*UCD CENTRE FOR ECONOMIC RESEARCH*

*WORKING PAPER SERIES*

*2023*

# Industrial policy on the frontier: lessons from the first two industrial revolutions

Morgan Kelly
University College Dublin

Kevin Hjortshøj O'Rourke
NYU Abu Dhabi

WP23/25

November 2023

**UCD SCHOOL OF ECONOMICS**
**UNIVERSITY COLLEGE DUBLIN**
**BELFIELD**
**DUBLIN 4**

**Industrial policy on the frontier: lessons from the first two industrial revolutions**

Morgan Kelly (University College Dublin)

and

Kevin Hjortshøj O'Rourke (NYU Abu Dhabi)

Very preliminary, not for citation.

## 1. Introduction

The Biden administration's Inflation Reduction Act symbolizes the return of industrial policy to the world's economic policy agenda, and poses a challenge to which European leaders are now having to respond. It comes at a time when the world is seeking to transition away from the fossil fuels that have powered our economies since the first industrial revolution, and reflects the belief that government policy can and should intervene to accelerate technological change and channel it into desirable pathways. It also demonstrates a political determination on the part of the US government that American tax dollars should promote technical progress and industrial production in the United States, and comes at a time of heightened political tension between the West and China which is bringing strategic considerations back into international trade policy.

Does the past have any lessons for today? The history of industrial policy remains understudied, although it is making a return to the academic agenda (Lane, 2020; Juhász et al., 2023; Juhász and Steinwender, 2024). Much of the existing literature has looked at strategies adopted by "backward" countries seeking to converge on the economic leaders of the time, with East Asia being a notable case in point (e.g. Amsden, 1992; Rodrik, 1995; Lane, 2022). But the current European debate is not about how best to catch up on a technological leader, but about whether and how the EU and its member states, already rich, should intervene to ensure that technologies that have not yet been invented are developed and used in Europe. In other words, it is about the role of industrial policy in countries already on, or very close to, the technological frontier, at a time of accelerating innovation: it is less about catching up, and more about trying to forge ahead, as opposed to falling behind (Abramovitz, 1986).

In this paper we revisit the histories of the first and second industrial revolutions, focussing on the experiences of countries that were already rich by the standards of the time, on or close to the technological frontier, and which could reasonably have aspired to industrial and economic leadership. Did governments intervene to promote economic growth, technological change, or industrial leadership, and if so what form did these interventions take? Were some strategies more successful than others, and if so why? The paper is structured thematically rather than chronologically, since we lack the space required to provide a proper narrative history. In the remainder of this introduction we make some general points about the history of industrial policy, beginning with a discussion of the variety of forms that it has taken over time.

### ***1.a. What is industrial policy?***

Juhász et al. (2023, p. 4) define industrial policy as: "government policies that explicitly target the transformation of the structure of economic activity in pursuit of some public goal. The goal is typically to stimulate innovation, productivity, and economic growth. But it could also be to promote climate transition, good jobs, lagging regions, exports, or import substitution." The breadth of this definition is useful when assessing the historical record, since as we will see governments have often been motivated by strategic considerations when intervening in the economy.

Industrial policy can take many forms. Consider support for technological change. Governments can promote general or sector-specific technical change by intervening directly in the markets for invention or innovation. For example:

- During the 18th and early 19th centuries the British Board of Longitude awarded £53,000 worth of prizes to innovators, most famously John Harrison in recognition of his chronometer. A condition of the awards was that details of inventions be made public; the Board therefore spent £45,000 on publications facilitating this (Kelly and Ó Gráda, 2022);
- Alternatively, governments could reward innovators by granting them monopolies; the first patent law is generally held to have been passed in Venice in 1474 (Comino et al., 2020). Patents were subsequently introduced in many European countries, and in England were given a legislative basis with the Statute of Monopolies of 1624. France

and the United States passed patent laws in the aftermath of their respective revolutions (Frumkin, 1945; Moser, 2013);

- A third possibility was for governments to finance public research institutions. Publicly funded agricultural research was very important in developing suitable grain varieties in late 19th century frontier economies such as Canada (Olmstead and Rhode, 2007), but governments also financed industrial research. For example, the Japanese government founded an Industrial Experiment Laboratory in 1900 to do research on behalf of domestic firms, and fifteen years later supported the establishment of a research centre focussed specifically on the iron and steel industry, the Iron and Steel Institute of Japan (Mazzoleni and Nelson, 2007, p. 1519).
- In recent decades governments have promoted inward transfers of technology by encouraging foreign direct investment. In the past, governments pursued the same goal by encouraging the immigration of skilled artisans embodying technical knowledge. Examples of such policies can be found in a wide variety of historical contexts, from Edward III's issuing letters of protection in the 14th century to foreign textile workers coming to England, to the government of Meiji Japan hiring foreign engineers and teachers who could assist in its programme of economic modernisation and industrial development (Lambert and Pajic, 2016; Sukehiro and Wakabayashi, 1989, pp. 466-70).

Governments can also try to stimulate innovation at one remove by intervening in input markets, specifically markets for those inputs most important for invention and innovation. Most obviously, they can finance higher education and technical training, but they can also intervene in capital markets to ensure that would-be innovators have access to an adequate supply of credit.

Third, governments can intervene in product via taxes, subsidies, and protectionist policies. Governments can also support industries directly via their procurement policies. For example, the Russian government embarked on a major programme of railway construction in the late 19th century, and through its subsidies and procurement decisions promoted the establishment of a domestic metallurgical and machine-building industry that could supply the railroads with locally-produced inputs (Kahan, 1978, pp. 268-9). And governments can take measures to stimulate the private consumption of favoured products, as in the case of the English laws of 1666 and 1678 requiring that people be buried in woollen shrouds (O'Brien et al., 1991, p. 397).

Finally, the Juhász et al. definition of industrial policy can be expanded to include targeting not only the structure of the domestic economy, but that of one's rivals. As a French demographer wrote in 1788, "The people that last will be able to keep its forges going will perforce be the master; for it alone will have arms" (cited in Landes, 2003, p. 326). In such a context, industrial policy may seek not only to promote domestic technological progress and economic growth at home, but to slow them abroad. Today's American attempts to weaken China's chip industry have several precedents: to take just one example, late medieval Venetian glassblowers faced the death penalty if they attempted to practice their craft overseas (Frumkin, 1945).

### *1.b. Laisser-faire: a historical exception, not the rule*

While the current turn towards industrial policy may strike observers as dramatic, in a historical context it is unexceptional. Western policy-making may largely have eschewed such interventions since the 1980s, but this was an atypical interlude.

Prior to the first industrial revolution, the major European states pursued mercantilist policies, inspired by the belief that plenty begat power and vice versa (Viner, 1948; Findlay and O'Rourke, 2007). An initial focus in Britain on securing and monopolising profitable trade routes was gradually replaced by what Barth (2016) calls industrial-capital mercantilism, emphasizing domestic manufacturing rather than the re-export of imported goods. The turn of the 18$^{th}$ century saw a switch in London from traditional revenue-raising tariffs on imports and exports of 5%, to much higher tariffs targeting the growth of silk, paper, and other domestic industries. During the 17$^{th}$ and 18$^{th}$ centuries continental statesmen such as Colbert also used tariffs to protect domestic industry, especially textiles, and to damage the trade of France's Dutch and

English rivals (Coleman, 1961, p. 38). Nor were tariffs the only industrial policy instruments used by early modern states, as we will see.

Industrial protection was common in the 19th century, although Britain adopted free trade in mid-century (Bairoch, 1989). In the United States tariffs had long shielded northern industries, and the country would remain protectionist into the 1930s. Education and railroad construction were other policies of the time that transformed "the structure of economic activity": Allen (2011, p. 114) goes so far as to speak of a "standard model" successfully pursued by countries throughout Western Europe and North America during this period, and into the 20th century, involving four elements: "railways, tariffs, banks, and schools."

