 24.
[50] Slack, *The Invention of Improvement*, 230.
[51] They might even have directed it toward non-technological ends, like William Cecil did with psalms. Mokyr points out that improvement in the age of Enlightenment could also mean the improvement of morals, society, justice, and the lot of the unfortunate: Mokyr, 'The Intellectual Origins of Modern Economic Growth', 291.
[52] Meisenzahl and Mokyr, 'The Rate and Direction of Invention in the British Industrial Revolution'.

Table 3
How Innovators displayed their commitment to Diffusing Innovation
(% of Total Innovators)

Date of First Innovation	Formal Society Involvement	Publishing Activity	Teaching, Education Funding	Society Sharing & Exhibitions	Other Sharing
Unknown	0 (0)	0 (0)	1 (20)	1 (20)	1 (20)
1651-1700	10 (32)	19 (61)	11 (35)	3 (10)	10 (32)
1701-1750	38 (40)	50 (53)	30 (32)	10 (11)	22 (23)
1751-1800	111 (45)	137 (56)	64 (26)	73 (30)	85 (35)
1801-1851	172 (57)	198 (66)	121 (40)	127 (42)	130 (43)
Total	**331 (49)**	**404 (60)**	**227 (34)**	**214 (31)**	**248 (37)**

Table 3: Note that formal involvement with a society only includes formal membership. Only formal, paying members were demonstrably committed to the diffusion of knowledge.

The publishing rate encompassed the writing of articles for encyclopaedias, and the translation of foreign works. The printer and coachbuilder Rudolph Ackermann translated Senefelder's work on lithography in 1818, thereby spreading the technique to Britain. He also published the *Repository of Arts, Literature, Commerce, Manufactures, Fashions, and Politics*, which between 1809 and 1828 sought to keep the public updated on current affairs and on new innovations. The Scottish clergyman Henry Liston, who improved musical instruments and agricultural machinery, in 1812 published an *Essay on Perfect Intonation*, in which he described a euharmonic organ he had patented. Liston also contributed the section on "Music" to the *Edinburgh Encyclopaedia*, and even translated Book VI of Caesar's *Gallic Wars* for use in schools. Though the translation of Caesar was unrelated to innovation, it demonstrates his wider commitment to education and the diffusion of knowledge.

As Table 3 also shows, innovators were committed to proselytising innovation by other means, which have not yet been counted by any other lists. Just over a third (34%) were committed to education. Robert Willis, an inventor of musical and scientific instruments, in 1838 attracted an audience of some 3,000 people, who flocked to the Newcastle meeting of the British Association for the Advancement of Science to hear him describe advancements in weaving, rope-making machinery, and organs. In 1851, Willis published *A System of Apparatus for the Use of Lecturers and Experimenters in Mechanical Philosophy,* so as to equip others to further instil his passion for innovation. Those who did not teach, could fund it. The shipbuilding innovator Sir Robert Seppings

donated to the Admiralty School of Naval Architecture (even though his own son failed to pass the entrance examinations). Richard Roberts, who applied steam power to the loom, in 1824 helped to establish the Manchester Mechanics' Institute.

Just under a third of innovators (31%) shared their innovations directly. Many sent their improvements to the Society for the Encouragement of Arts, Manufactures, and Commerce (founded in 1754, usually called the Society of Arts, and continuing today as the Royal Society of Arts), which made the designs freely accessible to the public. Some even shared their innovations with societies of which they were not members. Patrick Bell was not a member of any society (that we know of), but submitted his improved reaper machine to the Highland Agricultural Society and to the Society of Arts. The Irish antiquarian and amateur innovator John Whitley Boswell from 1796 submitted some of his inventions to the Society of Arts, but was never formally involved (though in 1807 he unsuccessfully applied there for a job).

Some bypassed societies completely, exhibiting their innovations directly to the public. Thomas Drummond from 1830 arranged for public demonstrations of his improved limelight (as well as publishing descriptions of his inventions in the Royal Society's *Philosophical Transactions*). And a few innovators promoted not only their own improvements, but those of others: William Snow Harris, who developed lightning conductors, between 1829 and 1851 curated the Plymouth Institution's museum.

