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Innovation Policy and Chronic Emergencies

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ABSTRACT

The COVID-19 pandemic has thrust the potential role of the state as a driver of scientific innovation onto center stage. Vaccines have been developed and brought to market in a timescale that seemed almost impossible when the crisis first struck. The pivotal nature of government intervention in this crisis has added to calls from academics and policy makers to adopt a more proactive, mission-oriented approach to innovation policy to tackle other key global challenges.

This Article considers the merits of these calls and argues that an important distinction must be drawn between what this Article terms acute and chronic emergencies. COVID-19 is a paradigmatic example of an acute emergency: its onset was rapid, its impact was dramatic, and it is a problem that demands resolution for life to proceed "as normal." Chronic emergencies, such as the problem of Anti-Microbial Resistance, can be just as, or more deadly than, acute emergencies but have a "frog in the pot" quality. They emerge over time, and, although they can have profound social and economic effects, they do so in ways that are less immediate and hence less demanding of government attention. Without the urgency, sense of purpose, and spirit of cooperation that accompany acute emergencies, there is a risk that mission-oriented approaches may fail to deliver new technologies the world urgently needs. This Article considers the problem of applying mission-oriented approaches to chronic emergencies. The analysis is grounded in an examination of Britain's system of innovation rewards in the eighteenth and nineteenth centuries, drawing on an extensive

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historical data set that the authors are continuing to develop. The central argument put forward in this Article is that Britain's historical system offers lessons for crafting state intervention to spur innovation aimed at chronic emergencies today. Britain's historical system was effective because rewards were largely bestowed post hoc with relatively little prescription as to the problems at which innovators should direct their efforts, and still less as to the methods and means that should be used to tackle them. Perhaps most importantly, these rewards fed into and helped create a culture of innovation.

The Article concludes with a proposal for change—namely, that the way innovation prizes are designed should be reconsidered. Prizes must preserve space for scientific and technical freedom and ought not to be built around the sort of rigidly defined criteria that proponents of mission-oriented innovation policies often advocate.

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I. INTRODUCTION

By September 2021, the COVID-19 pandemic was estimated to have killed roughly 4.6 million people.[1] Over the pandemic's duration, global deaths from Anti-Microbial Resistance (AMR) have totaled approximately 1.16 million,[2] and ambient air pollution has killed around 6.3 million people.[3] The latter killers have been a problem

1. *Cumulative Confirmed COVID-19 Cases and Deaths, World*, OUR WORLD IN DATA, https://ourworldindata.org/grapher/cumulative-deaths-and-cases-covid-19?time=2020-01-22..2021-09-30 [https://perma.cc/7EZA-8AHH] (last visited Sept. 15, 2021).

2. *See New Report Calls for Urgent Action to Avert Antimicrobial Resistance Crisis*, WORLD HEALTH ORG. (Apr. 29, 2019), https://www.who.int/news/item/29-04-2019-new-report-calls-for-urgent-action-to-avert-antimicrobial-resistance-crisis [https://perma.cc/SR2E-XTG8].

3. The WHO reports that ambient air pollution kills 4.2 million people annually. *Air Pollution*, WORLD HEALTH ORG., https://www.who.int/health-topics/air-pollution#tab=tab_1 [https://perma.cc/U8P3-AAX2] (last visited Sept. 15, 2021). The WHO declared the COVID-19 outbreak a global pandemic on 11 March 2020. Domenico Cucinotta & Maurizio Vanelli, *WHO Declares COVID-19 a Pandemic*, 91 ACTA BIOMEDICA 157 (2020). At the time of writing (July 2021), this suggests that ambient air

for many years,[4] and the death toll from these causes of mortality looks set to increase significantly.[5] There are, for example, estimates that AMR will cause 10 million deaths per year by 2050.[6] These grim estimates highlight some of the serious challenges facing humanity, but they also illustrate a marked variance in attitude and approach between acute emergencies and chronic emergencies. COVID-19 is a paradigmatic example of an acute emergency—its onset was rapid, its impact dramatic, and it is a problem that demands resolution so life can return to "normal." Faced with this emergency, governments around the world swung into action and played a critical part in the progress made in turning the tide of the pandemic.[7] As economist Joseph Stiglitz observed, "[The] government had a central role in the victory—from investments in basic science that enabled the rapid genomic characterization of SARS-CoV-2 and the development of COVID-19 vaccines, to contributing to the financing of the mass production and deployment of the vaccines."[8] The recent pandemic thus illustrates the potential for the state to drive science and innovation. The pivotal nature of government intervention in this crisis has added further impetus to calls for adoption of a more proactive, mission-oriented approach to "innovation policy" (used here in the broad sense of the full set of policy instruments used to support the creation and diffusion of novel products, processes, and services).[9] Calls for a shift towards a

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pollution will have killed approximately the number quoted, although we acknowledge that the disruption to travel and other polluting economic activity caused by the pandemic makes it harder to calculate a reliable figure for the period.

4. Awareness of the problem of air pollution increased across the 1960s and '70s leading to the adoption of the Convention on Long-Range Transboundary Air Pollution. Convention on Long-Range Transboundary Air Pollution, *opened for signature* Nov. 13 1979, 34 U.S.T. 3043, 1302 U.N.T.S. 217 (entered into force Mar. 16, 1983). The initial driver for this Convention was concern over the environmental impact of 'acid rain' but increasing scientific understanding of the importance of urban air pollution for human health meant that this issue soon came to the forefront in international discussions. *See* Jørgen Wettestad, *Designing Effective Environmental Regimes: The Case of the Convention on Long-Range Transboundary Air Pollution (CLRTAP)*, 10 ENERGY & ENV'T 671, 678 (1999). For a brief history of AMR, see Scott H. Podolsky, *The Evolving Response to Antibiotic Resistance (1945–2018)*, 4 PALGRAVE COMMC'NS 124 (2018) (noting that by the 1950s antibiotic resistant strains of *Staphylococcus aureus* were causing deaths worldwide).

5. REV. ON ANTIMICROBIAL RESISTANCE, ANTIMICROBIAL RESISTANCE: TACKLING A CRISIS FOR THE HEALTH AND WEALTH OF NATIONS 6 (2014), https://amr-review.org/sites/default/files/AMR%20Review%20Paper%20%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf [https://perma.cc/TD54-YFP8].

6. *Id.*

7. Joseph Stiglitz, *A Call to Arms to Change Capitalism*, 397 THE LANCET 1797, 1797 (2021).

8. *Id.*

9. *Cf.* Jakob Edler, Paul Cunningham, Abdullah Gök & Philip Shapira, *Impacts of Innovation Policy: Synthesis and Conclusion* 1 (Nesta Working Paper No. 13/21, 2013),

more mission-oriented approach to innovation policy predate the current crisis, however, and form part of a general intellectual backlash against the neoliberal trope that government intervention in the economy almost always does more harm than good.[10]

This Article is not premised on ideological opposition to the state playing a greater role in innovation policy nor, indeed, in the economy more broadly. But this does not mean that the response to COVID-19 or any other acute emergency constitutes the best way to structure innovation policy generally. Approaches that may work for dealing with acute emergencies do not necessarily translate to tackling chronic emergencies like AMR or ambient air pollution. Chronic emergencies have a "frog in the pot" quality. They emerge over time, and although they can have profound social and economic effects, they do so in ways that are less immediate and hence less demanding of government attention. Moreover, chronic emergencies are often felt most acutely in poorer parts of the globe.[11] Without the urgency, sense of purpose, and spirit of cooperation that accompany acute emergencies, there is a real risk that mission-oriented approaches may fail to deliver in other situations. The suggestion that a mission-oriented approach is the best way to produce the innovations necessary to confront the existential threat posed by climate change is, therefore, one that needs to be handled with care. There is, however, at least one historical precedent for the state playing an active role in helping to solve chronic

https://media.nesta.org.uk/documents/impacts_of_innovation_policy_synthesis_and_conclusion_final.pdf [https://perma.cc/XS5Y-QECM] (defining innovation policy as "public intervention to support the generation and diffusion of new products, processes or services"). For further discussion of the definition of "innovation policy" see, for example, Jan Fagerberg, *Innovation Policy: Rationales, Lessons and Challenges* 31 J. ECON. SURVS. 497 (2017).

10. *See, e.g.*, MARIANA MAZZUCATO, THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE MYTHS IN INNOVATION (2015) [hereinafter THE ENTREPRENEURIAL STATE].

11. This is true for both the current pandemic and climate change. *See* Meeting Coverage, General Assembly, Countries in Special Situations Hardest Hit by Climate Crisis, Pandemic, Delegates Say, as Second Committee Continues Session, U.N. Meetings Coverage and Press Releases, GA/EF/3551, (Oct. 7, 2021), https://www.un.org/press/en/2021/gaef3551.doc.htm [https://perma.cc/2Y52-PTP4]. It is also true for AMR. Sunil Pokharel, Shristi Raut & Bipin Adhikari, *Tackling Antimicrobial Resistance in Low-Income and Middle-Income Countries*, BMJ GLOB. HEALTH, Nov. 2019, at 1, 1 (noting that "AMR affects all countries, but the burden is disproportionately higher in low-income and middle-income countries"). The particular vulnerability of developing countries to adverse events is often said to flow from the more limited "adaptive capacity" of such countries. *See, e.g.*, LINDSEY JONES, EVA LUDI & SIMON LEVINE, TOWARDS A CHARACTERISATION OF ADAPTIVE CAPACITY: A FRAMEWORK FOR ANALYSING ADAPTIVE CAPACITY AT THE LOCAL LEVEL (2010), https://cdn.odi.org/media/documents/6353.pdf [https://perma.cc/C8PW-QNMP].

emergencies:[12] this is the system of rewards employed by the British State in the eighteenth and nineteenth centuries.[13]

This Article proceeds as follows. In Part II, the authors develop their analysis of the differences between acute and chronic emergencies and how these differences connect to recent calls for a greater use of mission-oriented interventions to spur innovation. In Part III, the Article explores the lessons that can be drawn from Britain's historical experience of using cash payments and other emoluments alongside the patent system to reward inventors. The authors demonstrate that Britain's system of rewards was effective because those rewards were typically granted post hoc with relatively little prescription as to the problems toward which innovators should direct their efforts, and still less as to the methods and means that should be used to tackle them—perhaps most importantly, they fed into and helped create a culture of innovation. In the final Part, the authors draw on these observations to make a proposal for change, namely, that governments and other bodies should reconsider the way in which they design innovation prizes. Prizes must preserve space for scientific and technical freedom and ought not to be built around the sort of rigidly defined criteria for which proponents of mission-oriented innovation policies often advocate are often advocated by proponents of mission-oriented innovation policies.