The interwar period saw widespread government intervention, which remained important even in the West after 1945. Industries were nationalized, governments invested heavily in secondary and higher education, and economic planning was adopted in several countries. In France the *Commissariat Général au Plan* devised plans whose goals included not only economic growth, but 'ensuring our defense' and aiding former African colonies 'which decided to keep special ties with our nation.' The French Atomic Energy Commission was established in 1945 to 'pursue scientific and technical research in the view of using atomic energy in the various domains of science, industry, and national defense' (Hecht, 2009, pp. 48, 58): nuclear power has been central to French energy and industrial policy ever since.  Across Continental Europe dividends were taxed and domestic investment subsidized; tripartite agreements between labour, capital and governments sought to boost investment by increasing profits (Eichengreen, 2007). While trade was liberalized between Western economies, especially from the 1960s, this was not a global phenomenon, and capital mobility remained largely restricted until the 1980s (Obstfeld and Taylor 2004). In 1949, shortly after the start of the Cold War, the United States passed the Export Control Act giving the administration widespread powers to control exports. In conjunction with its NATO Allies, a Coordinating Committee for Multilateral Export Controls (CoCom) was established to jointly restrict exports to the Soviet bloc: this was only disbanded in the 1990s.

The Reagan-Thatcher revolution of the 1980s pushed back the boundary of the state in many countries, and the 1980s and 1990s saw the emergence of a global market with much less government intervention than previously. But industrial policy did not disappear in the West: Airbus is an obvious example, as are the energy policies pursued by various governments. And industrial policy has been common in other parts of the world, notably China. In a broader historical perspective, therefore, there is nothing unusual about the re-emergence of industrial policy in the OECD: it is its relative absence in the preceding decades that seems anomalous.

### *1.c. Industrial policy and geopolitical tension*

Industrial policy has been motivated by a variety of concerns. Sectoral lobbying has undoubtedly mattered, but policy has also been driven by a desire to promote national economic development. And the extent to which industrial policies have historically been driven by strategic considerations is striking.

Economics and geopolitics were intertwined throughout the early modern period. As Wilson (1978, p. 1) points out, 1610 was the only year between the start of the 17$^{th}$ century and 1667 not to see war between the major European states. In consequence, war was taken as the normal state of affairs by politicians: 'Omit this and much of what came to be the national policy – in economic terms, the mercantile system – becomes unintelligible' (*ibid*.). Long distance trade absorbed the attentions of statesmen not only because of the revenue it could bring to state coffers in an era of mounting military expenditures, and the profits which it offered politically well-connected merchants, but because the shipping sector was a "nursery for seamen" and a source of ships that could be used in the event of war. This was a particularly important consideration for an island nation such as Britain: no fewer than 83% of the ships that warded off the Spanish Armada in 1588 originated in the merchant marine (Özveren, 2000, p. 25). Governments were unwilling to leave the fate of the shipping sector to the market, intervening with a range of prohibitions and other restrictions on trade, most famously the

English Navigation Acts, and being willing to go to war to further their countries' commercial interests. Domestic lobbying by merchants lay behind the legislation of this period, but so did strategic considerations: Adam Smith, no protectionist, concluded a century later that 'As defence…is of much more importance than opulence, the act of navigation is, perhaps, the wisest of all the commercial regulations of England.'

As we will see, the metallurgical industry was strategically important in the 18th century, and with the Industrial Revolution heavy industry became even more important: iron and steel were essential in producing not only cannons and guns, but ships, rails, trains, and other strategically vital goods. Not to have a domestic heavy industry capable of supplying such products risked catastrophe in the event of war, and governments intervened to ensure that they would not be thus exposed. Their military forces sent delegations to observe best technological practice in leading companies such as Krupps in Germany; governments tried to import technological expertise in the form of engineers and skilled workers; government procurement policies were used to ensure stable domestic markets for local companies; state-owned companies were subsidized; and tariffs were used to protect domestic firms from their foreign rivals. In 1878, for example, the Japanese navy sent officers to study how weapons-grade steel was produced by Krupp and Armstrong in the UK. As in other countries, the navy would become a major advocate for the establishment of a domestic steel industry. Military tensions between China and Japan in the 1890s eventually provided the impetus behind the formation of Asia's first integrated iron and steel works, the state-owned Yawata Works, which began production in 1901. The plant was loss-making for the first decade of its existence, but became a central component of Japan's flourishing iron and steel industry, facilitating technological diffusion via the mobility of engineers and direct technical assistance (Yonekura, 1994).

## 2. Patents and innovation

An influential school of thought holds that early modern British success was largely due to its progressive patent laws, reflecting a more general tendency to protect private property. In contrast, early modern France discouraged innovation by enmeshing the private sector in a web of bureaucracy and privileges. This New Whig view was articulated by North and Thomas (1973, pp. 155-156), who argued that ‘by 1700…England had begun to protect private property in knowledge with its patent law. The stage was now set for the industrial revolution’. Useful industrial policy, in this account, consists of government providing the private sector with the institutional tools it needs to innovate.

In fact, English patents were costly to obtain, and the ability to enforce a patent was uncertain at best. Registering a patent for a successful product was an invariable prelude to litigation from those who wanted to use it for free: ‘Indeed, by the late eighteenth century, it was becoming a dictum that a patent was of little commercial value until it had been successfully defended in the courts’ (MacLeod, 1988, p. 73). During the first parliamentary investigation into patent law in 1829, the engineer Marc Brunel said that ‘I might as well toss for the fate of a patent’ (MacLeod, 2009, p. 43)

The odds were even worse than that. Between 1750 and 1829 only one third of judgments went in favour of the patent holder. Almost none of the epochal inventions of the industrial revolution, with the exception of Watt’s separate condenser (although even he was reluctant to sue violators for fear that the patent specification would be found wanting), were successfully patented or stayed so for long. Hargreaves was denied a patent on his spinning jenny on the grounds that he had already sold some, Arkwright had his patents for the water frame and carding machine revoked, Crompton lacked the money to patent his mule, Tennant lost his patent for bleaching liquor after being sued by his licensees, Cort lost his patents for puddling and rolling in opaque circumstances following the revelation that his partner had misappropriated government funds, and Argand had his lamp patent revoked. In contrast with the view that the English patent system turbo-charged the industrial revolution, it would appear to have instead resembled an elaborate bait and switch scheme in which inventors laboured in the hope of a patent that would prove worthless if others found their invention valuable.

The German chemical industry during the second industrial revolution provides another fascinating example of the role of patents. The roots of German success can be found in local states competing to attract the best scientists to publicly financed research institutes: Lehrer, Nell, and Gärber (2009) note how the research funding model resembles that of US universities since the 1940s. German success was epitomised by the dye industry: on the eve of the First World War German firms and their foreign subsidiaries accounted for 90% of world production and dyestuffs were Germany's largest export. However, the early breakthroughs in synthetic dyes occurred in Britain and France, partly as a result of a domestic over-supply of German chemists leading them to seek employment elsewhere. Early German firms established in the early 1860s largely operated by pirating these products, aided by the *absence* of a coherent national patent system before 1877. A good deal of their success in this period, Murmann (2003, pp. 89-90) suggests, was the consequence of Darwinian selection in a highly competitive environment where, without patents to hide behind, only the most efficient and resourceful firms survived.

In 1877 a national patent law was introduced under pressure from the engineering industry. The sections dealing with chemicals were drafted by August Wilhelm von Hofmann, the first director of the British Royal College of Chemistry and co-founder of the *Deutsche Chemische Gesellschaft*. They ensured that chemical products, such as a particular dye molecule, could not be patented, only the process used to produce them. This allowed rivals to devise their own processes. It is from this date that German dye firms established their own research laboratories, staffed with graduates from institutes. The typical pattern was for particularly talented hires to be sent to work in a prestigious academic laboratory for several months on problems of interest to the firm (Meyer-Thurow, 1982).