At least 37% of innovators shared innovations in a less easily categorised way – their sharing activities fall under the Other Sharing heading of Table 3. Some of these (10% of all innovators) shared their improvements with the government or other official bodies. Henry Greathead constructed his lifeboat for a quasi-governmental organisation tasked with the maintenance of coastal safety, the Brethren of the Newcastle Trinity House. And the toolmaker Joseph Whitworth shared his designs for improved rifles and cannon with the Board of Ordnance. Of course, not all of these submissions were made out of patriotism or an altruistic concern for general welfare – many would have been motivated by the pursuit of personal glory or gain. But freely submitting a design to such organisations still involved the spilling of technological secrets.

Some among the Other Sharing innovators (15% of all innovators, or 103 people) consulted or otherwise assisted official bodies. The preacher and actuarial innovator Richard Price, perhaps more famous today for his works of moral and political

philosophy, drew up actuarial tables for the Royal Society, compiled tables for insurance and annuity proposals that were submitted to Parliament, and advised on the implementation of the National Debt sinking fund. John Frederick Herschel prepared major reports on reforming constellations, advised James Ross's expedition to the South Pole, and consulted on efforts to establish a global network of magnetic and meteorological observatories. He was also a trustee of the British Museum, a visitor to the Royal Observatory, and sat on the Royal Commission on Standards, set up to try to recover the official imperial measurements lost in the 1834 fire that destroyed Parliament. It may be argued that such consulting activities merely reflected the demands of governments for expertise as technology became more complex. Yet the decision to assist official bodies ultimately rested with innovators themselves. Price turned down requests from Benjamin Franklin and John Adams to advise the United States Congress on financial matters, even despite his vocal support for the nascent republic.

Among the Other Sharing innovators were also those (18% of all innovators, or 123 people) who we know to have assisted others informally. George Stephenson was renowned for being particularly generous with his advice. While waiting for a train at the platform he would offer tips to engineers to improve the efficiency of their locomotives, or show labourers how better to hold their shovels and barrows. The natural philosopher Stephen Hales, inventor of the ventilator, was seemingly incapable of holding a conversation without mentioning improvements. A friend described how "his whole mind seemed replete with experiment which of course gave a tincture and turn to his conversation often somewhat peculiar, but always interesting".[53] Hales offered casual tips to solve an astounding array of everyday problems, from ventilating houses and testing the water in wells, to advising housewives to place inverted teacups in their pies to prevent them boiling over.

In addition to such casual advice, some innovators financially supported other innovators. John "Iron Mad" Wilkinson (whose desk, chairs, and coffin were all cast in iron) supported Joseph Priestley, the dissenting preacher and chemist who first carbonated water, buying him a house in 1780, training his son, and giving him immediate aid in 1791 following the loss of his home and laboratory in the Birmingham

[53] Holt-White, *The Life and Letters of Gilbert White of Selborne*, 231.

"Church and King" riots. Particularly successful innovators also funded societies that disseminated innovations. Robert Stephenson, in addition to a number of other philanthropic and religious causes, bequeathed £7,000 to the Newcastle Literary and Philosophical Society, £2,000 to the North of England Mining Institution, and £2,000 to the Institution of Civil Engineers (altogether equivalent today to about £1million).

Taken together, Table 4 shows that *at least* 83% of innovators used one or more of these ways to share innovation – an overwhelming majority. The absence of evidence is again not necessarily evidence of absence, particularly with regards to the informal ways innovators supported one another, so this high figure likely still an underestimate. Nearly all of the rest are those innovators about whom we generally know very little.