II. EMERGENCIES AND MISSION-ORIENTED INNOVATION POLICY

Innovation policy changes in the face of emergency. Patent rights are weakened,[14] procurement rules are quietly rewritten,[15] and public agencies and philanthropic bodies that fund research shift their attention to projects that will help solve the crisis at hand.[16] These shifts in innovation policy have all formed part of the global response to the COVID-19 crisis.[17] Countries indicated a willingness to use compulsory licenses to lower the costs of patented COVID-19 vaccines at the very start of the pandemic.[18] More recently, a group of countries,

12. *See infra* Part III.

13. *See infra* Part III.

14. *See infra* notes 18–19 and accompanying text.

15. *See infra* note 21 and accompanying text.

16. *See infra* notes 22–23 and accompanying text.

17. *See infra* notes 18–23 and accompanying text.

18. *See, e.g.*, Proyecto de Resolucion para el Otorgamiento de Licencias No Voluntarias Contempladas en el Articulo 51 No. 2 de la Ley No. 19.030 de Propiedad Industrial para Facilitar el Acceso y Disponibilidad a los Medicamentos y Tecnologias para la Prevencion, Tratamiento y Cura del Coronavirus Covid-19, Camara de Diputadas y Diputados de Chile, *translated in English "Resolution for the Granting of Non-Voluntary Licenses Referred to in Article 51º Nº 2 of*

led by India and South Africa,[19] have proposed an intellectual property waiver over all products relevant to the prevention, containment, or treatment of COVID-19 under the TRIPS Agreement.[20] Sizeable advanced market commitments have been offered to companies developing vaccines.[21] Research-funding councils in the United Kingdom, Republic of Ireland, and elsewhere set up fast-track approval processes for projects addressing the pandemic.[22] Charitable bodies, such as Wellcome, have similarly directed significant funding towards the same ends.[23]

The proactive, mission-oriented approach to innovation policy that has developed in response to acute emergencies can unquestionably produce results.[24] Perhaps the most famous examples of these types of successful mission-oriented policies come from the

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Industrial Property Law N° 19.030 to Facilitate Access and Availability of Medicines and Technologies for the Prevention, Treatment and Cure of Coronavirus COVID-19", KNOWLEDGE ECON. INT'L, https://www.keionline.org/chilean-covid-resolution [https://perma.cc/K6SK-65NJ] (last visited Jan. 23, 2022).

19. Council for Trade-Related Aspects of Intell. Prop. Rts., *Waiver from Certain Provisions of the TRIPS Agreement for the Prevention, Containment and Treatment of COVID-19*, WTO Doc. IP/C/W/669 (Oct. 2, 2020); Council for Trade-Related Aspects of Intell. Prop. Rts., *Waiver from Certain Provisions of the TRIPS Agreement for the Prevention, Containment and Treatment of COVID-19: Revised Decision Text*, WTO Doc. IP/C/W/669/Rev.1 (May 25, 2021).

20. *See generally* Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299 (setting up a framework to harmonize intellectual property rights at a high level).

21. *See EU Strategy for COVID-19 Vaccines*, at 3–4, COM (2020) 245 final (June 17, 2020) [hereinafter *EU Strategy*]. Advanced market commitments were historically understood as a way of financing the development of novel therapeutics for the treatment of diseases prevalent in the global south. *See* Brook K. Baker, *Patents, Pricing, and Access to Essential Medicines in Developing Countries*, 11 VIRTUAL MENTOR 527, 529 (2009). However, in the conditions of the pandemic, many Western governments have entered into such arrangements with potential suppliers of vaccines. *See, e.g.*, *EU Strategy*, *supra*, at 3–4, 8–9. For example, the European Commission concluded eight advanced purchase agreements with pharmaceutical companies as part of the EU's strategy to tackle COVID. European Parliament Press Release, COVID-19: Updates on Advance Purchases of Vaccines (Mar. 22, 2021); *see also EU Strategy*, *supra*, at 3 (noting that such agreements "de-risk the necessary investments related to both vaccine development and clinical trials, and the preparation of the at-scale production capacity along the entire vaccine production chain").

22. *See, e.g.*, *Tackling the Impact of COVID-19*, U.K. RSCH. & INNOVATION, https://www.ukri.org/our-work/tackling-the-impact-of-covid-19 [https://perma.cc/8L7M-4G89] (last visited Dec. 16, 2021); *COVID-19 Rapid Response Funding Call (Phase 2)*, SCI. FOUND. IR., https://www.sfi.ie/funding/funding-calls/covid19-rapid-response [https://perma.cc/852V-X73V] (last visited Dec. 17, 2021).

23. *See Who We Are*, WELLCOME, https://wellcome.org/who-we-are [https://perma.cc/T2WD-6VCL] (last visited Dec. 17, 2021). Wellcome describes itself as "a politically and financially independent global charitable foundation, funded by a £29.1 billion investment portfolio." *Id.* For details of Wellcome's Covid programmes, see *COVID-19: Supporting Global Research and Development*, WELLCOME, https://wellcome.org/what-we-do/our-work/coronavirus-covid-19 [https://perma.cc/FW52-MY38] (last visited Dec. 17, 2021).

24. *See infra* notes 25–27 and accompanying text.

Second World War, including the mass production of penicillin and the development of novel vaccines, as well as technologies more directly related to success on the battlefield.[25] The critical role that the government played in bringing COVID-19 vaccines to market provides further illustration of the potential of well-directed, mission-oriented policies.[26] The consequent delivery of COVID-19 vaccines in an extraordinarily short period of time has created further impetus around calls for the state to play an active and interventionist role in the science and technology sphere.[27] But in many Western countries, such calls predate the current crisis.[28] For example, in early February 2020, Dominic Cummings—at the time, Chief Adviser to Boris Johnson and a key figure in his administration—was reported to have identified the creation of a UK equivalent to the US Defense Advanced Research Projects Agency (DARPA) as the second most important priority on the UK Government's agenda, behind only the completion of Brexit.[29] In a similar vein, the comprehensive strategic plan for Australian innovation published in 2017 placed renewed emphasis on the role of the public sector in driving and supporting innovation, including through more aggressive use of public procurement to support high-tech start-ups and other innovative businesses.[30] There have been similar moves in this direction in the European Union, where the European Commission has also been pushing to mobilize procurement expenditure as a driver of innovation.[31]

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25. *See* Daniel P. Gross & Bhaven N. Sampat, *Organizing Crisis Innovation: Lessons from World War II* 17–29 (Nat'l Bureau of Econ. Rsch., Working Paper No. 27909, 2021), https://www.nber.org/system/files/working_papers/w27909/w27909.pdf [https://perma.cc/G5UL-JACT]. For discussion of the development of vaccines during the Second World War, see KENDALL HOYT, LONG SHOT: VACCINES FOR NATIONAL DEFENSE 49–80 (2012).

26. *See, e.g.*, Filippo Reale, *Mission-Oriented Innovation Policy and the Challenge of Urgency: Lessons from Covid-19 and Beyond*, TECHNOVATION, Sept. 2021, at 1, 1 ("[F]inding a vaccine against SARS-CoV-2 (and all its strands) is more than just colloquially a "mission," it is in fact conceptually a prime example of 'mission-oriented innovation policy.").

27. *See, e.g.*, MARIANA MAZZUCATO, MISSION ECONOMY: A MOONSHOT GUIDE TO CHANGING CAPITALISM 123–24 (2021) [hereinafter MISSION ECONOMY].

28. *See infra* notes 29–31 and accompanying text.

29. Madeleine Gabriel, *ARPA: What Is It and Why Does Dominic Cummings Want One in the UK?*, CONVERSATION (Feb. 3, 2020, 4:10 PM), https://theconversation.com/amp/arpa-what-is-it-and-why-does-dominic-cummings-want-one-in-the-uk-130975 [https://perma.cc/SFK8-3EQR].

30. *See* INNOVATION & SCI. AUSTL., AUSTRALIA 2030: PROSPERITY THROUGH INNOVATION 57–73(2017), https://www.industry.gov.au/sites/default/files/May%202018/document/pdf/australia-2030- prosperity-through-innovation-full-report.pdf?acsf_files_redirect [https://perma.cc/TCS3-W7LR].

31. *See* Commission Notice, Guidance on Innovation Procurement, 2021 O.J. (C 267) 1, 11–27 [hereinafter Guidance II]. In 2014 the European Union introduced 'innovation partnerships', the main feature of which is that innovation occurs during the performance of the contract. Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014

The resurgence of interest in the state's role in fostering innovation has a number of interrelated causes.[32] Strategic competition with China has created a new urgency around the importance of not falling behind in the "global innovation race,"[33] language that has an echo of the Cold War rivalry of the mid-twentieth-century "Space Race."[34] China's rapid technological progress has been underpinned by an activist state, controlled by a communist party that legitimatizes itself as having rescued China from the "century of humiliation" caused by the country having fallen behind the West in science and technology.[35]

China's increasing technological prowess has coincided with a broader resurgence of academic interest in the role of the public sector in supporting innovation.[36] Mariana Mazzucato's enormously influential work on the "entrepreneurial state" puts the US government at the heart of America's technological pre-eminence and economic success.[37] She argues that the seemingly poor performance of the public sector in picking winners is often explained by the fact that the state is

on Public Procurement and Repealing Directive 2004/18/EC, art. 31, 2014 O.J. (L 94) 65, 112–13. Over more recent years the European Commission has been pushing for the use of these partnerships to mobilize procurement expenditure as a driver of innovation. *See* Guidance II, *supra*. These efforts can be traced back to the 2017 *Making Public Procurement Work in and for Europe*, COM 572 final (Oct. 3, 2017). This led to the publication in 2018 of the *Guidance on Innovation Procurement*, COM 3051 final (May 15, 2018), and its revision in 2021. *See* Guidance II, *supra*, at 5.