For Haber (1958, pp. 198–203), a major reason for the rise of German producers was their exploitation of the weaknesses of the British and French patent systems. These allowed dye molecules to be patented, even if not produced in the country. This allowed German firms to patent their new dyes without issuing licences to local producers, effectively blocking innovation. Foreigners were granted 600 patents for coal tar dyes during 1891-5, none of which were produced in Britain (Foreman-Peck, 1999, p. 123).

English patent law didn't have much to do with the first industrial revolution and was harmful during the second. The argument that the breakthrough to modern growth was sparked by the protection of private intellectual property rights in the first industrial nation is not supported by the facts. This is not to deny that private sector innovation was crucial in 18th century England, for it was. Nor does it mean that patents were not important in other contexts, since as the German dye example suggests, they were. It does mean that not all patent systems were alike, and that the details of the legislation mattered. It also suggests that we should be sceptical of the argument that the role of government in promoting British success was a passive one. In fact, the British state was highly interventionist, as we will see.

## 3. Zero sum industrial policy

The proposition that governments should intervene to address market failure is relatively uncontroversial, and there are arguments for industrial policy that would apply in a closed economy or at the level of the world as a whole. But there are other interventions whose logic relies more on the fact that the world is divided into states with competing economic or strategic interests, suggesting that individual states should grab technologies, markets, or resources for themselves rather than leave them to their competitors. Unsurprisingly, the historical record provides many examples of the latter.

### *3.1. The Navigation Acts*

The 17th and 18th centuries were characterised by a lengthy struggle between the main European powers – notably England (from 1707 Britain), France, and the Netherlands – for control over the trade and resources of the New World, maritime trade within Europe itself, and the long-distance trade between Europe and Asia. The rise of the English shipping industry to a position of global dominance was not a natural market outcome, but the result of conscious government policy involving strict controls on international trade, backed up with military force. The mid-17th century was the turning point. Materially, the Cromwellian regime invested massively in the navy, which was ten times larger at the Restoration than it had been under Charles I (Wilson, 1978, p. 79). Legislatively, the Navigation Laws established the framework under which British trade would be conducted up until the American Revolution on the one hand, and Britain's gradual conversion to free trade in the 19th century on the other. These Navigation Laws, of which the 1660 Navigation Act formed the basis, were aimed primarily against the Dutch who dominated international commerce in mid-century (Davis, 2012, pp. 295-6). The 1660 Act specified that all commodities imported from outside Europe, and a list of specified commodities imported from Europe itself, be imported in ships that were either English or belonging to the exporting nation. The European goods concerned included the major Baltic and Mediterranean exports, including such strategically important commodities as timber, masts, pitch, and potash. A list of "enumerated commodities", including tobacco, sugar, corn, indigo, and other dye-stuffs, produced in English colonies, could only be shipped to England or its possessions. English ships importing foreign goods could only do so from their original sources (as opposed to, notably, a Dutch entrepôt). The 1663 Staples Act further specified that English overseas colonies buy most of the European imports they required in England, thus reserving an important export trade for English shipping in addition to the import trades listed above.

The net impact of these restrictions was to cut the Dutch middleman out of English trade. Domestic shipbuilding was promoted, while the capture of over 1000 Dutch ships during the First Anglo-Dutch War of 1652-54 transformed the English fleet into a balanced one combining large, speedy and manoeuvrable ships capable of defending themselves, on the one hand, with cheaper but slower Dutch flyboats on the other (Davis, 2012, p. 12). Dutch ships entering the Baltic had outnumbered their English counterparts by thirteen to one in the first half of the 17th century; the margin was only four to one between 1661 and 1700 (Ormrod, 2003, p. 338). In

1670, the Netherlands accounted for 40% of the European merchant fleet, and Britain only 12%; by 1780 these figures were 12% and 26% respectively (van Zanden, 2001, p. 80).

England's gain was the Netherland's loss. While there is debate about the timing and causes of Dutch decline, and whether it was relative or absolute, in the long run there is no doubt that the Dutch lost their pre-eminent role in international trade. Ormrod (2003, p. 337) dates the beginning of the decline to the last third of the 17th century, and concludes that 'it is now clear that the Navigation Acts and English protectionist policies helped to secure English commercial hegemony within the North Sea and beyond'. Neither is there any doubt that the intention of English policy makers was to benefit at the expense of the Dutch. As a courtier described by Pepys as 'a blockhead but stout and honest to his country' put it in the early 1660s, when discussing arguments about whether England should embark on a second war against the United Provinces, 'What matters this or that reason? What we want is more of the trade the Dutch now have' (Wilson 1978, pp. 92, 107).

### *3.2. British Machinery Exports and Skilled Emigration*

Not all zero-sum policies were successful. In 1719, as a result of French attempts to lure away British artisans, and the suspicious appearance of Russian apprentices in England, an act was passed banning the emigration of skilled workers (Harris, 2017, pp. 8-9). The legislation was subsequently strengthened in 1750. The earliest restriction on machinery exports dates from 1696 and involved stocking frames, extremely complex knitting machines with more than 2000 parts that had been invented in 1589 and were the basis of a large and successful hosiery industry (Lewis, 1986). This was followed by an act of 1750 against the exportation of tools used in cotton and linen production. A stricter act in 1781 banned exports of all textile machinery, including models and plans, and this was extended in the following year to machines and copper plates used for textile printing. Metal technologies were added in 1785.

These efforts were unsuccessful. It was easy to conceal machinery parts, claim they were components of permitted exports, or bribe customs officials, while plans and models were impossible to control. Similarly, unless a man was carrying the tools of his trade it was difficult to distinguish a skilled artisan from an ordinary workman. In 1824 artisan emigration was no longer controlled, and in 1843, after years of extensive lobbying by both textile manufacturers and increasingly influential machine builders, restrictions on machinery exports were finally removed.

## 4. Industrial policy and unintended consequences

It is no surprise that industrial policy in the past often had unintended consequences. What may be less well appreciated is that sometimes these unintended consequences had broadly beneficial effects. We illustrate this proposition in the context of 17th and 18th century Britain.

### *4.1. The Navigation Acts*

We have seen that the Navigation Acts increased England's share of international trade at the expense of the Netherlands. This was their aim. More important was the effect of mercantilist policy on the structure of the British economy. Fuelled by international trade, London grew rapidly to become the largest city in Europe, with a population of almost 900,000 in 1800 (Malanima, 2010). The shipping industry and related activities may have employed a quarter of London's population in the early 18th century (Boulton, 2000, p. 320). By 1700 re-exports of imported commodities accounted for 38% of total exports (op. cit., p. 321). A variety of industries grew up processing imported raw materials. With trade came banking and insurance industries, financial development that in turn fuelled growth in other sectors of the economy, government revenues, a demand for educated workers, and other growth-promoting effects (Allen, 2009; Wright, 2020). With London's growth came high-productivity agriculture in its vicinity, an expansion of coal-mining in northeast England and the coastal trade transporting fuel from Tyneside to the capital, a consequent increase in shipbuilding, and knock-on effects on technologies relating to mining, including steam-driven pumps and horse-drawn railways (Wrigley, 1987, Chapter 6). Trade directly stimulated technical progress: for example, reverberatory furnaces smelting copper with coal rather than charcoal were developed in the late 17th century to satisfy the high overseas demand for copper (Zahedieh, 2013). Taxes on overseas trade became increasingly important: by the early 19th century they accounted for over 50% of British indirect taxation. By 1818 taxes on “imperial” goods such as tea, tobacco, coffee, sugar, and spices accounted for more than half of this figure (Dal Bo et al., 2023). In the words of Wilson (1978, p. 102), ‘It is no exaggeration to see these years as a turning-point in England's economic destiny’.

