Council on Geostrategy

Primer
Geostrategy Programme
No. GSPP04
March 2024

Britain's future is in technology and innovation

By Dr Mann Virdee

The march of modernisation: a look back in time

Let's take a quick journey back to late 18th century Britain – just before the Victorian era. How would you tell what time it is?

The time in each town was determined using a local sundial.[1] These sundials gave an approximate time based on sunrise and sunset at that location, which differed from town to town because of the time it takes for the Earth to rotate. This meant, for example, that Southampton was about six minutes behind Greenwich.[2] But as it took so long to travel such distances on horse, there was no need for standardisation across the country.

[1] Science Museum Group, 'Sundial from Liverpool Road Station', *Science Museum Group Online Collection*, No date, https://collection.sciencemuseumgroup.org.uk/ (checked: 06/03/2024).
[2] Martin Brisland, 'Heritage: Southampton is 6 minutes slower…', *In Common*, 01/12/2023, https://www.in-common.co.uk/ (checked: 06/03/2024).

Then, in the early 19th century, British engineers and innovators such as Trevithick, Blenkinsop, Murray, Hedley, Stephenson, and Hackworth[3] developed the steam locomotive and made it commercially viable. With the widespread use of the locomotive and increasingly complex railway networks, train drivers faced the challenge of having to adjust to local time zones when they pulled into stations. The time differences and lack of synchronisation between towns became a barrier to managing train schedules, which led to accidents and to the loss of lives.[4]

The invention of the electric telegraph meant that messages could be sent ahead of trains, and helped with the management of the growing rail network. But the unprecedented rapidity of this network of rails created the need for a standardised train time. In 1840, the Great Western Railway introduced a standardised train time known as 'Railway Time'. As an 1844 Great Western Railway timetable stated:

> LONDON TIME *is kept at all the Stations on the Railway, which is 4 minutes earlier than* READING *time*; 7 ½ *minutes before* CIRENCESTER *time*; 11 *minutes before* BATH *and* BRISTOL *time*; *and 18 minutes before* EXETER *time*.[5]

There were protests from those who felt that the replacement of the mosaic of local times with a standard national time would be to the detriment of local

[3] Richard Trevithick is credited with inventing the first high-pressure steam engine and the first operational steam locomotive. See: 'Richard Trevithick', The American Society of Mechanical Engineers, No date, https://www.asme.org/ (checked: 06/03/2024). John Blenkinsop is credited with creating the first rack-and-pinion steam locomotive, see: Keith Barry, 'June 24, 1812: Coal-Powered Locomotive Hauls Coal', *Wired*, 24/06/2010, https://www.wired.com/ (checked: 06/03/2024). Matthew Murray is credited with developing the first commercially successful railway locomotive, Salamanca, for the Middleton Railway, see: John McGoldrick, 'Matthew Murray's Beam Engine', Leeds Museams and Galleries, 28/09/2016, https://museumsandgalleries.leeds.gov.uk/ (checked: 06/03/2024). William Hedley demonstrated that a locomotive with smooth wheels could operate successfully on smooth rails, which led to the construction of some of the first locomotives, see: 'William Hedley : Locomotive Pioneer', *Nature*, 151:50 (1943). George Stephenson is often given the honorific 'Father of Railways'. Together with his son, he built Locomotion No. 1, which was the first steam locomotive to carry passengers on a public rail line, the Stockton and Darlington Railway. Stephenson also created the 'Stephenson rail gauge', which formed the basis for the standard gauge (4' 8" 1/2 inches) which is still used by most of the world's railways, see: 'George Stephenson', The Institute for Civil Engineers, No date, https://www.ice.org.uk/ (checked: 06/03/2024). Timothy Hackworth helped to demonstrate the advantages of the locomotive over horse-driven haulage. He helped pave the way for the general adoption of steam through rebuilding Locomotion No.1 and making it more reliable, see: 'Unsung Hero of the Railway Celebrated with Upgraded Listings', *Locomotion*, 22/06/2021, https://www.locomotion.org.uk/ (checked: 06/03/2024).

[4] Ian R. Bartky, *Selling the True Time: Nineteenth-Century Timekeeping in America* (Stanford University Press, 2000).

[5] Science Museum, 'Standardising Time: Railways and the Electric Telegraph', Science Museum, 04/10/2018, https://www.sciencemuseum.org.uk/ (checked: 06/03/2024).

identity.[6] But the march of modernisation culminated in a unified standard time across the United Kingdom (UK) in 1880 with the Statutes (Definition of Time) Act.[7]

The development of the locomotive and the electric telegraph increased connectivity – but they also served as a driver for further innovation through creating a unified standard time, which then helped form the basis for our current systems of communication and travel.