32. *See infra* notes 33–35, 37–48 and accompanying text.

33. This language has been used by both the Australian and UK governments. *See* Bill Ferris, *Foreword* to INNOVATION & SCI. AUSTL., *supra* note 30, at iii; DEP'T FOR BUS., ENERGY & INDUS. STRATEGY, UK INNOVATION STRATEGY: LEADING THE FUTURE BY CREATING IT 8 (2021), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf [https://perma.cc/TG5X-M3R2].

34. *See* Karsten Werth, *A Surrogate for War—The U.S. Space Program in the 1960s*, 49 AM. STUD. 563, 568–69 (2004). As to the importance of the rise of China to the shift in Western thinking, see, for example, Eric Schmidt, *I Used to Run Google. Silicon Valley Could Lose to China*, N.Y. TIMES (Feb. 27, 2020), https://www.nytimes.com/2020/02/27/opinion/eric-schmidt-ai-china.html [https://perma.cc/8M9P-P4F3] ("[I]n recent years, Americans—Silicon Valley leaders included—have put too much faith in the private sector to ensure U.S. global leadership in new technology. Now we are in a technology competition with China that has profound ramifications for our economy and defense—a reality I have come to appreciate as chairman of two government panels on innovation and national security. The government needs to get back in the game in a serious way.").

35. *See generally* ORVILLE SCHELL & JOHN DELURY, WEALTH AND POWER: CHINA'S LONG MARCH TO THE TWENTY-FIRST CENTURY 189–90 (2013) (emphasizing throughout the importance of the redemption narrative in Chinese culture and politics).

36. *See infra* notes 37–43 and accompanying text.

37. THE ENTREPRENEURIAL STATE, *surpa* note 10.

betting on races that the private sector avoids altogether.[38] Subsequent scholarship has, *inter alia*, demonstrated the importance of the support of the federal government and State of California to the evolution of Silicon Valley,[39] dusted off interest in the role of Japan's Ministry of International Trade and Industry (MITI) in the country's post-war economic miracle,[40] and looked at the role of Russia's "science cities" in continuing to produce internationally significant breakthroughs.[41] Scholars have even re-evaluated the role of Britain's industrial revolution which has historically been the poster child for supporters of a laissez-faire approach to innovation.[42] Contrary to the received wisdom, recent historical work has shown that public and quasi-public institutions played a vital role in encouraging and shaping innovation across the key period of Britain's industrial development.[43]

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38. *See id.* at 25 ("We are constantly told that the State should have a limited role in the economy due to its inability to 'pick winners', whether the 'winners' are new technologies, economic sectors, or specific firms. But what is ignored is that, in many of the cases that the State 'failed', it was trying to do something much more difficult than what many private businesses do . . . .").

39. MARGARET O'MARA, THE CODE: SILICON VALLEY AND THE REMAKING OF AMERICA 22–24 (2019).

40. *See, e.g.*, DYLAN GERSTEL & MATTHEW P. GOODMAN, CTR. FOR STRATEGIC & INT'L STUD. FROM INDUSTRIAL POLICY TO INNOVATION STRATEGY LESSONS FROM JAPAN, EUROPE, AND THE UNITED STATES 6 (Sept. 2020), https://www.wita.org/wp-content/uploads/2020/09/200901 Gerstel_InnovationStrategy_FullReport_FINAL_0.pdf [https://perma.cc/4Q4K-NTZW]. The importance of Japan's economic bureaucracy to that nation's success was famously articulated by CHALMERS JOHNSON, MITI AND THE JAPANESE MIRACLE: THE GROWTH OF INDUSTRIAL POLICY, 1925-1975 (1982).

41. Helena Schweiger, Alexander Stepanov & Paolo Zacchia, *The Long-Run Effects of R&D Place-Based Policies: Evidence from Russian Science Cities* 1 (Eur. Bank for Reconstr. & Dev., Working Paper No. 216, 2018). For further analysis of the history and modern operation of Russia's science cities, see, for example, Igor A. Monakhov, *Science Cities Within Innovative Environments of Russia and Great Britain: Cross-Country Comparison* 12 AKTUAL'NI PROBLEMY EKONOMIKY [ACTUAL PROBLEMS IN ECONOMICS] 220, 221 (2015) ("The history of Russian science cities can be traced back to the Soviet period, when the USSR was making enormous efforts to gain advantage in key technologies, win space and nuclear arms race with the USA. This has resulted in the foundation of science cities as territorial units with high concentration of top secret research centers and institutions, whose missions were to conduct fundamental and applied research in such fields as nuclear technology, aerospace, microelectronics etc.").

42. *See, e.g.*, TERENCE KEALEY, THE ECONOMIC LAWS OF SCIENTIFIC RESEARCH 60–81 (1996).

43. *See, e.g.*, Robert Burrell & Catherine Kelly, *Public Rewards and Innovation Policy: Lessons from the Eighteenth and Early Nineteenth Centuries*, 77 MODERN L. REV. 858, 859 (2014) [hereinafter *Public Rewards and Innovation Policy*] (focusing, in particular, on the complex system of prizes and rewards that were used to incentivize innovation during this period); ANTON HOWES, ARTS AND MINDS: HOW THE ROYAL SOCIETY OF ARTS CHANGED A NATION, at xi (2021) (arguing that the Royal Society of Arts, a notionally private body but one that enjoyed extremely close links to the State, served as "Britain's national improvement agency"). For a recent defense of the traditional view, see B. ZORINA KHAN, INVENTING IDEAS: PATENTS, PRIZES, AND THE KNOWLEDGE ECONOMY 82 (2020).

Other factors have also contributed to the recent trend in innovation policy. These include a broader intellectual shift away from the Washington consensus in the aftermath of the global financial crisis,[44] and in the face of concern about rising inequality.[45] At a more practical level, they include concerns about the high—and rising—cost of drugs that has caused attention to be focused on the role of public funding in the early stages of pharmaceutical research.[46]

Among the drivers for reform of innovation policy has been an additional factor that goes more directly to the theme of "emergency." This is, of course, the need to tackle climate change.[47] The need to reduce greenhouse gas emissions has, for example, led to calls for a new

44. *See* Andrew Sparrow, Katherine Baldwin & Heather Stewart, *Today's G20 Deal Will Solve Financial Crisis, Claims Gordon Brown*, GUARDIAN (Apr. 2, 2009, 1:32 PM), https://amp.theguardian.com/world/2009/apr/02/g20-summit-gordon-brown-hails-deal [https://perma.cc/T52G-GMXJ]. The Washington consensus referred originally to the set of policy prescriptions that Washington-based institutions were promoting to developing countries in the late 1980s. Over time it has come to denote the general set of free market ideas supported by organizations such as the IMF, World Bank and western governments. *See* John Williamson, *The Strange History of the Washington Consensus*, 27 J. POST KEYNESIAN ECON. 195, 195–96 (2004–2005) (this paper is particularly significant as it was Williamson who first coined the term "Washington consensus"); *see also* John Marangos, *The Evolution of the Term "Washington Consensus"* 23 J. ECON. SURV. 350, 350 (2009). The shift in meaning has been most pithily captured by Joseph E. Stiglitz, *The Post Washington Consensus Consensus*, *in* THE WASHINGTON CONSENSUS RECONSIDERED: TOWARDS A NEW GLOBAL GOVERNANCE 41, 41 (Narcis Serra & Joseph E. Stiglitz eds., 2008) ("Whatever its original content and intent, the term 'Washington Consensus', in the minds of most people around the world, has come to refer to development strategies that focus on privatization, liberalization, and macro-stability . . . .To most people, the Washington Consensus represents a set of policies predicated upon a strong faith—stronger than warranted either by economic theory or historical experience—in unfettered markets and aimed at reducing, or even minimizing, the role of government."). The role of the 2008 global financial crisis in shaking faith in the economic orthodoxy on which the Washington Consensus rested has been much discussed, but perhaps most famously the end of the era of the Washington Consensus was announced by British Prime Minister Gordon Brown at the G20 meeting in London that was organized in 2009 to coordinate the international responses to the still unfolding global financial crisis. *See* Sparrow et al., *supra*.

45. The latter concern was brought into sharp focus with the publication of THOMAS PIKETTY, CAPITAL IN THE TWENTY-FIRST CENTURY 657–58 (2014).

46. *See, e.g.*, U.K. LABOUR PARTY, MEDICINES FOR THE MANY: PUBLIC HEALTH BEFORE PRIVATE PROFIT 9 (2019), https://labour.org.uk/wp-content/uploads/2019/09/Medicines-For-The-Many.pdf [https://perma.cc/W6EL-C5FD]; *see also* Bhaven N. Sampat & Frank Lichtenberg, *What Are the Respective Roles of the Public and Private Sectors in Pharmaceutical Innovation*?, 30 HEALTH AFFS. 332, 332–33 (2011) (demonstrating that government funding played a role in almost half of all drugs examined in the study and almost two thirds of priority-review drugs).

47. *See, e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS (2021), https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf (reporting the seriousness of the challenge of anthropogenic climate change and arguing for urgent action).

Manhattan Project to promote energy and environmental solutions.[48] More generally, the challenge of climate change has informed much of the recent scholarship on the state's role in fostering innovation, including Mazzucato's work.[49] The scale of the challenge posed by climate change means that we should be slow to dismiss ideas for change, but conversely, the enormity of the threat is such that we need to ensure that changes in policy are underpinned by clear thinking. One area in which caution is needed is in the way the idea of "mission-oriented" innovation policy is being employed.