### *4.2. Protection for the woollen industry*

At the end of the 17th century woollen cloth exports accounted for more than two-thirds of total English exports (Davis, 1962, p. 292). The woollen textile industry owed its prominence to 14th century government policy. In 1336 Edward III raised export taxes on raw wool, and merchants were compensated via a monopoly of the export trade. The net effect was to make raw wool cheaper in England than elsewhere, benefiting the domestic woollen cloth industry, although this was ‘unpremeditated and certainly neither foreseen nor desired’ by the Company of the Staple of Calais that by the century’s end controlled raw wool exports (Power, 1941, p. 101). Government procurement of clothing for the armed forces provided further stimulus to the industry (Carus-Wilson, 1950, p. 165). The 1330s and 1340s saw English producers capture the domestic market, and by the 17th century they were outcompeting their Hanseatic rivals on northern European markets as well.

Holland retained a comparative advantage in bleaching, dyeing, and printing cloth. In 1614, a group of merchants, led by an Alderman named Cockayne, persuaded James I to ban the export of unfinished cloth in the hopes that it would then be finished at home. The experiment was a disaster. On the one hand England lacked the skilled workers needed to finish the cloth; on the other the Dutch responded by banning imports of finished English cloth. Even though the English also banned raw wool exports, in an attempt to further damage their rivals, the scheme was abandoned after a few years (Bowden, 1962, pp. 187-9; Wilson, 1978, pp. 29-30). There followed a series of attempts to ban exports not only of wool, but of other raw materials used by the textile industry, including materials used in bleaching such as fullers earth.

Despite the failure of the Cockayne project, by 1660 around two-thirds of British woollen textile exports consisted of fully finished cloth (O'Brien et al., 1991, p. 401). But a new threat now emerged: highly fashionable and colourful cotton calicoes imported from India. The East India Company exported not only finished Indian cotton textiles to the British market, but unfinished textiles that were printed by a small but rapidly growing calico printing industry based in London. Further competitive challenges facing the industry came from the Irish woollen industry, and the linen industry based in Ireland and Scotland. In 1699 parliament prohibited the export of woollen cloth from Ireland, which eliminated one source of competition at the expense of encouraging the Irish to expand their linen industry (Kearney, 1959).

Indian imports posed a greater challenge, and governments across Europe protected their textile industries. In France the sale of printed cotton textiles was effectively banned, and similar prohibitions came into effect elsewhere. But in England and Holland the East India Companies were an important political counterweight to the textile industries, lobbying to keep markets open to Indian calicoes (O'Brien et al., 1991, pp. 400-1). The Dutch VOC won its battle, while the English East India eventually lost it. The way this happened had important long-run effects.

In 1701 the English government banned the importation of printed calicoes, except for re-export. Crucially, nothing prevented London printers from finishing white Indian calicoes, and nothing prevented domestic cotton producers from manufacturing cotton textiles. The London dyeing and printing industry consequently flourished, much to the displeasure of the woollen lobby. In 1721, therefore, England followed France and other countries in banning the wearing of cotton cloth, which ended the importation of Indian cotton textiles. Again there was a loophole: fustians (a mixture of cotton and linen) were not included in the ban, and fustian production therefore thrived. By the mid-18th century the Irish linen industry, subsidized by the Linen Board which had been established in 1711, was growing rapidly, partly as a result of the ban on Indian cotton textiles. Rising linen cloth production raised the price of linen yarn, giving fustian producers an incentive to replace fustian's linen warp with cotton. The technological breakthroughs associated with the Industrial Revolution made this possible, and in 1774 it became legal to wear 100% cotton cloth 'wholly made of cotton spun in Great Britain' (O'Brien et al., 1991, p. 412). The British cotton textile industry would go on to experience explosive growth and dominate global markets for a century or more.

O'Brien et al. (1991, p. 416) comment that English policy makers 'never pretended to formulate anything recognizable as an industrial policy'. And yet, as they say, 'Between 1696 and 1774 laws emerged which were critical for the subsequent development of the cotton industry' (p. 396). Holland stuck with free trade and never developed a cotton textile industry of consequence, even losing their comparative advantage in finishing cloth (p. 418). France banned not only Asian calicoes, but all printed cotton textiles, from its domestic market, greatly hindering the development of a cotton textile industry there. In Britain, a set of policies designed to balance special interests, the fiscal needs of the crown, and a desire to promote stability in Ireland, ended up establishing the '"legislative foundations" for the first fully mechanized factory industry to emerge during the first industrial revolution' (p. 415).

**5. Resilience, geopolitics, and innovation**

Concerns about excessive import dependence are not new, and have tended to grow at times of rising international tension. Countries have adopted various strategies in trying to reduce such (actual or perceived) vulnerabilities. One is to seek alternative sources of supply; another is to use military force to ensure that supplies are secured during wartime.

Take Britain's dependence on the Baltic trade during the early modern period. The Royal Navy's ships, like other British ships of the time, were built almost entirely from material imported from the Baltic: masts, timber for smaller spars and decks, oak for hulls, flax and linen for sails, pitch and tar for waterproofing, high-quality Swedish wrought iron for anchors and other naval hardware, and Russian hemp needed for rigging and other cordage. The Baltic was also an important source of grain. The British were painfully aware of their reliance on a landlocked sea with a single narrow entrance and went to considerable lengths to find substitutes for Baltic timber and hemp. A high-level committee on the topic set up in 1800 included the eminent botanist Sir Joseph Banks. There was particular interest in Canadian masts and oak, along with East Indian jute, but all were dangerously weak compared with their Baltic counterparts. Other potential sources of hemp were tried and found wanting, while mast timber was sought literally all over the world with a considerable number of trees brought from New Zealand from 1804 despite the danger posed by its hostile Maori inhabitants.

In 1807 Russia joined Napoleon's Continental System, threatening Britain's ability to feed and protect itself and its supply lines. For five years starting in 1808 Britain maintained a fleet of 17,000 men in the Baltic and sent heavily escorted convoys to protect merchantmen from French privateers and small Danish and Norwegian gunboats: in the summer of 1809 2,210 ships were escorted through the Sound. In 1811 Britain lost three ships of the line, its worst loss during the Napoleonic period, but it won this Baltic battle, maintaining its own naval supplies and depriving its French enemies of theirs (Ryan, 1959).

Food is the ultimately strategic commodity. On the eve of World War I, 58% of the calories consumed by humans in England and Wales were imported (Floud et al., 2012, p. 160): such dependence on imported food was regarded as dangerous by military planners. In 1815 the UK had protected agriculture, partly on security grounds. After Britain's turn to free trade in the 1840s, the strategy adopted was to ensure that the Royal Navy controlled the seas (Offer, 1989, p. 218).

Britain managed to increase domestic food production during World War I, as had been the case during the Napoleonic Wars and would be again during World War II (Olson, 1963). To some extent this happened naturally, as a result of higher domestic prices, but it also reflected active government intervention promoting the production of grain and potatoes at the expense of animal products. There was however an additional complication. The new warfare that evolved rapidly on the western front was based around massive artillery barrages which meant that governments needed to maximize production of artillery shells. At the same time they needed to feed their populations. Both requirements ultimately came down to nitrogen, the main ingredient of high explosives and the most important agricultural fertilizer. Besides nitrogen, other militarily vital chemicals included toluene, acetone, and highly concentrated sulphuric acid. As contemporaries noted, the First World War was a chemists' war.

If the outcome of the war had depended on chemical technology the British would have lost. However, what they lacked in technology they could acquire by trade thanks to their naval dominance. Both Britain and Germany were highly dependent on supplies of Chilean nitrates. Once these were cut off by the Royal Navy, the Germans immediately faced a stark choice between producing munitions and growing food, one that was only partially solved by synthetic nitrogen. The British by contrast had access to nitrogen directly in the form of nitrates, and indirectly, in huge quantities, in the form of North American wheat (Offer, 1989). Besides raw materials, the British were also able to purchase American explosives. The U-boat campaign of 1917 caused a marked fall in nitrate imports but by that stage synthetic nitrogen was able to meet the deficiency (Haber, 1971, p. 204).