The markers of progress: How technology benefits humanity

Like the invention of railways and the electric telegraph and the standardisation of time, the modern world has been shaped by the progress of science and technology. The last 200 years have seen an almost unimaginable improvement in human lives. According to Deirdre McCloskey, Professor of Economics at University of Illinois at Chicago, the economic growth and technological progress brought about by the industrial revolution has led to:

> the increase of income per head by a factor of 15 or 20 since the 18th century in places like Britain...It is certainly the most important event in the history of humanity since the domestication of animals and plants, perhaps the most important since the invention of language. It bids fair to free us all, eventually.[8]

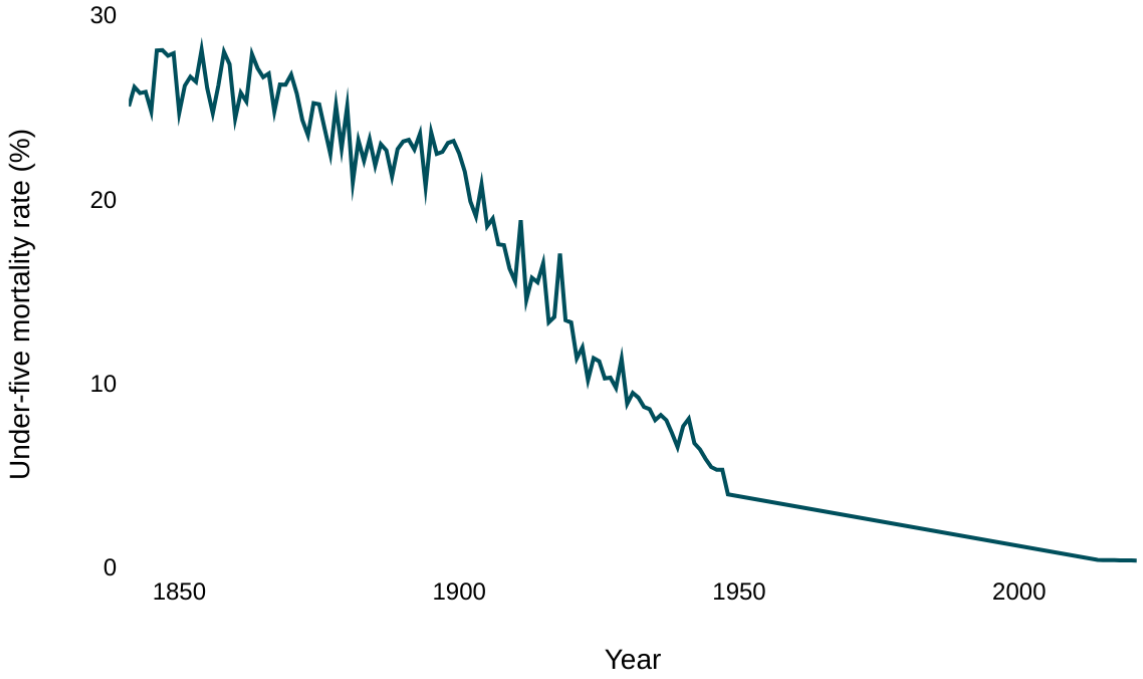
Advances in medicine and agriculture have enabled humans to live longer and healthier lives. In 1840, when Railway Time was introduced, life expectancy in England was about 41 years.[9] It has now doubled to about 80 years.[10] In 1840, child mortality was about 25%; it is now about 0.4% (see Figure 1).[11] These are

[6] Johan Goudsblom, *The Worm and the Clock: On the Genesis of a Global Time Regime* (London: Sage Publications, 2004).
[7] David Rooney and James Nye, '"Greenwich Observatory Time for the Public Benefit": Standard Time and Victorian Networks of Regulation', *The British Journal for the History of Science*, 42:1 (2009).
[8] Deirdre McCloskey, 'Review of The Cambridge Economic History of Modern Britain', *Prudentia*, 15/01/2004, https://www.deirdremccloskey.com/ (checked: 06/03/2024).
[9] 'How has life expectancy changed over time?', Office for National Statistics, 09/09/2021, https://www.ons.gov.uk/ (checked: 06/03/2024).
[10] 'National life tables – life expectancy in the UK: 2020 to 2022', Office for National Statistics, 11/01/2024, https://www.ons.gov.uk/ (checked: 06/03/2024).
[11] 'Data Page: Under-five mortality rate', Our World in Data, 19/09/2024, https://ourworldindata.org/ (checked: 06/03/2024).

astonishing markers of progress, unprecedented in all of human history. It is sometimes forgotten how dire things were in the recent past. As Thomas Hager, the popular science author, put it:

> The diseases we vaccinate against now seem like harmless ghosts for the most part, robbed of their power to terrify – because vaccines have made them a thing of the past. Few people living today have ever seen a case of smallpox, or diphtheria, or polio.[12]

Figure 1: United Kingdom under-five mortality rate[13]



Technology has also freed billions of people from the back-breaking drudgery which was such a core part of the human experience before industrialisation. Appliances such as the washing machine have transformed the structure of British society. The late Hans Rosling, Professor of International Health at the Karolinska Institute, went so far as to say that the washing machine was the greatest invention of the industrial revolution for the way it enabled

[12] Thomas Hager, *Ten Drugs: How Plants, Powders, and Pills Have Shaped the History of Medicine* (New York: Abrams Press, 2019).
[13] 'Data Page: Under-five mortality rate', Our World in Data, 19/09/2024, https://ourworldindata.org/ (checked: 06/03/2024).

people, especially women, to spend their time more productively and focus on their education and on their children's education.[14]

Rosling said that the washing machine was 'a miracle' to people like his grandmother. Looking at the world today – with self-driving cars, smartphones, and generative artificial intelligence – people can be sure their ancestors could not have imagined the advances in technology over the last two centuries. As Arthur C. Clarke, the popular science fiction writer, put it: 'any sufficiently advanced technology is indistinguishable from magic'.[15]

Technology has become the cornerstone of modern existence, underpinning not only human prosperity but also economic growth, strategic advantage, and national security.

Why did the industrial revolution happen in the United Kingdom?

Britain pioneered industrialisation. It sparked a paradigm shift; a technological and engineering revolution which has touched every part of the world and is a core component of the tapestry of human progress.

Yet, there is no consensus on what drove the industrialisation of the British economy. Bob Allen, Professor of Economic History at New York University, Abu Dhabi, wrote: 'It is still not clear among economic historians why the industrial revolution actually took place in 18th century Britain'.[16] The economist Deirdre McCloskey, meanwhile, put it thus:

> The central puzzle is why Britain, or why Northwestern Europe, and why the 18th and 19th centuries. Why did Britain then escape permanently from the poverty that has been the human lot since Adam, or the mitochondrial Eve? Was it freedom of an unusual sort? Was it the ideology of capitalism? Was it science, itself a cumulative miracle? No one knows, and until we do we will not understand the modern world.[17]

[14] 'Hans Rosling and the magic washing machine', TED, 12/2010, https://www.ted.com/ (checked: 06/03/2024).
[15] Arthur C. Clarke, *Profiles of the Future* (New York: Harper and Row, 1973).
[16] Robert Allen, 'Why was the Industrial Revolution British?', Centre for Economic Policy Research, 15/05/2019, https://cepr.org/ (checked: 06/03/2024).
[17] Deirdre McCloskey, 'Review of The Cambridge Economic History of Modern Britain', *Prudentia*, 15/01/2004, https://www.deirdremccloskey.com/ (checked: 06/03/2024).

However, there are geographic, strategic, and economic factors we can be sure did contribute to Britain's advantage, and which meant that the UK played a central role in igniting the industrial revolution that would transform the entire world.

Geographic enablers

The UK had a natural abundance of vital resources necessary for industrialisation, including coal, iron, and non-ferrous metals.[18] The geography of the UK was supportive in other ways too, such as having navigable rivers for transportation and large estuaries.[19] The sea surrounding the British Isles formed a natural barrier which helped dissuade potential invaders; Britain had not been torn apart by invasion since the Norman Conquest of 1066.[20] These geographic factors helped provide stability and a conducive environment for innovation during the industrial revolution.

Strategic and economic advantages

Britain's success in intercontinental trade was based on 'the acquisition of colonies, mercantilist trade promotion, and naval power'.[21] This economic growth led to expansion of Britain's rural manufacturing industries, as well as to rapid urbanisation in cities across the UK.

The expansion of Britain's rural manufacturing industries led to an increase in demand for labour and to increases in the wages and living standards of workers in the UK, to the extent that they were the highest in the world.[22] The rapid urbanisation of London created a shortage of wood fuel, which was offset by turning to coal for heating homes and other uses. In turn, this led to the coal trade, meaning Britain had ready access to the cheapest energy in the world at that time.[23] Rapid urbanisation and the growth of British cities, combined with