Historical case studies demonstrate that mission-driven innovation policies can produce results.[50] But one also must take care in moving from the success of the Manhattan Project,[51] the Soviet nuclear weapons program,[52] or the Apollo moon landings to support for dirigiste innovation policies generally.[53] Mission-oriented policies can, but do not always, work well when societies are confronted with the need to solve a serious and discrete problem in a short period of time (that is, in the authors' terminology, an "acute emergency").[54] Even in these cases, "success" requires that an agreed solution can be identified and measured.[55] Further, the underlying science must be at a point

48. Naomi Oreskes, *We Need a New Manhattan Project to Deal with Climate Change*, N.Y. TIMES (Nov. 14, 2013), https://www.nytimes.com/roomfordebate/2013/11/14/is-nuclear-power-the-answer-to-climate-change/we-need-a-new-manhattan-project-to-deal-with-climate-change [https://perma.cc/58E6-US5C].

49. THE ENTREPRENEURIAL STATE, *supra* note 10, at 117–18.

50. *See supra* note 25 and accompanying text; *infra* notes 51–55 and accompanying text.

51. *See generally* JIM BAGGOTT, THE FIRST WAR OF PHYSICS: THE SECRET HISTORY OF THE ATOM BOMB, 1939-1949 (2011) (describing in part the innovations which made the Manhattan Project a success).

52. *See generally id.* (describing in part the innovations which made the Soviet nuclear weapons program a success).

53. *See generally* THE ENTREPRENEURIAL STATE, *supra* note 10 (describing in part the innovations which made the Apollo project a success).

54. For a comparative analysis of the success and failure of different mission-oriented policies, see DEBORAH D. STINE, CONG. RSCH. SERV., RL34645, THE MANHATTAN PROJECT, THE APOLLO PROGRAM, AND FEDERAL ENERGY TECHNOLOGY R&D PROGRAMS: A COMPARATIVE ANALYSIS 5–8 (2009), https://sgp.fas.org/crs/misc/RL34645.pdf [https://perma.cc/29QF-96QV] (discussing the relative failure of the federal energy technology R&D programs of the 1970s, and noting that "the threat posed by climate change, which is related to energy consumption, will likely be gradual and long-term").

55. This is a point that has been emphasized, *inter alia,* in discussions of Cold War era mission-oriented policies. *See, e.g.*, Slavo Radošević & Imogen Wade, *Modernization Through Large S&T Projects: Assessing Russia's Drive for Innovation-Led Development via Skolkovo Innovation Centre* 13 (Ctr. for Compar. Econ., Univ. Coll. London Sch. Slavonic & E. Eur. Stud., Econ. & Bus. Working Paper No. 131, 2014), https://discovery.ucl.ac.uk/id/eprint/1454656/2/Skolkovo_WP_Sep_2014_WP_final.pdf [https://perma.cc/7C9A-L8HQ] (noting that in the case of developing nuclear weapons and launching a satellite into space Russia had a sharply focused goal and an immediate means of determining success); *see also* STINE, *supra* note 54, at 8. (arguing that

where the necessary "leaps" to achieve a technological solution are at least conceivable.[56] There have long been scholars who have cautioned against using the success of mission-oriented policies, in fields like defense, as a model for tackling the multidimensional or "wicked" problems of today.[57] Doubts about the translatability of a mission-oriented approach to tackling problems like climate change or AMR have also underpinned the muted reaction that Mazzucato's more recent work has received in some quarters.[58]

The authors are by no means advocates of the view that the best thing government can do for innovation is to stay out of the way. Nevertheless, caution needs to be exercised before assuming that the success of mission-oriented approaches in dealing with acute emergencies can be readily translated to chronic emergencies, like climate change. Acute emergencies are accompanied by broader societal changes that produce shifts in culture and mindset.[59] Taking the current pandemic as an example, scientists responsible for developing new vaccines have received standing ovations at sporting events.[60] Indeed, they have even had dolls made in their image.[61] Authorities on

"[t]he Manhattan project had a clear and singular goal—the creation of a nuclear bomb. For the Apollo program, the goal was also clear and singular—land American astronauts on the moon and return them safely to Earth.").

56. For example, vaccines which could be modified to target the Covid "spike" protein existed prior to the current pandemic and, thus, the potential for a Covid vaccine was an achievable technological goal. *See* Lauran Neergaard, *Years of Research Laid Groundwork for Speedy COVID-19 Vaccines*, PBS NEWS HOUR (Dec. 7, 2020, 6:44 PM), https://www.pbs.org/newshour/health/years-of-research-laid-groundwork-for-speedy-covid-19-vaccines [https://perma.cc/7P8N-UPFJ].

57. *See, e.g.*, David C. Mowery, *Defense-Related R&D as a Model for "Grand Challenges" Technology Policies*, 41 RSCH. POL'Y 1703, 1705 (2012).

58. John Kay, *Mission Economy by Mariana Mazzucato – Could Moonshot Thinking Help Fix the Planet?*, FIN. TIMES (Jan. 13, 2021), https://www.ft.com/content/86475b94-3636-49ec-9b3f-7d7756350b30 [https://perma.cc/369X-GR2Y].

59. There has long been a strand of sociology interested in the interrelated themes of emergency, disaster and catastrophe, and the capacity of such crises to produce social change. *See, e.g.*, SAMUEL HENRY PRINCE, CATASTROPHE AND SOCIAL CHANGE (1920); Frederick L. Bates & Walter G. Peacock, *Disaster and Social Change, in* SOCIOLOGY OF DISASTERS (Russell R. Dynes, Bruna De Marchi & Carlo Pelanda eds., 1987).

60. Tom Morgan, *Toast of Wimbledon: Standing Ovation for the Vaccine Scientist Who Smashed It*, TELEGRAPH (June 28, 2021, 8:01 PM), https://www.telegraph.co.uk/news/2021/06/28/toast-wimbledon-vaccine-hero-receives-standing-ovation/ [https://perma.cc/J3XS-J7BP].

61. Nicola Slawson, *Vaccinologist Barbie: Prof Sarah Gilbert Honoured with a Doll*, GUARDIAN (Aug. 4, 2021, 12:00 AM), https://amp.theguardian.com/society/2021/aug/04/vaccinologist-barbie-prof-sarah-gilbert-honoured-with-a-doll [https://perma.cc/TK6S-FE2F]. Of course, this emergency has also seen some sectors of the community express extreme distrust of scientists and other experts. *See* Robert Burrell & Catherine Kelly, *The COVID-19 Pandemic and the Challenge for Innovation Policy*, 71 N. IR. LEGAL Q. 89 (2020). As we have noted previously, the

previously obscure subjects, like theoretical epidemiology and the history of pandemics, have become regular guests on radio and television.[62] With this rehabilitation of the role of the expert in public life, the anti-intellectualism that accompanied recent populist political movements has begun to lose its appeal, at least among swing voters.[63] Against this backdrop, political objections to throwing large sums of public money at scientific projects with uncertain prospects of success become much less persuasive.[64]

Acute crises can also motivate individuals to go to extraordinary lengths to contribute to the commonweal.[65] It is notable, for example, that both modern and contemporary accounts of innovation during the Second World War emphasize the importance of the pressure of the times in motivating both individual effort and collective action.[66] For example, James Bryant Conant, chairman of the pivotal wartime US National Defense Research Committee, wrote in 1947 that the "emotional pressure of war" was such that "no peacetime effort could possibly operate as effectively…simply because human beings outdo themselves when their friends and relatives are facing the ordeal of battle. They outdo themselves both in terms of hours of labor and in terms of cooperation with other people."[67] The sense of common purpose and the drive to contribute that accompany acute emergencies also

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anti-vaxxer movement presents significant challenges to the successful role out of public health responses. *See id.*

62. *See, e.g.*, *Covid-19 Portfolio: In the Media*, YALE UNIV.: PROGRAM IN THE HIST. OF SCI. & MED., https://hshm.yale.edu/covid-19-portfolio/in-the-media [https://perma.cc/US7C-HGF6] (last visited Sept. 15, 2021) (detailing the radio, television and podcast contributions of academics in Yale University's Program in the History of Science and Medicine).

63. For a discussion of the relationship between anti-intellectualism, mistrust of scientific opinion, and populism, *see, e.g.*, Eric Merkley, *Anti-Intellectualism, Populism, and Motivated Resistance to Expert Consensus,* 84 PUB. OP. Q. 24 (2020). It has been reported that an internal report for the Trump campaign blamed poor handling of the pandemic for President Trump's failure to be re-elected. *See* Josh Dawsey, *Poor Handling of Virus Cost Trump His Reelection, Campaign Autopsy Finds*, WASH. POST (Feb. 1, 2021, 11:26 PM), https://www.washingtonpost.com/politics/poor-handling-of-virus-cost-trump-his-reelection-campaign-autopsy-finds/2021/02/01/92d60002-650b-11eb-886d-5264d4ceb46d_story.html [https://perma.cc/MEE7-SFJC].

64. This is a point that Margaret O'Mara has made in relation to the money that flowed into the US electronics industry in the context of the space race and the cold war. *See* Jackson Square Ventures Book Club, *Margaret O'Mara discusses The Code: Silicon Valley and the Remaking of America*, YOUTUBE (Dec. 11, 2019), https://www.youtube.com/watch?v=Zt14lSOzLIs [https://perma.cc/V3A3-75A2] ("[T]here was no one in Washington [asking] aren't you spending too much?").

65. *See infra* notes 69–70 and accompanying text.