Table 4
Innovators committed to Sharing or Stifling Innovation
(% of Total Inventors)

Date of First Innovation	Shared	Stifled	Both	Neither
Unknown	3 (60)	0 (0)	0 (0)	2 (40)
1651-1700	22 (71)	6 (19)	4 (13)	7 (23)
1701-1750	63 (66)	14 (15)	10 (11)	28 (29)
1751-1800	208 (84)	29 (12)	22 (9)	31 (13)
1801-1851	269 (90)	34 (11)	25 (8)	22 (7)
Total	**565 (83)**	**83 (12)**	**61 (9)**	**90 (13)**

A few more innovators planned to share knowledge, but never acted upon the urge – at least that we know of. Robert Chessher, a pioneer of orthopaedics, was either too busy or too nervous to publish his accumulated manuscripts, apparently possessing "retiring manners".[54] Others simply never had the chance. John Lombe, who stole the Piedmontese secret to silk-throwing machines to England, was reportedly assassinated by a woman sent to gain his confidence and poison him in revenge. Regardless of the truth of this tale, Lombe died before he could patent and exploit the secret, let alone make it public (though his brother Thomas, who did exploit it, was not very forthcoming when it came to sharing).

The proportion of innovators committed to sharing innovation may be higher still. Mokyr anecdotally identifies innovators who abstained from taking out patents,

[54] Bettany, 'Chessher, Robert (1750-1831)'.

suggesting they did so for the good of society.[55] 235 people in the sample abstained from taking out patents (excluding those who innovated in industries where patenting was impossible or unheard of). If they were counted among the innovators committed to diffusing innovation, the total figure would rise to 89% (602). But the inclusion of such innovators should be treated with caution – it is not always clear exactly why some people chose not to patent. The druggist John Walker simply considered his invention of the friction match to be too trivial, and the ingenious carpenter John Wyatt, employed by Lewis Paul on his early spinning machine, seems to have failed to patent out of poverty rather than principle. It matters little to the total figure, in any case, as to whether non-patentees are included: a minimum of 83% is still an overwhelming majority.

But not all innovators shared. As Table 4 shows, about 12% did things to stifle the spread of innovation. About 36 innovators (5% of the total) are known to have been secretive, and the rest either lobbied Parliament to extend their patents beyond the usual terms, or enforced their patents through litigation. A case might also be made for patenting as being opposed to the diffusion of knowledge. But patents were used for a number of reasons. Patenting could be defensive rather than offensive, aimed at protecting innovators from litigation by more aggressive innovators, rather than being used to prevent others from adopting innovations.[56] Patents could also be used to merely signal the quality of a product to consumers (sometimes even used to boost the sales of fraudulent products), rather than to prevent others from selling similar products.[57] Patents also became increasingly detailed, and accompanied by diagrams, thus enabling others to more easily take pre-existing innovations and improve upon them further.[58] So patents were not wholly opposed to the diffusion of innovation – they may even have aided it.

More obviously stifling of innovation than simply obtaining a patent was to use them *aggressively*. By far the most celebrated and cited example of aggressive patenting activity was James Watt.[59] In 1775, he managed to obtain an astonishing 25-year

[55] Mokyr, *The Enlightened Economy*, 91.
[56] MacLeod, *Inventing the Industrial Revolution*, 73; Macleod and Nuvolari, 'Patents and Industrialisation', 11–12.
[57] MacLeod, *Inventing the Industrial Revolution*, 85–86.
[58] Bottomley, *The British Patent System during the Industrial Revolution 1700–1852*.
[59] For example, see Allen, *The British Industrial Revolution in Global Perspective*, 167; Mokyr, *The Enlightened Economy*, 92.

extension on his 1769 patent for steam engine improvements, and then tracked down and prosecuted numerous alleged infringers. He threatened many more, such as the dissenting pastor Humphrey Gainsborough (brother of the artist Thomas), who was on the verge of patenting his own improvements as a defensive measure (rather than drag the dispute through the courts, Gainsborough was unfortunately forced to tend to his wife's last illness, and then to his own fatally deteriorating health).

Watt's aggressive stifling of innovation, however, was by no means the most extreme. The iron pioneer Isaac Wilkinson sued his old partners over patent infringement and the poaching of his workers, and on at least four separate occasions sued his own son. The innovative gun-maker Joseph Manton spent so much money prosecuting rivals for patent infringement in the 1820s that he continually went bankrupt, and was committed to debtors' prison at least five times. One of the rivals he prosecuted was his own brother.