[18] David Levine, *Reproducing families: The Political Economy of English Population History* (Cambridge University Press, 1987) and Leif van Neuss, 'Why Did the Industrial Revolution Start in Britain?' Social Science Research Network, 07/12/2015, http://dx.doi.org/ (checked: 06/03/2024).
[19] Leif van Neuss, 'Why Did the Industrial Revolution Start in Britain?', Social Science Research Network, 07/12/2015, http://dx.doi.org/ (checked: 06/03/2024).
[20] Joel Mokyr, 'Editor's Introduction: The New Economic History and the Industrial Revolution', Joel Mokyr (ed.), *The British Industrial Revolution: an Economic Perspective* (Boulder: Westview Press, 1999), pp. 1-127.
[21] Robert Allen, 'Why was the Industrial Revolution British?', Centre for Economic Policy Research, 15/05/2019, https://cepr.org/ (checked: 06/03/2024).
[22] *Ibid.*
[23] *Ibid.*

the high wages and living standards of workers, led to a transformation of agriculture.[24]

Agriculture itself had been undergoing a period of intense change, the agricultural revolution, in the previous century – with the introduction of new farming innovations such as the seed drill, the introduction of new crops and crop rotations, and improvements in livestock breeding.[25]

Innovation: a British tradition

British innovation and ingenuity were key to industrialisation. Advancements such as the steam engine (particularly for pumping water out of the new coal mines), textile equipment, precise tool-making, powered locomotion and the telegraph were pioneered in the UK.

Besides the railways knitting the British Isles together, establishing a national consciousness and contributing to an integrated system of time, Richard Arkwright's power looms led to the building of vast factories and stimulated further urbanisation. Joseph Bazalgette's visionary sewage system transformed London, improved public health, and laid the groundwork for modern urban planning.[26] Isambard Kingdom Brunel revolutionised public transport and infrastructure, which have changed how people travel. Later, in the 20th century, Sir Frank Whittle is credited with inventing the jet engine and propelling humanity into the jet age. Tim Berners-Lee is credited with inventing the World Wide Web while working at CERN (although the role of the United States (US) Advanced Research Projects Agency should not be overlooked in the establishment of ARPANET, the forerunner of the internet).[27] Such innovations have shrunk distances, reshaped landscapes, and brought people together.

Unintended consequences: pollution and environmental degradation

But industrialisation had a negative side. While it gave humanity command over nature, it also provided humanity with the ability to destroy it. As William Wordsworth wrote in his 1814 poem, *The Excursion*:[28]

---

[24] *Ibid.*
[25] David Levine, *Reproducing families: The Political Economy of English Population History* (Cambridge University Press, 1987) and Leif van Neuss, 'Why Did the Industrial Revolution Start in Britain?' Social Science Research Network, 07/12/2015, http://dx.doi.org/ (checked: 06/03/2024).
[26] Gordon Charles Cook, 'Construction of London's Victorian sewers: the vital role of Joseph Bazalgette', *Postgraduate Medical Journal*, 77:914 (2021).
[27] 'From ARPANET to the Internet', The Science Museum, 02/11/2018, https://www.sciencemuseum.org.uk/ (checked 06/03/2024).
[28] William Wordsworth, *The Excursion, Book 8*, Wikisource, 22/12/2023, https://en.wikisource.org/ (checked: 06/03/2024).

> Meanwhile, at social Industry's command,
> How quick, how vast an increase! [...]
> O'er which the smoke of unremitting fires
> Hangs permanent, and plentiful as wreaths
> Of vapour glittering in the morning sun.
> [...]
> With You I grieve, when on the darker side
> Of this great change I look; and there behold,
> Through strong temptation of those gainful Arts,
> Such outrage done to Nature as compels
> The indignant Power to justify herself;
> Yea, to avenge her violated rights.
> For England's bane.

Human action since the industrial revolution has fundamentally changed the planet and led to widespread environmental degradation. Water pollution and air pollution were a direct result of industrialisation and urbanisation, and caused serious health problems. An article in *The Times* in 1882 noted:

> There was nothing more irritating than the unburnt carbon floating in the air; it fell on the air tubes of the human system, and formed a dark expectoration which was so injurious to the constitution; it gathered on the lungs and there accumulated.[29]

The consequences of industrialisation are still being experienced. Human activity has released so much carbon dioxide and other greenhouse gases into the atmosphere that the Earth's climate has changed and warmed by an average of 1.1℃ above the pre-industrial level.[30] Climate change has led to droughts, wildfires, and extreme rainfall; it is a threat to human wellbeing and the health of the planet.[31]

But the world has seen instances where collective action and focus have managed to meet environmental challenges humanity has created. This should give humanity hope for the future.

---

[29] W. Walker Hanlon, 'Pollution and Mortality in the 19th Century', *National Bureau of Economic Research*, 04/10/2015, https://www.nber.org (checked: 06/03/2024).
[30] 'How do we know climate change is happening?', *Imperial*, No date, https://www.imperial.ac.uk/ (checked: 06/03/2024).
[31] 'The Effects of Climate Change', National Aeronautics and Space Administration, No date, https://climate.nasa.gov/ (checked: 06/03/2024).