66. Gross & Sampat, *supra* note 25.

67. James B. Conant, *The Mobilization of Science for the War Effort*, 35 AM. SCIENTIST 194, 200 (1947).

increase the ability of the state to recruit and retain managerial expertise.[68] James Bryant Conant was President of Harvard when he was recruited to the war effort.[69] During the present crisis, the UK government recruited Kate Bingham, a well-known British venture capitalist, to run the United Kingdom's vaccination rollout program, one of the few elements of the pandemic that the UK government has handled well.[70]

A degree of caution also needs to be exercised over the characterization of the Space Race and the success of the Apollo missions. It is now easy to forget that at the time the American space program was launched, Soviet dominance in the field was widely perceived as an existential threat, and it has been said that "space exploration is a prime example of the blurring lines between military and civilian activities during the Cold War."[71] It is also worth remembering that key figures in the American space program had their identity and approach fashioned during the Second World War.[72] For example, Robert Gilruth, Director of NASA's Manned Spacecraft Center in the 1960s and early 1970s, had worked during the war on aircraft design and the physical stresses on pilots caused by increased flight speeds.[73] More (in)famously, Wernher von Braun, Director of NASA's Marshall Space Flight Center and chief architect of the Saturn V launch vehicle, headed the team that developed the V-2 missile for the Nazis.[74]

Replicating the urgency, sense of purpose, and spirit of cooperation that accompany acute emergencies is always going to be a challenge when dealing with chronic emergencies and other scenarios. This should make us cautious about the likely efficacy of mission-oriented initiatives. Consider, for example, the lists of strategic research priorities that have become *de rigueur* for public research funding agencies.[75] This approach exemplifies the sort of

68. *See supra* notes 66–67 and accompanying text; *infra* notes 69–70 and accompanying text.

69. *James B. Conant*, BRITANNICA, https://www.britannica.com/biography/James-B-Conant [https://perma.cc/HPE3-CSGH] (last visited Sept. 15, 2021).

70. Mark Landler & Benjamin Mueller, *Vaccine Rollout Gives U.K. a Rare Win in the Pandemic*, N.Y. TIMES, https://www.nytimes.com/2021/01/29/world/europe/covid-vaccine-uk.html [https://perma.cc/X9SA-KZSL] (Mar. 1, 2021).

71. Werth, *supra* note 34, at 586.

72. *See infra* notes 73–74.

73. *See* Andrew Chaikin, *Bob Gilruth, the Quiet Force Behind Apollo*, SMITHSONIAN MAG.: AIR & SPACE MAG. (Feb. 2016), https://www.smithsonianmag.com/air-space-magazine/quiet-force-behind-apollo-180957788/ [https://perma.cc/U6XZ-L37P].

74. MICHAEL NEUFELD, VON BRAUN: DREAMER OF SPACE, ENGINEER OF WAR 69 (2008).

75. *See Strategic Priorities Fund*, U.K. RSCH. & INNOVATION, https://www.ukri.org/our-work/our-main-funds/strategic-priorities-fund/ [https://perma.cc/T6NM-CSNB] (last visited

mission-oriented intervention that some scholars would like to see more of and, at least in form, is largely indistinguishable from the strategic expedition of research related to the current pandemic. However, if the impetus provided by an acute emergency is absent, scientists and researchers will be less likely to bend their agendas to meet priorities set by others.[76] Consequently, there is a danger that in ordinary times, such strategic research priorities may be less effective and encourage some applicants to engage in the window dressing of projects that are only tangentially related to a strategic goal.[77]

To reiterate, none of this is a call for inaction, but rather a call for caution. There is now a body of scholarship that takes the limits and possibilities of mission-oriented approaches seriously.[78] This literature is too rich to summarize fairly here, but one consistent theme is that mission-oriented approaches do much better when there is decentralization, preservation of space for scientific and technical creativity, and the opportunity to work on different potential solutions in parallel.[79] As British economist John Kay has put it, in typically acerbic style, the US government may have paved the way for Silicon Valley, "but thank goodness the development was in the hands of Steve Jobs, Travis Kalanick, and Elon Musk rather than a committee in the

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Jan. 24, 2022); *Search and Research Priorities*, AUSTL. RSCH. COUNCIL, https://www.arc.gov.au/grants/grant-application/science-and-research-priorities [https://perma.cc/68EH-D9JR] (Nov. 4, 2019).

76. *See generally* Jochen Gläser & Grit Laudel, *Governing Science: How Science Policy Shapes Research Content*, 57 EUR. J. SOCIO. 117 (2016) (exploring the link between states' public policy goals and governance initiatives and research and development).

77. *Id.* at 126–27 ("Scientists responded to this new funding strategy by casting their fields and topics as particularly promising . . . . [I]n addition to the window dressing triggered by targeted funding, such funding also increases research on the intended topics."); *see also* Norma Morris, *Science Policy in Action: Policy and the Researcher*, 38 MINERVA 425 (2000) (discussing the history and impact of incorporating "national economic benefits" and other public goals into the allocation of research funding in the United Kingdom).

78. *See generally* Richard R. Nelson, *The Moon and the Ghetto Revisited*, 38 SCI. & PUB. POL'Y 681 (2011) (identifying the reasons for uneven technological progress and exploring how progress might be increased in areas of great need). As Nelson explains, one of the key intellectual insights to emerge from the innovation studies literature is that technological change needs to be understood in terms of "innovation systems." *Id.* at 687. He argues, "the innovation-system concept provided an alternative to a point of view that government support of R&D should only be justified on grounds of 'market failure'." *Id.* However, this observation by itself does not tell us when and how government intervention can produce meaningful results. *Id.*

79. *See, e.g.*, Conant, *supra* note 67, at 200 ("Flexibility and decentralization were characteristics of the organization which was built, and without these basic principles I believe success could never have been attained . . . . Perhaps all this is mere rationalization on my part. But at all events, my story is concerned with a highly decentralized and flexible temporary government agency created under stress. It resembled a university with many faculties and many almost autonomous departments, rather than an industrial corporation.").

department of commerce."[80] This conclusion chimes with Margaret O'Mara's detailed study of the early years of Northern California's electronics industry: "The case of the Valley chipmakers underscores that public investment mattered greatly, but that *how* that money was spent mattered even more. The decentralized, privatized, fast-moving public contracting environment encouraged entrepreneurship."[81]

In summary, acute emergencies create the conditions in which mission-oriented policies stand the best prospects of producing successful outcomes: funding increases; researchers are motivated by some combination of commitment to the public good and fears for themselves and loved ones; public attention and acclaim feeds into this motivation and causes new actors to turn their minds to the problems at hand. But even if these conditions apply, there are still good and bad ways of implementing mission-oriented innovation policies, with decentralization and preservation of scientific freedom being key. With these issues in mind, we consider what lessons can be learned from Britain in the eighteenth and nineteenth centuries, particularly regarding the approach to solving chronic challenges.

III. THE REWARDS OF HISTORY

Before embarking on a discussion of historical examples of mission-oriented solutions to technological problems, we must first ask why looking back at Britain's experience of the industrial revolution is an instructive exercise for modern policy makers. Part of the answer lies in the fact that this was a period of extraordinary technological growth,[82] but two further considerations are also worth mentioning.

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80. Kay, *supra* note 58.

81. O'MARA, *supra* note 39, at 73.

82. That the industrial revolution was characterized by rapid technological change is universally accepted and understood, but the drivers of the industrial revolution remain fiercely contested, and there are some historians who maintain that technological change was a *symptom* rather than a *cause* of the industrial revolution. *See, e.g.*, ERIC HOBSBAWM, INDUSTRY AND EMPIRE (Penguin Books 1999) (1969) (arguing that it was only once the United Kingdom had secured a vast market for its products in colonial territories by means of an aggressive military strategy that it made sense for entrepreneurs to invest in new technologies, and concluding that the new technologies of the period rested on the "application of simple ideas and devices, often of ideas available for centuries"). However, in most recent accounts there seems to be a consensus that some degree of importance has to be attached to the new ways in which technical information came to be shared and employed over the course of the eighteenth century and the new "improving mentality" that emerged during this period. As to this mentality, see *infra* notes 148–56 and accompanying text. For an excellent and accessible historiography of the industrial revolution, see JOSEPH E. INIKORI, AFRICANS AND THE INDUSTRIAL REVOLUTION IN ENGLAND 89–155 (2002). For an earlier, but still influential and important historiography, see R. M. Hartwell, *The Causes of the Industrial Revolution: An Essay in Methodology* 18 ECON. HIST. REV. 164 (1965).

The first is that this period already looms large in contemporary academic and political debates about mission-oriented innovation policy.[83] In particular, it appears to have become obligatory in all modern discussions of prizes to reference the Longitude Prize.[84] The Longitude Prize was created by the British Parliament in 1714 and offered a cash sum to anyone who could invent a method of finding a ship's longitude at sea, one of the greatest scientific problems of its time.[85] In the United Kingdom, a new grand innovation challenge prize fund has been established to tackle antibiotic resistance by incentivizing the production of a point-of-care test kit for bacterial infections.[86] Operating as Longitude 2014, this prize was self-consciously modeled on its eighteenth-century precursor.[87]

If history is to help guide our decisions—something that, for better or worse, is already occurring—then at the very least, we need to be careful about the lessons that history has to offer. As argued in detail elsewhere[88] and outlined below, it should be recognized that the original Longitude Prize was not in any way typical of the levers used by the British state to incentivize innovation during the eighteenth and early nineteenth centuries.

A second consideration is that during this period, significant strides were made to tackle what might now be classified as chronic emergencies.[89] The absence of an accurate means of determining longitude was one such problem—it had plagued navigation for hundreds of years. European nations had intermittently sought a technical solution for more than a century before Britain established the Board of Longitude.[90] Other chronic problems to which innovators turned their attention included contagious diseases like smallpox,

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83. *See, e.g.*, KHAN, *supra* note 43 at 72–75; THE ENTREPRENEURIAL STATE, *surpa* note 10, at 125–26; M. Diane Burtona & Tom Nicholas, *Prizes, Patents and the Search for Longitude*, 64 EXPLS. ECON. HIST. 21 (2017); Jaison G. Morgan, *Inducing Innovation Through Prizes*, 3 INNOVATIONS: TECH., GOVERNANCE, GLOBALIZATION 105 (2008).

84. Burtona & Nicholas, *supra* note 83.

85. *Id.*

86. *About the Prize*, LONGITUDE PRIZE, https://longitudeprize.org/about-the-prize/ [https://perma.cc/WA3J-ZECR] (last visited Sept. 14, 2021) (striving to enable healthcare professionals to administer the most appropriate antibiotic and thereby slow the development of antibiotic resistance).