But such attempts to stifle innovation were rare. Only 21 innovators (3% of the total) either sought or obtained extensions for their patents, and only 48 (7%) were involved in suing others. The figure for suing is especially low considering it includes all those involved, such as Watt's innovative employee William Murdoch who, despite initiating no legal proceedings of his own, conducted the industrial espionage to build Watt's case for prosecution.

Activity that stifled innovation was not just rare – some even concsidered it unrespectable. Shortly before his death, Gainsborough wrote to Watt to complain about his aggressive behaviour and the extension of his patent:

> As you have been ungenteel enough to give me unnecessary trouble, I am only sorry that I did not endeavour to hinder your Bill passing in any form, which I have good reason to believe would have been in my power.[60]

Perhaps the fear of being seen to be "ungenteel" explains why so few innovators aggressively used the patent system or resorted to secrecy. Given the vast majority of innovators were committed to the ideal of spreading innovation, a distaste for the opposite behaviour would be unsurprising. Evolving ideas of dignity or respectability for commerce may thus have penalised overtly selfish or monopolistic behaviours

[60] Tyler, 'Humphrey Gainsborough', 68.

rather than simply giving all commercial endeavours license, and thereby aided the acceleration of innovation.[61]

But opposing the spread of innovation in some contexts did not mean opposing it in *all* contexts. Many of the anti-sharing innovators were otherwise pro-sharing. Table 4 shows that three quarters (61 of 83) of the anti-sharing innovators were *also* demonstrably committed to the spread of knowledge. Even James Watt, despite his aggressively acquisitive and anti-sharing behaviour, otherwise favoured the dissemination of innovation. He was a member of the Birmingham Lunar Society and financially supported an innovative pneumatic medical institute to combat tuberculosis. In later life too, he appears to have mellowed a little in his instinctual preference for appropriation over sharing: in 1811, aged 75, he refused all offers of payment for finding innovative solutions to Glasgow's problems of water supply.

Innovators were rarely straightforwardly either pro- or anti-sharing. The number of zealously self-interested innovators, without any countervailing commitment to sharing innovation, was vanishingly small – only 22 people, or 3% of the total. There were certainly zealots on the other end too, who apparently subverted their personal interests in pursuit of the ideal of innovation for all. But most innovators charted a course between the two extremes. They were nearly all committed to the dissemination of innovation, but to varying degrees, and for different reasons. Innovators, like anyone else, had complex motivations.

Richard Roberts, who applied steam power to the loom, was one such character. He was an extremist when it came to improvement: in 1842 after the death of his business partner, his obsession with tinkering and experimentation became unmoderated by business acumen and prudence, and he died in abject poverty as a result of his numerous costly experiments. He was also demonstrably committed to the wider proselytisation of improvement, in 1824 helping to establish the Manchester Mechanics' Institute, in 1839 co-founding the Royal Victoria Gallery, and in 1855 donating sixteen scientific models, of which only half were of his own invention, to the Salford Royal Museum. But Roberts also took out some 29 patents and even obtained a seven-year extension on his patent for a steam-powered spinning mule. Given his obvious commitment to sharing innovation, it seems he merely considered patents to be

[61] This would tend to confirm Deirdre McCloskey's emphasis on bourgeois values other than prudence, and on a distaste for monopolies. McCloskey, *Bourgeois Dignity*, 283–84.

just another form of appropriation. Though he was an ideologically committed evangelist for innovation, he also felt it was perfectly legitimate to make money from inventions using available legal means.

Many innovators found ways to reap the rewards of innovation in a way that did not conflict with their ideological commitment to sharing innovation. The outright use of secrecy was extremely rare, but patents were used by 49% of innovators – a strategy to appropriate rewards that did not automatically stop the spread of invention, and that with detailed specifications could aid it. Innovators also submitted their innovations to societies such as the Society of Arts with the hope of winning honorary medals, or could pursue prestige by publishing their designs.

Allen has identified how, under certain circumstances, it could be in a person's self-interest to share information about improvements through a system of collective invention.[62] And Nuvolari and Sumner identify a strategy of selective revealing, particularly in the brewing industry,[63] whereby innovators could boost the sales of their products by publishing some details of their innovations or openly demonstrating them to the public. Thomas Savery extended the patent for his vacuum pump, yet also described its principles to the Royal Society, in 1702 published a description of a proposed steam engine, and later openly demonstrated how the engine worked to potential clients.