In other words, the key British industrial policy was arguably its ability to maintain overseas supply chains in wartime while disrupting, or destroying, those of their opponents. Britain's control of the seas, combined with the food production of her overseas colonies and allies, meant that hunger was not a serious issue during the war (Offer, 1989). In Germany and the rest of Central Europe, facing an Allied naval blockade, it was a different story. Hunger was widespread in Germany, particularly during the winter of 1916-17, and across the continent several hundreds of thousands of people died of starvation. While Offer (1989) denies that the Allied blockade led to Germany starving, he still maintains that ‘Food played a critical role in Germany’s collapse’ (p. 2), being highly damaging to both civilian and army morale. Moreover, the blockade was maintained after the war, until the peace treaties at Versailles had been signed to the satisfaction of the Allies.

Across Central Europe, the lesson was drawn that ‘countries should never again be dependent on foreign imports for food’ (Zahra, 2023, p. xxiii). The policy prescription in most cases was agricultural protection, but elsewhere it was more aggressive. In Japan, naval officers drew the conclusion that ‘nations had to be able to supply themselves during wartime with adequate quantities of raw materials and manufactured goods. Reliance on other countries for the materiel of war was a sure path to defeat . . . The need for security became, slowly, an impulse for empire, and it led directly to the Pacific War’ (Barnhart, 1987, p. 9). Similarly, Tooze (2007) shows how Nazi aggression in the East was partly motivated by a desire to become ‘blockade-proof’: as Hitler told a Swiss diplomat, he needed ‘the Ukraine, so that no one will starve us out as they did in the last war’ (Hildebrand, 1973, p. 88). The aftershocks of this period continued to reverberate into the post-war world, not least in Europe, where food security was a key aim of the Common Agricultural Policy. And energy supplies have been a key driver of Western geopolitical strategy since 1945.

Another way for states to maintain food supplies in the face of wartime scarcities was to promote innovation. Finding substitutes for imported goods in anticipation of, or during, wartime blockades has been an important dimension of “resilience” historically, and has typically involved government intervention. A famous example is the sugar beet industry, effectively established by an 1811 Napoleonic decree. This established sugar beet schools, financed students wishing to study there, decreed that land be set aside for beets and subsidized their cultivation, and ordered that factories be established. Within a year forty French factories were producing 3.3 million pounds of sugar. By the end of the century beet was a more important source of sugar globally than sugar cane (Arrington, 1967, pp. 1-2).

Another example is the development of synthetic fuel and rubber, critical raw materials in an age of motorized warfare and potentially subject to blockade given their geographically concentrated sources of supply. Germany tried to produce synthetic rubber during the First World War but with little success. In 1933, however, I.G. Farben was granted a patent on a superior product, Buna S, and under Hitler's Four Year Plan, designed to promote self-sufficiency, large-scale production commenced in 1937. The Germans also invested heavily in synthetic fuel, which had been developed by Standard Oil due to concerns about American petroleum reserves, and whose technology had been transferred to IG Farben. As part of the same deal Buna technology was transferred to the US. With the outbreak of war, and the seizure by Japan of Southeast Asia's rubber plantations, the US government sponsored research to resolve various practical issues arising when substituting Buna S for natural rubber; the result was explosive growth in synthetic rubber production, which eventually outstripped its natural counterpart in global importance (Morton, 1981; Tooze, 2007).

## 6. War and innovation

### *6.1 Metallurgy and the British industrial revolution*

War has been a frequent-driver of government-led innovation. Consider metallurgy, which along with textiles was one of the key innovating sectors during the first industrial revolution. Driving improvements in the quality of British cast iron was naval demand for cannons, by far the most massive cast iron artefacts of their time. Having a cannon explode on gun decks crowded with men and gunpowder was a catastrophic event, and the Royal Navy, unlike its French counterparts, went to considerable lengths to prevent such failures. Each gun was tested intensively, and the navy maintained intense pressure on suppliers to improve quality.

The traditional source of naval guns was from small producers in the Weald of Kent, but quality was low. From 1764, the navy began to take coke-smelted guns from the Carron ironworks in

Scotland, and then from south Wales and the West Midlands. In 1769, John Smeaton replaced the clumsy bellows in Carron with a water powered blowing engine, and shortly after John Wilkinson devised blowing cylinders powered by steam. These enabled longer blasts at higher temperatures in large furnaces, increasing the quantity and quality of iron: French observers were astonished to see a gun made in a single continuous pour from two furnaces. Instead of making the barrel during casting, in 1774 John Wilkinson patented the use of a solid casting drilled out with a rigid lathe that gave precisely circular bores, improving accuracy and reducing windage, the loss of propellant gases from around the cannonball. This technique he then used to make the cylinder of Watt's engine.[1].

Moving on to the smelting of wrought iron with coal, the most famous figure was the naval agent Henry Cort who devised the process of puddling (stirring molten iron in a furnace to burn off carbon by bringing it in contact with air) and passing it through grooved rollers to remove slag and consolidate its grain. Puddling was already known and the rolling process, which he patented first, was his real contribution. Its stated purpose in the patent was to recycle naval scrap, like anchors and chains, by heating it to a welding temperature and then rolling it into new bars: the possibility of using rollers in smelting iron was only mentioned in passing.

Naval demand was also important in the copper industry. The largest single source of demand for copper in the late 18$^{th}$ century was for sheathing the hulls of ships, with the Royal Navy leading the way. Teredo worms could rapidly eat through ship hulls in tropical waters and had been carried into colder waters. It was discovered that copper sheets would not only protect timber from the boring molluscs, but would also prevent weeds and barnacles from encrusting the hull by poisoning them as it dissolved, reducing time in dry dock and leading to a noticeable rise in sailing speed: the passage time to India, for instance, was said to have fallen by a quarter. When war broke out between England and France in 1778, naval demand for coppered ships soared, and the exportation of copper was prohibited (Harris, 1966).

[1] Predictably, as with most major innovations, his patent was revoked by the government, in this case to permit all its suppliers to use the method.

Unfortunately, galvanic action between the sheets and the iron bolts used secure the frame of ships caused such rapid corrosion that the Navy came close to removing all coppering in the early 1780s. This problem was solved by “two ingenious artists of Birmingham,” Westwood and Collins, who, rapidly imitating Cort’s application to iron, patented a way of cold rolling copper bolts with grooved rollers to make them as hard as iron ones. By 1784 Williams was producing 40,000 bolts a week for the navy. At this time, Matthew Boulton estimated that private shipyards were using around 1,000 tons of copper per year for sheathing, with another 1,500 going to naval yards, which together was around one quarter of British production (Evans and Miskell, 2020, pp.64–65).

### *6.2. War and innovation in France during the first industrial revolution*

Eighteenth century France made extensive and expensive efforts to acquire three strategic British technologies: steelmaking, iron casting, and copper plating. The first two projects were expensive failures while the third succeeded.

The breakthrough technology allowing coal to be used in smelting iron was the reverberatory furnace. Each new material raised fresh challenges in the design of furnaces, grates, flues, refractory bricks, and crucibles to hold the material, which meant that the skills needed to transfer coal technology to new uses often took a long time to acquire (Harris, 1976). The result was that British metallurgy involved a tightly intermeshed web of artisan skills in coke making, furnace design, crucible making, and stoking. As French ironmasters quickly learned, converting an ironworks from charcoal to coal meant that every single part of the plant and production process had to be redesigned. While a spinning machine could be easily understood, successful adoption of coal based metallurgy required an entire team of artisans to be transplanted. In the words of one French visitor to Sheffield “It is the workers who are the true metallurgists.”

Steel was needed to produce files which could shape metal parts so that they fit together properly, notably in gunlocks. Files were, in other words, the machine tools of their time. Serious efforts to imitate British steel began in the 1760s, but output was low and quality unreliable as a consequence of using French iron in a charcoal furnace, and the lack of suitable refractory clay for the cementation chests (Harris, 2017, pp. 208–10). In 1764 the outstanding young metallurgist Gabriel Jars was sent to Britain to observe, and if necessary spy on, all aspects of British coal and metal manufacture. He gave detailed and well informed accounts of both blister and crucible steelmaking as well as file manufacturing, and attempted to manufacture steel on his return, but the experiment again appears to have been an expensive failure (Harris, 2017, pp. 224–37). It was only in the late 1820s that successful crucible steelmaking was transplanted into France (Henderson, 1954, pp. 61–62).