87. *See, e.g.*, *David Cameron promises £1m 'Longitude Prize' for Big Ideas*, BBC (June 14, 2013), https://www.bbc.co.uk/news/uk-politics-22892443 [https://perma.cc/2HKT-3YKL] (noting, for example, that the Prime Minister stated "[t]he original Longitude Prize stimulated a solution to a great technical problem of the time—and it was won by an 'outsider'.").

88. *See Public Rewards and Innovation Policy*, *supra* note 43, at 873.

89. *See infra* notes 90–92 and accompanying text.

90. *See* KHAN, *supra* note 43, at 73–74.

ophthalmia, and tuberculosis.[91] This was a product of a profound shift in the understanding of what science might achieve. Before this shift, most people, including scientific elites, understood disease to be inextricably intertwined with the divine, and not necessarily susceptible to human agency.[92]

The foundation of our historical analysis is a dataset the authors compiled and published in 2014 looking at prizes and rewards (broadly interpreted) for inventors in Britain between 1732 and 1840.[93] The following summarizes the arguments and findings presented in detail in that publication. The research revealed a complex pattern of state intervention in science and technology in the eighteenth and nineteenth

91. The smallpox example is straightforward. Smallpox had been a problem for centuries and by the eighteenth century was still killing hundreds of thousands of people each year. It is estimated, for example, that across the course of the eighteenth century, smallpox killed every tenth child born in Sweden or France and every seventh child born in Russia. WHO, THE WORLD HEALTH REPORT 2007: A SAFER FUTURE 5 (2007). The severity and longstanding nature of the disease helps explain why Edward Jenner's pioneering work in developing a successful vaccination is still widely remembered. *See infra* notes 103, 163 and accompanying text. Jenner's work did not, however, occur in a vacuum. On the contrary, in English medical circles there was active interest in inoculating patients against smallpox from 1718 onwards. Cary P. Gross & Kent A. Sepkowitz, *The Myth of the Medical Breakthrough: Smallpox, Vaccination, and Jenner Reconsidered*, 3 INT'L J. INFECTIOUS DISEASES 54, 56 (1998). Ophthalmia, in contrast, became a significant health problem in Europe after 1798 when it was contracted by troops fighting in Egypt during the Napoleonic wars and brought back to Europe at the conclusion of that campaign. *See* Robert M. Feibel, *John Vetch and the Egyptian Ophthalmia*, 28 SURV. OPHTHALMOLOGY 128, 128–29 (1983). The scale and significance of the chronic health problems that were caused by what was at the time known as "Egyptian ophthalmia" are now only remembered by medical historians, but it has been said that after 1798, "[f]or the next forty years, the Egyptian ophthalmia was to have a greater impact upon civilian and military affairs than any other disease since the bubonic plague." *Id*. at 128. For analysis of the efforts of medical officers stationed in Egypt to treat Egyptian ophthalmia and other chronic diseases like the plague, see Catherine Kelly, *The Development of the Military Medical Officer During the Napoleonic Wars c. 1798–1801*, 27 CAN. BULL. MED. HIST. 321 (2016). For a detailed description of the military and government response to the epidemic in Britain in the first decade of the nineteenth century, see CATHERINE KELLY, WAR AND THE MILITARIZATION OF BRITISH ARMY MEDICINE, 1793–1830 (2011). Tuberculosis is a somewhat more complicated example. At the time tuberculosis was known as consumption and, like smallpox, had been a scourge throughout much of human history. Thomas M. Daniel, *The History of Tuberculosis*, 100 RESPIRATORY MED. 1862 (2006). However, during the period with which the authors are concerned, consumption was also aestheticized and became associated with virtues like delicacy and sensitivity. SUSAN SONTAG, ILLNESS AS METAPHOR 61 (1978). It has been argued, however, that the relationship between the medical profession and this romanticized image was complex, and physicians like Dr. Thomas Beddoes were committed to treating consumption as a serious disease that required the development of novel treatments. Clark Lawlor & Akihito Suzuki, *The Disease of the Self: Representing Consumption, 1700–1830*, 74 BULL. HIST. MED. 458 (2000).

92. *See* HANNAH NEWTON, MISERY TO MIRTH: RECOVERY FROM ILLNESS IN EARLY MODERN ENGLAND 9–14 (2018).

93. *Public Rewards and Innovation Policy*, *supra* note 43.

centuries.[94] State intervention came in diverse guises and was not static across the period.[95] However, the most striking feature of state intervention in this period, at least to modern eyes, is the central importance of post hoc rewards for inventors.[96] The authors have argued elsewhere that, because post hoc rewards were such a prominent part of the innovation landscape during the industrial revolution, it is appropriate to talk about the existence of a reward system that sat alongside the still-developing patent system and ameliorated some of its failures.[97]

At the apex of this system of rewards were grants from Parliament.[98] These grants were awarded by Parliament in response to petitions from inventors, but Parliament gave no guidance as to the categories of endeavors that might attract its approval.[99] The British state used these rewards to endorse some of the most important discoveries of the period.[100] Sometimes this was done through lump-sum payments.[101] In total, the authors have identified thirty or so payments made to individuals in the period 1730–1840 worth, in aggregate, in excess of £200,000.[102] The most famous example is probably the payment of £30,000 to Edward Jenner for developing the smallpox vaccine,[103] but smaller sums were awarded for improvements

94. *Id.*

95. *Id.*

96. *Id.*

97. *Id.*; *see also* Robert Burrell & Catherine Kelly, *Parliamentary Rewards and the Evolution of the Patent System*, 74 CAMBRIDGE L.J. 423 (2015).

98. *Public Rewards and Innovation Policy*, *supra* note 43, at 886.

99. *Id.* at 873–74.

100. *Id.*

101. *Id.*

102. *Id.* Providing the equivalent current value is complex. For example, if one takes this sum at 1800 (as representing more or less the midpoint in the system of parliamentary payments), the commonly accepted methods of conversion produce a range of slightly more than £14 million to considerably in excess of £800 million. *Five Ways to Compute Relative Value of a UK Pound Amount, 1270 to Present*, MEASURING WORTH, https://www.measuringworth.com/calculators/ukcompare/ [https://perma.cc/WL3Z-G4W2] (last visited Jan. 25, 2022) (enter "1800" in the box labelled "1270 to 1970 Initial Year"; enter 200,000 in the box labelled "Initial Amount: pounds"; enter 2013 in the box labelled "Desired Year"; then click calculate). For current purposes, however, the most useful comparator is that of equivalent 'economic status,' which in 2013 (when we were creating our dataset) would have equated to £206.8 million. *Id.*

103. *Public Rewards and Innovation Policy*, *supra* note 43, at 860, 863. *See generally* JOHN BARON, THE LIFE OF EDWARD JENNER, M.D. 1–61 (Cambridge Univ. Press 2014) (1827) (describing Edward Jenner's life); RICHARD B. FISHER, EDWARD JENNER 1749–1823 (1991), 99–132.

in textile manufacture,[104] dyes,[105] ship repair,[106] safety at sea,[107] papermaking,[108] fire prevention,[109] and a method of distilling potable water from seawater.[110] In addition to the cases in which Parliament rewarded inventors through lump-sum payments, there was a small number of cases in which Parliament chose to grant inventors an annual pension, as, for example, with the pension of £1,200 awarded to Henry Shrapnel for his invention of "spherical case" cannon shot.[111] The third means by which Parliament intervened on behalf of inventors was through the grant of patent extensions.[112] More than a dozen inventors were rewarded in this way, and some received very valuable monopolies as a result, including James Watt, who ended up enjoying a monopoly over his steam engine that lasted more than thirty years (the ordinary term of protection at the time being fourteen years).[113]

Parliamentary rewards were important, but they were only part of a broader and more complex set of arrangements.[114] For long periods, there were also publicly funded bodies specifically charged with promoting innovation by means of financial reward.[115] However, the Board of Longitude is the only one that is still commonly remembered. There were also bodies charged with improving agriculture, and others with specific responsibility for Scotland.[116] Moreover, government departments would also sometimes intervene directly to promote innovation.[117] The Admiralty was particularly active in this regard, and its intervention extended to paying money to deserving inventors.[118] The authors found, for example, that the Admiralty made payments to inventors of improved anchors and methods of raising ships on blocks.[119]

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104. *Public Rewards and Innovation Policy*, *supra* note 43, at 886.
105. *Id.* at 861–63.
106. *Id.* at 864.
107. *Id.* at 863.
108. *Id.* at 864.
109. *Id.* at 862.
110. *Id.* at 882.
111. *Id.* at 864.
112. *Id.* at 865.
113. *Id.* at 865–68. As to the ordinary term of protection, see Statute of Monopolies 1624, 21 Jac. c. 3, § 6 (Eng.).
114. *Public Rewards and Innovation Policy*, *supra* note 43.
115. *Id.* at 868–69.
116. *Id.* at 870–71.
117. *Id.* at 869.
118. *Id.*
119. *Id.*

Furthermore, no account of the reward system would be complete without mention of the Society for the Encouragement of Arts, Manufactures and Commerce—later the Royal Society of Arts (the "Society"). The Society was established in 1755 and was a private body insofar as it was funded through subscription.[120] In practice, however, the Society was entwined in a complex network of relations with state actors, and support from the Society was often important to the reception of inventions by government.[121] The granting of rewards formed an important part of the Society's activities and, by the standards of the day, led to the disbursement of impressive sums.[122] For example, in the period 1755–1763, the Society expended £8,496 on cash prizes and medals.[123] Beyond these peak bodies, there were all sorts of other organizations and arrangements that popped up across the period for conferring rewards.[124] For example, the short-lived Anti-Gallican Association, founded in 1745 "to oppose the insidious arts of the French nation" and "promote British manufactures," awarded a number of premiums for improvements in English lace and needlework.[125]

Subsequent historical research has shown that the system of rewards spread beyond Britain to its colonies.[126] For example, Aaron Graham has shown that rewards formed an important part of the Jamaican legal landscape in the late eighteenth and early nineteenth centuries.[127] Similarly, the authors have discovered that rewards were given to inventors in the early Australian colonies,[128] where they were

120. *See generally* DEREK HUDSON & KENNETH LUCKHURST, THE ROYAL SOCIETY OF ARTS, 1754–1954, at 12 (1954) (describing the founding of the Royal Society of Arts).