Chlorofluorocarbons (CFCs) were first synthesised in the 1920s. They were widely used in new technological innovations such as refrigerators, air conditioners, solvents, and aerosol sprays. In 1985, scientists at the British Antarctic Survey discovered a hole in the ozone layer, a part of the Earth's stratosphere that absorbs the Sun's ultraviolet radiation and helps make our planet habitable.[32] It was discovered that CFCs were leading to this destruction of the ozone layer. Due to their long half-lives (between 50-100 years), CFCs were causing long-term damage.[33] These findings resulted in the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. It is estimated that around 99% of ozone-depleting substances have been phased out, and the hole in the ozone has been recovering.[34] It is also estimated that two million people a year are saved from skin cancer as a result of action taken to phase out the use of CFCs.[35]

This is one example of how collective action has helped undo environmental damage humans have caused, but there are still many other areas which need to be tackled – from climate change to air pollution to plastic waste to the increasing problem of human-made space debris surrounding the planet.

So, how can technology help tackle these issues? And how can technology be harnessed to promote prosperity across the UK?

The British technological base

Britain has a strong technological base. It is now one of only three countries whose technology industry is worth more than US$1 trillion.[36] It has created more 'unicorn' technology startups (those worth US$1 billion or more) than Germany, France and Sweden combined.[37] The UK ranks fourth in the Global Innovation

[32] 'Ozone Layer', Met Office, No date, https://www.metoffice.gov.uk/ (checked: 06/03/2024) and Steve Colwell and Jonathan Shanklin, 'The Ozone Hole', British Antarctic Survey, 30/06/2022, https://www.bas.ac.uk/ (checked: 06/03/2024).
[33] Amit Bharath and Richard Turner, 'Impact of climate change on skin cancer', *Journal of the Royal Society of Medicine*, 102:6 (2009).
[34] 'Ozone Layer', Met Office, No date, https://www.metoffice.gov.uk/ (checked: 06/03/2024).
[35] 'Rebuilding the ozone layer: how the world came together for the ultimate repair job', UN Environment Programme, 15/09/2021, https://www.unep.org/ (checked: 06/03/2024).
[36] Kemi Badenoch, Speech: 'Kemi Badenoch heralds thriving $1 trillion UK tech sector', Department for Business and Trade, 13/06/2023, https://www.gov.uk/ (checked: 06/03/2024).
[37] *Ibid.*

Index,[38] making it an 'innovation leader',[39] and it is ranked first in the Future Possibilities Index.[40] As His Majesty's (HM) Government's 2023 International Technology strategy put it, the UK is:

> ...home to extraordinary technology expertise, with a flourishing tech sector, world-leading strength in cutting-edge technologies and a reputation for global leadership in developing forward thinking, agile legislation and regulation.[41]

But now another technological revolution is on the horizon, sometimes called the Fourth Industrial Revolution.[42] The promise and possibilities opened up by artificial intelligence (AI), as well as fields such as green (including nuclear) energy, biomedical sciences, and quantum computing will reshape economies and societies. They will also be vital tools in helping to ensure a sustainable future for the planet and for humanity.

Challenges ahead

While competitive in specific sectors, the UK is not in the same league as technological powerhouses such as the US and the People's Republic of China (PRC). Despite lacking the mass of the US and PRC, Britain's technology sector is sophisticated in other ways, and the country can build on this.

The modern UK technology sector has carved out a niche in the global arena not by consistently outcompeting every other nation, but by excelling in specific areas. London has emerged as a global financial technology (fintech) titan.[43] Two Cambridge-based companies, AstraZeneca and GlaxoSmithKline, rank in the top 10 pharmaceutical companies in the world by revenue.[44] Britain has a vibrant creative industry, with hubs for gaming, media, and design acting

[38] The Global Innovation Index is an annual ranking of countries by their capacity for, and success in, innovation, published by the World Intellectual Property Organization (WIPO).
[39] 'United Kingdom ranking in the Global Innovation Index 2023', *Global Innovation Index 2023*, 24/09/2023, https://www.wipo.int/ (checked: 06/03/2024).
[40] The Future Possibilities Index (FPI) is a future trends study by Newsweek Vantage and Horizon Group. It measures the capacity of countries to leverage possibilities emerging from six transformational trends for their future economic growth and societal wellbeing. 'Future Possibilities Index 2024', Horizon Group and *Newsweek*, 15/01/2024, https://d.newsweek.com/ (checked: 06/03/2024).
[41] 'The UK's International Technology Strategy', Department for Science, Innovation and Technology (UK), 22/03/2023, https://www.gov.uk/ (checked: 06/03/2024).
[42] Klaus Schwab, *The fourth industrial revolution* (London: Penguin Group, 2017).
[43] 'FinTech Investment Landscape 2022', *Innovate Finance,* 31/12/2022, https://www.innovatefinance.com/ (checked: 06/03/2024).
[44] Kevin Dunleavy, 'The top 20 pharma companies by 2022 revenue', *Fierce Pharma,* 18/04/2023, https://www.fiercepharma.com/ (checked: 06/03/2024).