The varying degrees to which appropriation was tolerated reflected the varying motivations of inventors. As Mokyr points out, innovators were driven to invent and share their innovations by a mixture of motivations: curiosity, ambition, greed and altruism.[64] McCloskey's identification of prudence, rather than greed, better encompasses the combined acquisitiveness and calculated pursuit of financial self-interest. But her focus on values *in addition to* prudence is needed to adequately account for the panoply of motivations that drove innovators. She suggests people innovated in pursuit of the following virtues: courage, hope, temperance, justice, love, and faith. [65]

[62] Allen, 'Collective Invention'.
[63] Nuvolari and Sumner, 'Inventors, Patents, and Inventive Activities in the English Brewing Industry, 1634–1850'. See also Henkel, 'Selective Revealing in Open Innovation Processes'.
[64] Mokyr, *The Enlightened Economy*, 54.
[65] McCloskey, *Bourgeois Dignity*, 346.

Innovators sometimes applied their newfound improving mentality in the pursuit of more specific causes too. Lewis Gompertz's inventions were aimed at reducing cruelty to animals – he was also a founder of the Society for the Prevention of Cruelty to Animals (still active today as the RSPCA), and published widely on the subject, including a *Moral Inquiries on the Situation of Man and of Brutes* (1824). The agricultural machinery manufacturer James Sharp, upon the suggestion of his brother, the prominent slavery abolitionist Granville Sharp, attempted to invent a labour-saving device for use on plantations, with the aim of reducing the demand for slave labour.[66] Joseph Glass in 1828 designed a mechanical chimney-sweeping device, which he purposefully did not patent so that it could readily be adopted by the Society for Superseding the Necessity of Climbing Boys in Cleaning Chimneys. Glass was a prominent campaigner on the issue, giving evidence to legislative committees, and actively prosecuting those who evaded the provisions of anti-climbing boy legislation.

We ought to also add an enthusiasm for innovation for its own sake: the sheer thrill of envisioning and then realising improvements. John Austin, who improved the power loom and invented a stenographic system of music notation, was once heard to remark that he wished someone could put him in prison so that he could spend time working on his innovations undisturbed.[67] And we have already seen how Richard Roberts bankrupted himself because with his experiments.

So the vast majority of innovators found a way to reconcile their diverse aims and values with the *norm* of sharing innovation. British innovators did not just improve things – they then tried to spread improvement further. And looking at innovators alone fails to take into account the many more people who spread innovation further – the cheerleaders from the side-lines, who were not necessarily innovators themselves. The natural philosopher John Dalton was a tutor and mentor to no fewer than five innovators in the sample, including the gas lighting innovator Samuel Clegg; the brewer and pioneer of thermodynamics James Prescott Joule; and the civil engineer Eaton Hodgkinson. And university lecturers, particularly in Scotland, helped too: Colin MacLaurin, Alexander Monro primus, and Andrew Plummer, were particularly effective *communicators* of the improving mentality rather than innovators themselves.

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[66] 'Letter to Granville Sharp'.

[67] Kay, *A Series of Original Portraits and Caricature Etchings. With Biographical Sketches and Illustrative Anecdotes*, 377.

The improving mentality, combined with the commitment to sharing it, might even be considered an *ideology* of innovation. The word has many connotations, but it serves as a useful analogy. Like a religious faith or political ideology, the improving mentality spread from person to person. But to become so widespread, it needed its preachers and proselytisers too. It needed only a handful of fanatics, accompanied by a much larger body of fellow-travellers, each of them practising with varying levels of enthusiasm. And just as with any religious faith or political ideology, the ideology's practices could be perpetuated for varying reasons: prudence, curiosity, ambition, altruism, or simply a sheer delight in innovation for its own sake. Innovators had their disagreements of course, particularly over what counted as acceptable or genteel behaviour. But ultimately, the vast majority of Britain's innovators adhered to two commandments: improve, and pass it on.

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