French interest in cast iron stemmed from a desire to improve the low quality of its naval cannon that frequently burst when fired. In 1781 the French decided to establish a coke fired ironworks, and by 1786 had built a huge plant at Le Creusot, with four large furnaces supplied with air by steam blowing engines, large steam powered hammers, and six leagues of iron railway for horse pulled trucks. However, the iron ore was unsuitable and the coke of poor quality so the cast iron produced was unusable Harris (1998, pp. 238–58). Again, it was a large scale transplantation of British skill in the 1820s that turned the Le Creusot works into a highly successful venture (Henderson, 1954, pp. 61–62).

By contrast, the French attempt to copper ships was successful. French adoption was due to an audacious private act of espionage by the industrialist Le Camus de Limare who in 1781, at the height of the Anglo-French War of 1778, slipped into England and managed to persuade a number of workers capable of melting and rolling copper to come to France. He built a rolling mill at Romilly, and after hostilities ended he obtained a proper iron roller for plates in London and the grooved rollers needed for bolts. Throughout Le Camus seems to have had a large British workforce who trained French workers. Although the supply of British copper ended with the renewal of war in 1791, the French navy had been coppered and extra metal would be obtained by melting down church bells Harris (2017, pp. 268–83). It is easy to see how coppering succeed where iron making had failed. Iron needed suitable coal, iron ore, fireclay, and, above all, large teams of workers with different skills. Coppering by contrast required only a simple furnace to reheat copper, and machinery to roll plates and bolts.

Whereas the *Ancien Regime* had mixed fortunes in developing metallurgical industries, after the Revolution France made several important advances, notably in artificial alkalis, gunpowder, leather, and canned food. The difference is that while metals relied on artisan skills that the French lacked, these latter advances rested on France’s unique abundance of skilled chemists, many of world renown. While this skill base was important in promoting innovation on the supply side, on the demand side supply military demand was crucial.

The most important innovation was the Leblanc process of making artificial soda for soap, glassmaking, and scouring textiles. Whereas Britain’s naval supremacy meant that it could rely on supplies of vegetable alkali in the form of Spanish barilla (the ash of a seashore plant), North American potash, and Scottish kelp, France only had access to the first which could easily be disrupted in wartime. In response, the *Académie* offered a large prize for a process to generate an artificial substitute. The solution, derived by Leblanc in 1797, was adopted on a large scale in 1808 when war with Spain ended the supply of barilla. A large alkali industry developed, with output rising from 1000 tons in 1810 to 9000 by 1820, concentrated around the soap producing centre of Marseille. The Leblanc process, which generated chlorine bleach as a by-product, became the basis of British alkali making until the late nineteenth century, long after it had been abandoned elsewhere (Haber, 1958, pp. 5–8).

The main component of gunpowder is saltpeter which provides oxygen to burn the charcoal and sulphur present. Britain could draw on large supplies from India, whereas France had to rely on traditional methods of scraping crystals from cellar walls, or leaving a mix of dung, urine, straw, and woodchips to ferment. Refining the saltpetre was done by boiling the raw material and adding potash, and then collecting the crystals that appeared as the liquor evaporated, an expensive and chemically inefficient process. Lavoisier came up with the idea of running a saturated solution of saltpetre through the raw crystals, a process that was perfected by the leading chemical manufacture Chaptal after Lavoisier's execution. The following 20 years of warfare, learning by doing, and advancing scientific knowledge saw French saltpetre production advance to a fully industrial scale.

While the chemistry of tanning began to be explored from the 1770s onward the real impetus for improvements in the production process came from Revolutionary France's desperate need for military boots. In 1793, Armand Seguin was approached by Berthollet on behalf of the Committee of Public Safety to continue his earlier researches on tannin. Seguin introduced two chemical innovations allowing boot soles to be produced in days rather than years. By 1795, a factory with 400 workers was in full production, with artisans from across France being trained to spread the new methods. Seguin became legendarily rich in the process but the extent to which the technique, which yielded lower quality leather, was used after the wartime emergency is unclear (Gillispie, 2004, pp. 393–95).

A final French advance involved preserving food (Graham, 1981). Heavy losses of troops due to starvation motivated the *Académie* in 1795 to offer a large prize for a technique that would successfully conserve the freshness of food. After 15 years of systematic research a Paris confectioner, Nicolas Appert, came up with a process in which food in glass jars that had been carefully sealed with a cork were placed in a bath of boiling water, which he subsequently replaced with autoclaves for cooking under pressure. Besides meat and vegetables, Appert also succeeded in preserving milk, beer, and wine, anticipating the work of Pasteur.

### *6.3. War and the British chemical industry*

In 1914 the British chemical industry was small and technologically backward relative to Germany. Government thus took a central role in munitions production, building plants that were operated by private firms and running some factories directly. The effort was successful on its own terms: output of TNT tripled during 1916. Whereas in 1916 Britain imported roughly two thirds of its high explosives, by 1918 it was self-sufficient and supplying large amounts to its allies (Van der Kloot, 2014). Dyes were also vital to the war effort. In early 1915 the government funded the establishment of British Dyes Ltd, which in November 1918 was forcibly merged with its main rival into the British Dyestuffs Corporation. The government held 17 per cent of the firm and had special voting powers to veto unreasonable prices, contracts with foreign manufactures, or diversification into other products. British Dyestuffs thus marks a watershed in British industrial policy where, for the first time, government took a direct role in financing and managing a commercial company. Other dyers were eligible for grants and loans to expand plants and develop new dyes, again in return for close government oversight of their operations (Haber, 1971, pp. 234–36). Despite its clumsy implementation, Haber concludes that without government support the British industry would have been wiped out by German competition in the early post-war years.

Britain produced 25 thousand tons of dye in 1929 compared with 4 thousand in 1913, equal to 90 per cent of consumption (Morgan, 1939), so it is possible to conclude that the government policy of fostering a national dye industry succeeded to a considerable degree. On the other hand, despite the fact that the post-war industry benefitted from protection, imports of German dyes (although only a fraction of their pre-war level) in 1930 were over five times what they had been in 1921, indicating the poor performance of British firms in producing specialty dyes (Haber, 1971, p. 244). This reflects the fact that the number of chemists employed by British Dyestuffs fell from 80 in 1920 to 30 in 1925, and subsequently to 15 (Reed, 2017). Ultimately British Dyestuffs was merged with three other firms (including Nobel Industries, formed from the merger of explosive firms in 1918) into Imperial Chemical Industries (ICI).
In contrast to the wide range of highly profitable new products generated by the over 1,000 researchers of the German IG Farben combine, ICI largely functioned by producing a small range of products at prices usually fixed by international agreement, and contributed little to progress in dyestuffs or organic chemicals. When it joined the international dye cartel in 1931 it had a quota of 7% compared with 66% for the Germans (Haber, 1971, pp. 291–303). Ultimately,

hopes that Britain with its limited educational resources could develop a chemical industry in a decade that would match what Germany had evolved over two generations were destined to be frustrated.

## 7. Conclusion

As we have seen, a variety of industrial policies were attempted before and during the first and second industrial revolutions. Some were successful, others less so. We doubt that the past contains any “general lessons from history”, since context matters so much. But there is one theme that runs through the literature that we think is worth highlighting, namely the importance of an appropriate skill base.