as catalysts for areas such as virtual reality and augmented reality (VR/AR). VR and AR will have applications beyond the creative industry – such as in construction, infrastructure, education, healthcare, and the military.

But there are challenges ahead. Scaling tech companies into global giants, such as Meta, Alphabet, and Apple, remains a challenge for the UK. In addition, Britain has often had contradictory digital strategies,[45] as well as significant churn in its industrial strategy.[46]

Britain can still be a key player in technological innovation, and in leading the way to a healthier and more sustainable future. But protecting and enhancing this advantage requires Britain to focus on several key areas.

1. Strategic investment in key technologies

Targeted investments in critical areas such as artificial intelligence, cybersecurity, advanced manufacturing, and clean energy is paramount to ensuring the UK remains at the forefront of innovation and ensures its strategic advantage.[47]

While there is scepticism from some around government action and 'picking winners', recent geopolitical tensions have meant that policymakers around the world are turning to industrial policy, such as the US Inflation Reduction Act, the European Battery Alliance, and Japan's initiatives to secure supply chains.[48]

By dedicating resources to these strategically important sectors, Britain can unlock new economic opportunities, bolster national security, and contribute to a more sustainable future. Several areas of focus have been proposed over the last decade (see Table 1).

Note, technologies from the recent Department of Science, Innovation and Technology's (DSIT) 'Areas of Research Interest (ARI) 2024' are not included here as that document states 'The ARI does not cover all of the department's research endeavours. DSIT remains interested in research that is outside the areas outlined, which may still be relevant to DSIT policy or delivery'.[49]

---

[45] Mark Scott, 'How politics scuppered Britain's grand plan for tech', *Politico*, 01/03/2023, https://www.politico.eu/ (checked: 06/03/2024).
[46] Thomas Pope, 'Churn in "levelling up" policies in the UK', Institute for Government, 24/03/2022, https://www.instituteforgovernment.org.uk/ (checked: 06/03/2024).
[47] Gabriel Elefteriu, William Freer and James Rogers, 'What is strategic advantage?', Council on Geostrategy, 23/11/2023, https://www.geostrategy.org.uk/ (checked: 06/03/2024).
[48] Ira Kalish and Michael Wolf, 'The return of industrial policy', *Deloitte Insights,* 12/06/2023, https://www2.deloitte.com/ (checked: 06/03/2024).
[49] 'DSIT Areas of Research Interest 2024', Department for Science, Innovation, and Technology (UK), 26/02/2024, https://www.gov.uk/ (checked: 06/03/2024).

Table 1: Areas of emerging technologies of interest to HM government over the last decade[50]

Eight great technologies (2013)[51]	UK Innovation Strategy (2021)[52]	Science and Technology Framework (2023)[53]	The UK's International Technology Strategy (2023)[54]	Innovate UK's 50 Emerging Technologies (2023)[55]
Department for Business, Innovation and Skills	*Department for Business, Energy and Industrial Strategy*	*Department for Science, Innovation and Technology*	*Department for Science, Innovation and Technology* *Foreign, Commonwealth and Development Office*	*Innovate UK (non-departmental body of UK Research and Innovation)*
Synthetic Biology	Engineering Biology	Engineering Biology	Engineering Biology	Biotechnology
	AI, Digital and Advanced Computing	AI	AI	AI, Digital and Computing Technologies
	Electronics, Photonics and Quantum	Quantum	Quantum	Electronics, Photonics and Quantum Technologies
Advanced Materials	Advanced Materials and Manufacturing			Advanced Materials and Manufacturing
Energy	Energy and Environment Technologies			Energy and Environmental Technologies
Robotics and Autonomous	Robotics and Smart Machines			Robotics and Space Technologies

[50] This table was compiled by the author.
[51] The Rt. Hon. David Willetts, Speech: 'Eight great technologies', Department for Business Innovation and Skills (UK), 24/01/2013, https://www.gov.uk/ (checked: 06/03/2024).
[52] 'Science and Technology Framework', Department for Science, Innovation and Technology (UK), 05/03/2023, https://assets.publishing.service.gov.uk/ (checked: 06/03/2024).
[53] *Ibid.*
[54] 'The UK's International Technology Strategy', Department for Science, Innovation and Technology (UK), 22/03/2023, https://www.gov.uk/ (checked: 06/03/2024).
[55] 'Welcome to the future: Innovate UK's 50th Emerging Technologies', Innovate UK, 05/12/2023, https://www.ukri.org/ (checked: 06/03/2024).