121. *Public Rewards and Innovation Policy*, *supra* note 43, at 870.

122. *See infra* note 123 and accompanying text.

123. HUDSON & LUCKHURST, *supra* note 120.

124. *See infra* note 125 and accompanying text.

125. *Public Rewards and Innovation Policy*, *supra* note 43, at 871.

126. *See infra* notes 127–31 and accompanying text.

127. Aaron Graham, *Patents and Invention in Jamaica and the British Atlantic Before 1857*, 73 ECON. HIST. REV. 940, 954–57 (2020).

128. Such rewards included, *inter alia*, the grants given to John Macarthur in 1805 for his work with sheep breeding and to James King in 1832 for his work using white sand to make glass. Wool Away, *John Macarthur*, SYDNEY MORNING HERALD, Apr. 7, 1934, at 11; David S. Macmillan, *King, James (1800–1857)*, AUSTL. DICTIONARY OF BIOGRAPHY (2006), https://adb.anu.edu.au/biography/king-james-2307 [https://perma.cc/HZY9-A7RV]. The grant of land to Macarthur is noted, for example, in the obituary that was published to mark the centenary of his death and is recorded in his entry in the *Australian Dictionary of Biography*. Wool Away, *supra*; Margaret Steven, *Macarthur, John (1767–1834)*, AUSTL. DICTIONARY OF BIOGRAPHY (2006), https://adb.anu.edu.au/biography/macarthur-john-2390 [https://perma.cc/RHM8-4WJB]. The right of King to acquire crown land at a reduced price is similarly recorded in the *Australian Dictionary of Biography*. Macmillan, *supra*.

understood to have a role in establishing new industries in the harsh conditions of Australia's founding.[129] Moreover, as in Britain, this system of rewards overlapped and intersected with rewards granted by other bodies, with the Society doing so through its Committee of Colonies and Trade.[130] The Society was particularly active in New South Wales, awarding medals to a number of local innovators, including those petitioning the government for rewards.[131] The spread of the reward system to the colonies helps demonstrate that it was an accepted and important legal technology that had its place alongside the patent system.

A system of rewards largely under state control created an innovation ecosystem far removed from the paradigm of neoliberal imagination. Equally, however, the reward system cannot comfortably be characterized as mission-oriented. Above all, a generalized system of rewards does not provide a proactive steer as to the types of innovation that society is seeking to incentivize any more than the patent system does. This is not to say that no efforts were made to steer the direction of inventive effort.[132] On the contrary, there were times when both the Society and state bodies, including Parliament, would signal priorities.[133] When, for instance, Parliament granted the Board of Agriculture an additional £800 over and above its usual operating budget in 1801, this was on the basis the money would be distributed in "premiums for essays on breaking up grasslands."[134] Even when granting rewards directly, Parliament would sometimes express the expectation that part of the sum granted would be plowed back into research to help perfect the invention.[135] Importantly, however, even in

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129. *See, e.g.*, ROBERT HUGHES, THE FATAL SHORE: THE EPIC OF AUSTRALIA'S FOUNDING 282–322 (1986).

130. *See* Henry Trueman Wood, *The Royal Society of Arts IV—The Society and the Colonies (1754–1847)*, 59 J. ROYAL SOC'Y ARTS 1030 (1911); *see also* D. G. C. Allan, *"Dear and Serviceable to Each Other": Benjamin Franklin and the Royal Society of Art*, 144 PROCS. AM. PHIL. SOC'Y 245 (2000) (discussing Benjamin Franklin's work as chairman of this committee during the early 1760s at a time when Franklin was living in London).

131. For example, the Society granted medals to both Macarthur and King. *See* T. Nowlan, Marsh & Ebsworth, *Colonies and Trade*, 40 TRANSACTIONS SOC'Y, INSTITUTED LONDON, FOR ENCOURAGEMENT ARTS, MFRS., & COM. 230, (1822); James King & Apsley Pellat, *No. III. Sand for Glass, from New South Wales*, 51 TRANSACTIONS SOC'Y, INSTITUTED LONDON, FOR ENCOURAGEMENT ARTS, MFRS., & COM. 90, 90 (1836).

132. *See, e.g.*, *infra* note 134 and accompanying text.

133. *See, e.g.*, *infra* note 134 and accompanying text.

134. *Accounts, Presented to the House of Commons, Respecting the Public Income of Great Britain, for the year ending fifth of January 1802* (May 31 & June 11, 1802).

135. *Public Rewards and Innovation Policy*, *supra* note 43, at 864 (discussing, for example, the payments to Sir William Congreve to enable him to continue his experiments with

these instances, the system remained entirely decentralized, leaving the maximum possible latitude for scientific creativity.

Against this background, it is ironic that the Longitude Prize attracts so much attention in modern scholarship.[136] The Longitude Prize was not regarded as a success by contemporaries and, notably,[137] was not a model that was rolled out to tackle other problems of the time. The Board of Longitude suffered from a range of problems, but a key consideration that is now sometimes lost is that the original Longitude Prize was governed by a strict set of clearly articulated criteria.[138] The struggles of John Harrison to claim the reward have been extensively documented by historians of the period.[139] There may be truth in the argument that Harrison was unfairly treated by the scientific establishment of the day because of his background,[140] but there also may be truth in the view that Harrison was an awkward character who did little to help himself.[141] But a further consideration, as Jonathan Siegel has carefully documented, is that the criteria governing the prize were such that it was difficult for the Board to determine what a "win" looked like.[142] Yet even the original Longitude Prize, as modern defenders are quick to point out, was careful not to prescribe the means by which a solution might be found:

> The Longitude Act set forth a simply stated goal with no mention of any specific method or solution that might lead to success—or any discussion of solutions that should be avoided . . . the Act left the field of possible solutions entirely open, and potential contributors free to pursue their own divergent ideas.[143]

It is now more or less impossible to imagine the re-creation of a comprehensive system of post hoc financial rewards given modern

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methods of impeding the forgery of bank notes and to Charles Babbage to allow him to continue working on the production of his "difference engine").

136. *See, e.g.*, KHAN, *supra* note 43, at 72–75; MISSION ECONOMY, *supra* note 27, at 125–26.

137. Katy Barrett, *"Explaining" Themselves: The Barrington Papers, the Board of Longitude, and the Fate of John Harrison*, 65 NOTES & RECS. ROYAL SOC'Y LONDON 145 (2011) (examining the efforts of the Commissioners of the Board of Longitude to defend their actions to an increasingly skeptical Parliament).

138. *See* Jonathan R. Siegel, *Law and Longitude*, 84 TUL. L. REV. 1 (2009).

139. The most famous analysis is DAVA SOBEL, LONGITUDE: THE TRUE STORY OF A LONE GENIUS WHO SOLVED THE GREATEST SCIENTIFIC PROBLEM OF HIS TIME (1995).

140. *Id.*

141. Jim Bennett, *The Travels and Trials of Mr Harrison's Timekeeper*, *in* INSTRUMENTS, TRAVEL AND SCIENCE: ITINERARIES OF PRECISION FROM THE SEVENTEENTH TO THE TWENTIETH CENTURY 75, 81–84 (Marie N. Bourguet, Christian Licoppe & H. Otto Sibum eds., 2002).

142. *See* Siegel, *supra* note 138, at 38–39.

143. Robin W. Spencer, *Open Innovation in the Eighteenth Century: The Longitude Problem*, 55 RSCH. TECH. MGMT. 39, 41 (2012).

controls on the dispersal of public funds.[144] Moreover, given the problems of political patronage that dogged the operation of the reward system,[145] it is far from clear that re-creation of such a system would be desirable. And yet, it is difficult not to be struck by the extraordinary creativity and ingenuity of British society during this period.[146] A variety of explanations have been offered for this phenomenon, but one thing that has often struck those immersed in the period is that there was a culture of innovation and improvement that infused society.[147] As Alfred North Whitehead writing in the 1920s put it, the early half of the nineteenth century was a period "in which a new attitude to change was first established and enjoyed."[148] More recently, Anton Howes has stressed the importance of the "improving mentality" that emerged during the late eighteenth and early nineteenth centuries.[149] This "mentality was not an abstract ideal, nor was it a skill: it was a lens through which to see the world. It was a frame of mind through which processes and products appeared imperfect and in need of bettering."[150]

Moreover, this improving mentality was consciously and actively evangelized.[151] This was the period in which the cult of the heroic inventor began to emerge.[152] Even if, as Christine Macleod has argued, the transformation of inventors into national heroes was more about domestic politics than the desire to promote science or technology per

144. *See* MICHAEL POWER, THE AUDIT SOCIETY 43 (1997) (noting that since the 1980s "there have been profound changes in the nature of public administration" that have "emphasize[d] cost control, financial transparency, the autonomization of organizational sub-units, the decentralization of management authority, the creation of market and quasi-market mechanisms separating purchasing and providing functions and their linkage via contract"). A general system of unplanned, post hoc payments for inventors on the basis of their commitment to the collective good would be almost impossible to square with the mentality of audit that has brought with it different understandings of trust and risk. Indeed, we acknowledge that even our preferred model of open-ended and flexible prize competitions would strain the boundaries of what is now thought to be acceptable.

145. *See Public Rewards and Innovation Policy*, *supra* note 43, at 875–76.

146. *See, e.g.*, Ralf Meisenzahl & Joel Mokyr, *The Rate and Direction of Invention in the British Industrial Revolution: Incentives and Institutions*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY REVISITED 443, 446–49 (Josh Lerner & Scott Stern, eds., 2012).