That skills were seen as a constraint on industrial growth can be seen by the efforts made by governments, from 14$^{th}$ century England to 19$^{th}$ century Japan, to attract skilled workers, or to prevent them from emigrating to rival countries. And we have also seen cases when industrial policy either failed completely, or did not lead to the establishment of internationally competitive industries, due to the lack of skilled workers domestically: this was true of the English Cockayne scheme, which ran into a shortage of workers skilled in the finishing of cloth; of French attempts during the first industrial revolution to import British metallurgical techniques; and of the British chemical industry established during World War I, which played a notable role in the war effort but remained internationally uncompetitive thereafter. In contrast, solid skill bases meant that military demand helped to transform the British metallurgical industry, and the French chemical industry, at the turn of the 19$^{th}$ century. Similarly, the United States’ Office of Scientific Research and Development (OSRD), established during World War II, offers a striking example of successful industrial policy that had a long run impact on the geographical location and direction of US innovation (Gross and Sampat, forthcoming). Again, this success did not arise in a vacuum, but depended on previous investments in education, scientific research, technical societies, and mass production

(Kettering, 1946). As the German example shows, investing in such capabilities can pay handsome dividends.

Another theme running through this paper is the link between war and industrial policy, with first industrial revolution occurring during the “second hundred years war”. Indeed, the successful industrial policies associated with the Covid vaccine had a lot to do with the war-like nature of that crisis. Perhaps the relative absence of industrial policy in the 1990s and 2000s is related to the fact that this was a brief interlude between two cold wars, and perhaps we should not be surprised by its resurgence today?

**References**

Abramovitz, M. 'Catching up, forging ahead, and falling behind', *Journal of Economic History* 46 (1986), pp. 385-406.

Allen, R. C., *The British industrial revolution in global perspective* (Cambridge, 2009).

Allen, R. C., *Global economic history: A very short introduction* (Oxford, 2011).

Amsden, A. H., *Asia's next giant: South Korea and late industrialization* (Oxford, 1989).

Arrington, L. J. 'Science, government, and enterprise in economic development: The western beet sugar industry', *Agricultural History* 41 (1967), pp. 1-18.

Bairoch, P. 'European trade policy, 1815–1914', in P. Mathias and S. Pollard eds., *The Cambridge economic history of Europe from the decline of the Roman empire*, (Cambridge, 1989), pp. 1-160.

Barnhart, M. A., *Japan prepares for total war: The search for economic security, 1919-1941* (Ithaca, 1987).

Barth, J. 'Reconstructing mercantilism: Consensus and conflict in British imperial economy in the seventeenth and eighteenth centuries', *William and Mary Quarterly* 73 (2016), pp. 257-290.

Boulton, J. 'London 1540–1700', in P. Clark ed., *The Cambridge urban history of Britain: Volume 2: 1540–1840*, (Cambridge, 2000), pp. 315-346.

Bowden, P. J., *The wool trade in Tudor & Stuart England* (London, 1962).

Carus-Wilson, E. M. 'Trends in the export of English woollens in the fourteenth century', *The Economic History Review* 3 (1950), pp. 162-179.

Coleman, D. C. 'Economic problems and policies', in F. L. Carsten ed., *The new Cambridge modern history: Volume 5: The ascendancy of France, 1648–88*, (Cambridge, 1961), pp. 19-46.

Comino, S., Galasso, A. and Graziano, C. 'Market power and patent strategies: Evidence from Renaissance Venice', *Journal of Industrial Economics* 68 (2020), pp. 226-269.

Davis, R. 'English foreign trade, 1700–1774', *Economic History Review* 15 (1962), pp. 285-303.

Davis, R., *The rise of the English shipping industry in the seventeenth and eighteenth centuries* (Liverpool, 2012; 1st edition 1962).

Eichengreen, B. J., *The European economy since 1945: Coordinated capitalism and beyond* (Princeton, N.J., 2007).

Evans, C. and Miskell, L., *Swansea copper: A global history* (Baltimore, 2020).

Findlay, R. and O'Rourke, K. H., *Power and plenty: Trade, war, and the world economy in the second millennium* (Princeton, N.J., 2007).

Floud, R., Fogel, R. W., Harris, B. and Hong, S. C., *The changing body: Health, nutrition, and human development in the western world since 1700* (Cambridge, 2011).

Foreman-Peck, J. 'The balance of technological transfers 1870–1914', in J.-P. Dormois and M. Dintenfass eds., *The British industrial decline*, (London, 1999), pp. 114-138.

Frumkin, M. 'The origin of patents', *Journal of the Patent Office Society* 27 (1945), pp. 143-149.

Gillispie, C. C., *Science and polity in France: The end of the old regime* (Princeton, NJ, 2004).

Graham, J. C. 'The French connection in the early history of canning', *Journal of the Royal Society of Medicine* 74 (1981), pp. 374-381.

Gross, D. P. and Sampat, B. N. 'America, jump-started: World War II R&D and the takeoff of the U.S. innovation system', *American Economic Review* (forthcoming).

Haber, L. F., *The chemical industry during the nineteenth century: a study of the economic aspect of applied chemistry in Europe and North America* (Oxford, 1958).

Haber, L. F., *The chemical industry, 1900-1930: International growth and technological change* (Oxford, 1971).

Harris, J. R. 'Copper and shipping in the eighteenth century', *Economic History Review* 19 (1966), pp. 550-568.

Harris, J. R. 'Skills, coal and British industry in the eighteenth century', *History* 61 (1976), pp. 167-182.

Harris, J. R., *Industrial espionage and technology transfer: Britain and France in the eighteenth century* (London, 2017).

Hecht, G., The radiance of France: nuclear power and national identity after World War II (Cambridge, MA, 2009).

Henderson, W. O., *Britain and industrial Europe, 1750-1870: studies in British influence on the industrial revolution in western Europe* (Liverpool, 1954).

Hildebrand, K., *The foreign policy of the Third Reich* (London, 1973).

Juhász, R., Lane, N. and Rodrik, D. 'The new economics of industrial policy', Mimeo. (2023).

Juhász, R. and Steinwender, C. 'Industrial policy and the great divergence', *Annual Review of Economics* 16 (2024, forthcoming).

Kahan, A. 'Capital formation during the period of early industrialization in Russia, 1890–1913', in M. M. Postan and P. Mathias eds., The Cambridge economic history of Europe: Volume 7: The industrial economies: Capital, labour and enterprise, (Cambridge, 1978), pp. 265-307.

Kearney, H. F. 'The political background to English mercantilism, 1695-1700', *Economic History Review* 11 (1959), pp. 484-496.

Kelly, M. and Ó Gráda, C. 'Connecting the scientific and industrial revolutions: The role of practical mathematics', *Journal of Economic History* 82 (2022), pp. 841-873.

van der Kloot, W. 'Lord Justice of Appeal John Fletcher Moulton and explosives production in World War I: ‘The mathematical mind triumphant’', *Notes and Records: The Royal Society Journal of the History of Science* 68 (2013), pp. 171-186.

Lambert, B. and Pajic, M. 'Immigration and the common profit: Native cloth workers, Flemish exiles, and royal policy in fourteenth-century London', *Journal of British Studies* 55 (2016), pp. 633-657.

Landes, D. S., *The unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present* (Cambridge, 2nd edn, 2003).

Lane, N. 'The new empirics of industrial policy', Journal of Industry, *Competition and Trade* 20 (2020), pp. 209-234.

Lane, N. 'Manufacturing revolutions: Industrial policy and industrialization in South Korea', Mimeo (2022).

Lehrer, M., Nell, P. and Gärber, L. 'A national systems view of university entrepreneurialism: Inferences from comparison of the German and US experience', *Research Policy* 38 (2009), pp. 268-280.

Lewis, P. 'William Lee's stocking frame: Technical evolution and economic viability 1589–1750', *Textile History* 17 (1986), pp. 129-147

MacLeod, C., *Inventing the industrial revolution: The English patent system, 1660–1800* (Cambridge, 1988).

MacLeod, C. 'Patents for invention: Setting the stage for the British industrial revolution?', *Empiria* (2009), pp. 37-58.

Malanima, P. 'Urbanization', in K. H. O'Rourke and S. Broadberry eds., *The Cambridge economic history of modern Europe: Volume 1: 1700–1870*, (Cambridge, 2010), pp. 235-263.

Mazzoleni, R. and Nelson, R. R. 'Public research institutions and economic catch-up', *Research Policy* 36 (2007), pp. 1512-1528.