Systems				
Space				
		Semiconductors	Semiconductors	
		Future Telecoms	Future Telecoms	
Big Data			(other technologies are underpinned and enabled by) data	
Regenerative Medicine				Health and Medical Technology
	Bioinformatics and Genomics			
Agri-science				

2. Strengthening international partnerships

Collaboration is crucial for tackling challenges such as climate change and pandemics. This can include sharing best practices and shaping the future of the technological landscape. The UK has tried to lead on this, such as by convening the AI Safety Summit at Bletchley Park in 2023.[56] While this summit did not solve issues relating to AI safety, it took a step forward by convening delegates from around the world on this issue, achieving something of a diplomatic coup. By strategically partnering with allies and partners, including the US, European Union (EU), Japan, South Korea, and Taiwan, the UK can leverage and multiply collective expertise, pool resources, and amplify its voice in shaping global norms and standards for responsible technology development.

3. Infrastructure

Britain has a problem building infrastructure (see Table 2).[57] Recently, the Crewe to Manchester leg of the High Speed 2 rail project was cancelled. The Hinkley Point C nuclear reactor is both delayed (until about 2031) and over budget (its

[56] 'AI Safety Summit', AI Safety Summit, No date, https://www.aisafetysummit.gov.uk/ (checked: 06/03/2024).
[57] Gill Plimmer, 'Budget blowouts and delays: why the UK struggles with infrastructure', *Financial Times*, 26/01/2024, https://www.ft.com/ (checked: 06/03/2024).

cost may spiral to £35 billion). By the end of the decade, most of the UK's operational nuclear power generating capacity will be retired.[58] Meanwhile the PRC has 26 power plants under construction and another 42 planned.[59] Heathrow's third runway is still unbuilt despite having been in the works for decades, while the PRC has built about seven airports every year since 2012.[60] The Elizabeth Line was four years late and £4 billion over budget.[61]

Table 2: Selection of recent large infrastructure projects in the UK, including cost overrun and delay in delivery[62]

Type	Name	Original budget	Current or final cost	% increase	Late
Rail	HS2	£37.5bn	£110bn	193%	Indefinite (connections beyond Birmingham scrapped)
Energy	Hinkley Point C	£18bn	£35bn	94%	4 years
Road tunnel	Lower	£5.3bn	£9bn	70%	2 years

[58] 'Nuclear Power in the United Kingdom', World Nuclear Association, 02/2024, https://world-nuclear.org/ (checked: 06/03/2024).
[59] 'Plans For New Reactors Worldwide', World Nuclear Association, 03/2024, https://world-nuclear.org/ (checked: 06/03/2024).
[60] 'China Airport: Number of Airport', CEIC Data, 12/2023, https://www.ceicdata.com/ (checked: 06/03/2024).
[61] 'London Reveals New Elizabeth Line', *Tunnel Insider*, 03/11/2023, https://tunnelinsider.com/ (checked: 06/03/2024).
[62] This table was compiled by the author. For HS2, see: Graham Atkins, 'High Speed 2 costs', Institute for Government, 29/01/2020, https://www.instituteforgovernment.org.uk/ (checked: 06/03/2024); for Hinkley Point C, see: Alex Lawson, 'Hinkley Point C could be delayed to 2031 and cost up to £35bn, says EDF', The Guardian, 23/01/2024, https://www.theguardian.com/ (checked: 06/03/2024) and Forrest Crellin, Benjamin Mallet and Nina Chestney, 'EDF's UK Hinkley Point nuclear plant start date delayed again, costs mount', *Reuters*, 25/01/2024, https://www.reuters.com/ (checked: 06/03/2024); for Lower Thames Crossing, see: 'Lower Thames Crossing', Britain Remade, No date, https://www.britainremade.co.uk/ (checked: 06/03/2024) and 'Lower Thames Crossing project delayed by two years', *BBC*, 09/03/2023, https://www.bbc.co.uk/ (checked: 06/03/2024); for Tideway tunnel, see: Greg Pitcher, 'Tideway tunnel cost grows again to £4.5bn', *Construction News*, 26/04/2023, https://www.constructionnews.co.uk/ (checked: 06/03/2024), 'Thames Tideway hit by nine-month delay and cost hike', *Construction Management*, 26/08/2020, https://constructionmanagement.co.uk/ (checked: 06/03/2024); for Elizabeth Line, see: Euan O'Byrne Mulligan, 'How much did the Elizabeth Line cost? When the Crossrail project started and delays in its opening explained', *iNews*, 25/05/2022, https://inews.co.uk/ (checked: 06/03/2024) and Ross Lydall, 'Elizabeth line's "staggering achievement" with 300m journeys made since opening', *The Standard*, 13/02/2024, https://www.standard.co.uk/ (checked: 06/03/2024).

	Thames Crossing				
Sewer	Tideway tunnel	£3.5bn	£4.5bn	29%	9 months
Rail	Elizabeth Line	£14.8bn	£18.9bn	28%	3.5 years

The cost overruns and delays are caused by the UK's planning system, its legal and regulatory approach, technical challenges, optimism bias, and strategic misinterpretation.[63] To prosper, Britain should set out clear outcomes, review procurement, and improve forecasting for infrastructure projects. And Britain ought also to turn its attention to the infrastructure of the future, such as building foundational AI-era infrastructure.[64]

4. Research and development expenditure

The UK should increase public research and development investment to make itself a leader among comparable nations, coupled with reforms to the way British institutions of science, research and innovation are funded and regulated to give more freedom and better incentives. Britain should strive to reach the target of 3% of gross domestic product (GDP) being invested in research and development per year. This is comparable to Germany but still far behind leaders such as South Korea and Israel, which spend 5-6% each on research and development.[65]

5. Improve scale up and commercialisation

Although the UK has a strong start-up ecosystem, companies face challenges in scaling up. This is caused by barriers in access to finance and talent, as well as access to infrastructure and building a strong investment case. It is crucial that the UK fixes its 'scale up' economy so British firms have the opportunity to become global champions. As the Royal Academy of Engineering has noted, there

[63] Amandeep Bahra, 'What causes delays and cost overruns on major infrastructure projects?', Construction Products Association, 24/05/2019, https://www.constructionproducts.org.uk/ (checked: 06/03/2024).
[64] 'Nvidia CEO Huang says countries must build sovereign AI infrastructure', *Reuters*, 12/02/2024, https://www.reuters.com/ (checked: 06/03/2024).
[65] 'A UK Tech Plan: How the next Government can use technology to build a better Britain', Tech UK, 06/06/2023, https://www.techuk.org/ (checked: 06/03/2024).

are a number of key barriers small businesses face – including, but not limited to:

- The lack of availability of long term investment for startups to scale and avoid either market exit or overseas relocation;
- Excessive complexity and administrative burden involved in accessing funding; and,
- Risk averse venture capital firms.[66]

Through tackling these barriers, the UK can foster an ecosystem more conducive to start-ups, and particularly those that will help Britain in its ambitions for a greener and more sustainable economy.

Conclusion

Two hundred years ago, Britain was in the midst of a great transformation. It did not yet have a unified time across the nation and the locomotive was still being developed. That transformation, the industrial revolution, heralded a paradigm shift almost unprecedented in its impact on humanity. It led to an enormous improvement in the length and quality of life, and freed billions from back-breaking drudgery. At the same time, it has led to widespread environmental degradation and to climate change. Technology has the potential to help humanity in the endeavour for a more sustainable future. The UK still has a strong technology base and is one of the most innovative economies in the world. But there are challenges ahead. If Britain is to remain competitive and prosper, His Majesty's Government should:

1. Invest strategically in key technologies;
2. Strengthen international partnerships;
3. Improve its ability to build infrastructure to budget and on time;
4. Increase investment in research and development to 3% of GDP;
5. Improve 'scale up' and commercialisation.

[66] 'Written evidence submitted by The Royal Academy of Engineering', UK Parliament, 09/2023, https://committees.parliament.uk/ (checked: 06/03/2024).

Acknowledgments

The author would like to acknowledge and thank the reviewers for their feedback on this Primer.

This Primer is kindly sponsored by John Caudwell as part of the Council on Geostrategy's ***Caudwell Strong Britain*** *project.*

About the author

Dr Mann Virdee is a Senior Research Fellow in Science, Technology, and Economics at the Council on Geostrategy. Previously, he was a researcher at the RAND Corporation, where he managed and conducted research on areas such as artificial intelligence (AI), quantum computing, 5G, space science and governance, biotechnology and the life sciences, and research and innovation.

> **Dedicated to making Britain, as well as other free and open nations, more united, stronger and greener.**

ISBN: 978-1-914441-60-8

Address: 14 Old Queen Street, Westminster, London, SW1H 9HP
Phone: 020 3915 5625
Email: info@geostrategy.org.uk