Meyer-Thurow, G. 'The industrialization of invention: A case study from the German chemical industry', *Isis* 73 (1982), pp. 363-381.

Morgan, G. T. 'Achievements of British chemical industry in the last twenty-five years: Lecture II', *Journal of the Royal Society of Arts* 87 (1939), pp. 1011-1029.

Morton, M. 'History of synthetic rubber', *Journal of Macromolecular Science: Part A - Chemistry* 15 (1981), pp. 1289-1302.

Moser, P. 'Patents and innovation: Evidence from economic history', *Journal of Economic Perspectives* 27 (2013), pp. 23-44.

Murmann, J. P., *Knowledge and competitive advantage: The coevolution of firms, technology, and national institutions* (Cambridge, 2003).

North, D. C. and Thomas, R. P., *The rise of the western world; a new economic history* (Cambridge, 1973).

Obstfeld, M. and Taylor, A. M., *Global capital markets: Integration, crisis, and growth* (Cambridge, 2004).

O'Brien, P., Griffiths, T. and Hunt, P. 'Political components of the industrial revolution: Parliament and the English cotton textile industry, 1660-1774', *The Economic History Review* 44 (1991), pp. 395-423.

Offer, A., *The first world war: An agrarian interpretation* (Oxford, 1989).

Olmstead, A. L. and Rhode, P. W. 'Biological globalization: The other grain invasion', in T. J. Hatton, K. H. O'Rourke and A. M. Taylor eds., *The new comparative economic history: Essays in honor of Jeffrey G. Williamson*, (Cambridge, MA., 2007), pp. 115-140.

Olson, M., The economics of the wartime shortage, a history of British food supplies in the Napoleonic war and in world wars I and II (Durham, N.C., 1963).

Ormrod, D., *The rise of commercial empires: England and the Netherlands in the age of mercantilism, 1650-1770* (Cambridge, 2003).

Özveren, Y. E. 'Shipbuilding, 1590-1790', *Review (Fernand Braudel Center)* 23 (2000), pp. 15-86.

Power, E., *The wool trade in English medieval history* (London, 1941).

Reed, P. 'John Fletcher Moulton and the transforming aftermath of the chemists' war', *The International Journal for the History of Engineering & Technology* 87 (2017), pp. 1-19.

Rodrik, D. 'Getting interventions right: How South Korea and Taiwan grew rich', *Economic Policy* 10 (1995), pp. 53-107.

Ryan, A. N. 'The defence of British trade with the Baltic, 1808-1813', *English Historical Review* 74 (1959), pp. 443-466.

Sukehiro, H. and Wakabayashi, B. T. 'Japan's turn to the west', in M. B. Jansen ed., *The Cambridge history of japan: Volume 5: The nineteenth century*, (Cambridge, 1989), pp. 432-498.

Tooze, J. A., *The wages of destruction: The making and breaking of the Nazi economy* (London, 2007).

Viner, J. 'Power versus plenty as objectives of foreign policy in the seventeenth and eighteenth centuries', *World Politics* 1 (1948), pp. 1-29.

Wilson, C., *Profit and power: A study of England and the Dutch wars* (The Hague, 1978; 1st edition 1957).

Wright, G. 'Slavery and Anglo-American capitalism revisited ', *Economic History Review* 73 (2020), pp. 353-383.

Wrigley, E. A., *People, cities and wealth: The transformation of traditional society* (Oxford, 1987).

Yonekura, S., *The Japanese iron and steel industry, 1850-1990: Continuity and discontinuity* (Basingstoke, 1994).

Zahedieh, N. 'Colonies, copper, and the market for inventive activity in England and Wales, 1680–1730', *Economic History Review* 66 (2013), pp. 805-825.

Zahra, T., *Against the world: Anti-globalism and mass politics between the world wars* (New York, 2023).

van Zanden, J. L. 'Early modern economic growth; a survey of the European economy, 1500–1800', in M. Prak ed., *Early modern capitalism: Economic and social change in Europe 1400-1800*, (London, 2001), pp. 67-84.

UCD CENTRE FOR ECONOMIC RESEARCH – RECENT WORKING PAPERS

WP22/28 Ronald B. Davies, Zuzanna Studnicka: 'Tariff Evasion, the Trade Gap, and Structural Trade' December 2022
WP23/01 Xidong Guo: 'An Analysis of a Rural Hospital’s Investment Decision under Different Payment Systems' January 2023
WP23/02 Emanuele Albarosa, Benjamin Elsner: 'Forced Migration and Social Cohesion: Evidence from the 2015/16 Mass Inflow in Germany' January 2023
WP23/03 Xidong Guo: 'Hospital Efficiency and Consultants’ Private Practices: Analysing the Impact of a Voluntary Reform' February 2023
WP23/04 Tadgh Hegarty, Karl Whelan: 'Calculating The Bookmaker’s Margin: Why Bets Lose More On Average Than You Are Warned' February 2023
WP23/05 Tadgh Hegarty, Karl Whelan: 'Forecasting Soccer MatchesWith Betting Odds: A Tale of Two Markets' February 2023
WP23/06 Karl Whelan: 'How Do Prediction Market Fees Affect Prices and Participants?' March 2023
WP23/07 Kevin Devereux, Zuzanna Studnicka: 'Local Labour Market Concentration and Wages in Ireland' March 2023
WP23/08 Kevin Devereux, Zuzanna Studnicka: 'When and Where do Minimum Wage Hikes Increase Hours? Evidence from Ireland' April 2023
WP23/09 Karl Whelan 'Fortune’s Formula or the Road to Ruin?The Generalized Kelly CriterionWith Multiple Outcomes' April 2023
WP23/10 Manuel E. Lago: '#MeToo...or not? Do salient shocks affect gender social norms?' April 2023
WP23/11 Cormac Ó Gráda, Tyler Anbinder, Simone A. Wegge: 'Gaming theSystem: The Not-So-Poor and Savings Banks in Antebellum New York' April 2023
WP23/12 Tadgh Hegarty, Karl Whelan: 'Disagreement and Market Structure in Betting Markets: Theory and Evidence from European Soccer' May 2023
WP23/13 Tadgh Hegarty, Karl Whelan: 'Do Gamblers Understand Complex Bets? Evidence From Asian Handicap Betting on Soccer' May 2023
WP23/14 Matthew Amalitinga Abagna: ‘Special Economic Zones and Local Economic Activities in Ethiopia.’ May 2023
WP23/15 Gregory Corcos, Stefanie Haller: 'Importer Dynamics: Do Peers Matter?' July 2023
WP23/16 Karl Whelan: 'How Does Inside Information Affect Sports Betting Odds?' July 2023
WP23/17 Michele Gubello: 'Social Trust and the Support for Universal Basic Income' July 2023
WP23/18 Constantin Bürgi, Zuzanna Studnicka: ‘Online Interactions, Trade And The Gravity Model’ August 2023
WP23/19 Juan S. Morales, Margaret Samahita: 'Can Social Pressure Stifle Free Speech?' August 2023
WP23/20 Fabrice Kämpfen, Xavier Gómez-Olivé, Owen O’Donnell, Carlos Riumallo Herl: 'Effectiveness of Population-Based Hypertension Screening: A Multidimensional Regression Discontinuity Design' August 2023
WP23/21 Annette Alstadsæter, Ronald Davies, Mathieu Parenti, Farid Toubal: 'The Real Effects of Tax Havens' October 2023
WP23/22 Ronald B. Davies, Dieter F. Kogler, Guohao Yang: 'Construction of a Global Knowledge Input-Output Table' October 2023
WP23/23 Taipeng Li, Lorenzo Trimachi, Rui Xie, Guohao Yang: 'The Unintended Consequences of Trade Protection on the Environment' October 2023
WP23/24 Constantin Bürgi, Mengdi Song: 'Do Professional Forecasters Believe in Uncovered Interest Rate Parity?' November 2023

UCD Centre for Economic Research
Email economics@ucd.ie