147. JOEL MOKYR, A CULTURE OF GROWTH: THE ORIGINS OF THE MODERN ECONOMY 4–6 (2017).

148. ALFRED NORTH WHITEHEAD, SCIENCE AND THE MODERN WORLD 96 (Simon & Schuster 1967) (1925).

149. Anton Howes, The Spread of Improvement: Why Innovation Accelerated in Britain 1547–1851, at 7 (Apr. 2017) (unpublished working paper) (cited with the author's permission), https://www.antonhowes.com/uploads/2/1/0/8/21082490/spread_of_improvement_working_paper.pdf [https://perma.cc/GY2J-LKJB].

150. *Id.*

151. *Id.* at 12, 17–18.

152. Christine MacLeod, *The Invention of Heroes*, 460 NATURE 572 (2009).

se, the effect was still to place scientists and engineers at the center of public imagination. The "elevation of inventors to fame" was one of the factors that pushed the emergent middle classes "to begin innovating on an immense scale."[153] Consequently, the landscape for innovation was characterized not just by a handful of inventors of revolutionary breakthroughs but also by an army of "tweakers" who "improved and debugged existing inventions, adapted them to new uses, and combined them in new applications."[154]

In a society with a culture of inventorship and improvement, there is reason to believe that a good deal of innovation was happening without regard to patents, rewards, or other financial inducements, with the promise of recognition and the sheer joy of creative endeavor being sufficient motivation.[155] It was an environment in which the "instinct of contrivance" was fostered and given free rein.[156] This is not to suggest that the institutional environment was unimportant. There is a good case to be made that the patent system was at least somewhat effective in providing returns to inventors from the middle of the eighteenth century.[157] There is also every reason to believe that some inventors would have hoped for recognition through the reward system.[158] The publicity that attached to the grant of rewards during this period was such that some inventors must have internalized this possibility.[159] That some such inventors may have been guilty of irrational exuberance in harboring hopes of a reward does not mean that the reward system was ineffective in spurring their efforts.[160]

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153. DEIRDRE N. MCCLOSKEY, BOURGEOIS DIGNITY: WHY ECONOMICS CAN'T EXPLAIN THE MODERN WORLD 17 (2010).

154. Meisenzahl & Mokyr, *supra* note 146, at 446.

155. This is a point that is now most often made in the relation to the production of works of fanfiction and the like, but it is a point that can equally be applied to other forms of creative endeavor, particularly in an environment where such endeavors are lauded. For a sophisticated analysis of these themes in the copyright context, see Rebecca Tushnet, *Economies of Desire: Fair Use and Marketplace Assumptions*, 51 WM. & MARY L. REV. 513 (2009).

156. *Cf.* FRANK W. TAUSSIG, INVENTORS AND MONEY-MAKERS 12–19 (1915) (describing inventors' inclination to invent as influenced by both instincts and environmental influences).

157. *See* SEAN BOTTOMLEY, THE BRITISH PATENT SYSTEM DURING THE INDUSTRIAL REVOLUTION, 1700–1852: FROM PRIVILEGE TO PROPERTY (2014).

158. Robert Burrell & Catherine Kelly, *Myths of the Medical Methods Exclusion: Medicine and Patents in Nineteenth Century Britain*, 38 LEGAL STUD. 607, 620–22 (2018).

159. *Id.*

160. In a similar vein, *see* JOEL MOKYR, THE LEVER OF RICHES 252 (1990) [hereinafter LEVER OF RICHES] (discussing the impact of Britain's admittedly flawed patent system during this period, and arguing "[i]t could thus well be that the patent system fooled would-be inventors into exerting more effort than they would have had they known how stacked the deck was against them").

There is, however, another important feature of the institutional environment that has received less attention than it deserves; namely, that it was also a period marked by regulatory innovation. The original Longitude Act may have been a failure, but on another view, it was itself an "important invention: the well-defined, goal-oriented, open innovation challenge . . . the Longitude Act remains highly relevant as the invention of a process."[161] There was an unshakable commitment to getting what society would now think of as innovation policy right, and this commitment was itself accompanied by a spirit of experimentation. This is why the period is characterized by overlapping systems of sometimes short-lived arrangements: the grant of patent extensions, pensions, prizes, and rewards were all part of a commitment to finding the best means of ensuring that existing inventors were fairly remunerated and future inventors were adequately incentivized. Therefore, it is unsurprising that in this period, there was at least one attempt to incentivize innovation through what would now be understood as a tax expenditure regime: as part of Parliament's attempt to encourage the development of new ways of transporting fish to London, legislation was passed to reduce the tolls for fish carriages.[162] Some of these regulatory innovations, including the original Longitude Act, were unquestionably ill-conceived, but they also served as markers of what society thought was important. They fed into (as well as fed off) the improving mentality that defined the era. Rewards, in particular, were used to send a signal that society valued scientific and technical endeavors; that accumulation of wealth was not the only criterion by which to judge an individual's contribution to society; that there was something noble about "giving an invention to the world with liberality."[163]

The industrial revolution remains a key reference point for scholars interested in the conditions that produce rapid technological change.[164] Therefore, it is unsurprising that debates about the merits of mission-oriented innovation policy have come to encompass Britain's use of a prize competition to stimulate innovation in the eighteenth and early nineteenth centuries.[165] However, the attention that has been

161. Spencer, *supra* note 143, at 40.

162. Fish Carriage Act 1762, 2 Geo. 3, c. 15.

163. This was the language used in Parliament to describe Jenner's decision to make his method of vaccinating against smallpox available to the public, rather than attempting to profit from secrecy. HC Deb (Mar. 15, 1802) (17) col. 203 (UK).

164. *See, e.g.*, KEALEY, *supra* note 42; Meisenzahl & Mokyr, *supra* note 146; LEVER OF RICHES, *supra* note 160, 81–112.

165. *See, e.g.*, KHAN, *supra* note 43 at 72–75; THE ENTREPRENEURIAL STATE, *supra* note 10, at 125–26; Burtona & Nicholas, *supra* note 83; Morgan, *supra* note 83.

lavished on the Longitude Prize has proven to be something of a distraction. It has caused scholars to fail to notice that it was post hoc rewards, rather than prizes, that were a central feature of Britain's innovation landscape during the period. The system of rewards both emerged from and helped strengthen a culture of innovation and improvement that has long stood out to historians as one of the central drivers of the industrial revolution.[166] Importantly, moreover, the spirit of improvement and experimentation that characterized the period also extended to the regulatory sphere, this being an additional feature of the innovation landscape that has received less attention than it deserves. The final part of the Article builds on this historical analysis and considers what lessons this analysis might have for contemporary mission-oriented policy interventions.

IV. A SUGGESTION FOR REFORM

If there are lessons to be drawn from Britain's experience during the industrial revolution, they can only be at a relatively high level of abstraction. Public life was markedly different in the eighteenth and early nineteenth centuries. There was an acceptance of the role of political patronage that would now be unthinkable,[167] and controls over the use of public funds were not the same. It must also be remembered that Britain was at war with France for a significant part of the period with which this Article is concerned,[168] and as was noted in Part II of this Article, care must always be taken in extrapolating from wartime conditions. The nature of invention may also have changed in the interim. The myth of the heroic inventor working in isolation was only

166. *See supra* notes 146–56 and accompanying text.

167. The role of patronage during the period has been widely discussed, but for present purposes the most salient analyses are those that look at the role of patronage as a way of organizing and promoting science during the period. *See*, *e.g.*, Tim Fulford, *The Role of Patronage in Early Nineteenth-Century Science, As Evidenced in Letters from Humphry Davy to Joseph Banks*, 73 NOTES & RECS. 457 (2019).

168. *See, e.g.*, H. M. Scott, *The Second 'Hundred Years War', 1689–1815*, 35 HIST. J. 443, 444 (1992) ("Britain's principal adversary throughout this period was France. This has led historians to describe the decades from 1688 to 1815 as the Second 'Hundred Years War', recalling the long period of conflict between the two states during the fourteenth and fifteenth centuries. The precise applicability of this label to the eighteenth century can be contested. The generation after the Peace of Utrecht (1713) saw good relations and perhaps even a suspension of hostility: 'Seventy Years War', to denote the almost continual fighting from the 1740s to 1815, or even 'Eighty Years War', to describe the period of unbroken rivalry from the breakdown of the Anglo-French entente in 1730-1, might be more accurate. Nevertheless, the sheer continuity and intensity of Anglo-French rivalry, from 1688 to 1815 and even beyond, are striking.").

ever that, but any new initiative must be mapped onto the world of the modern university, today's technology start-ups, and so on.

Nevertheless, the British experience should perhaps tell us that there is something valuable in the public signaling of the importance of innovation and scientific endeavor. Modern societies are not, of course, entirely bereft of such signals: there are Nobel prizes, scientists and innovators are still frequently rewarded through national honors systems, and there is no shortage of press coverage of Silicon Valley's leading figures.[169] Viewed through a historical lens, however, the public attention and accolade afforded to modern-day innovators are lamentable relative to their contribution to society. One does not have to subscribe to the figure of the heroic inventor to think that society would do well to capture something of the additional attention given to scientists and scientific expertise during the pandemic.

The challenge posed by the wicked problems of our time, the increasing evidence that serious problems dog the patent system, and the potential to create stronger signaling effects all point to the importance of finding alternative ways to incentivize innovation.[170] One area in which we might productively emulate Georgian Britain is in a willingness to be adventurous when implementing such alternatives. Policy makers need to be open to experimenting with different ways of incentivizing innovation, including through the tax system, public procurement programs, intellectual property reform, and prizes. It needs to be accepted that some initiatives will fail, and even if an intervention is shown to work in one field, it may not be applicable in

169. *See, e.g.*, Tom Hannen, Ryan Croke & Dan Dominy, *This Tesla Co-founder Has a Plan to Recycle Your EV Batteries*, FIN. TIMES (Sept. 15, 2021), https://www.ft.com/video/d59734d9-5745-46d1-afbe-622c200b3783 [https://perma.cc/N9AW-JSYT]; Fani Papageorgiou, *Peter Thiel, Jeff Bezos and the Quest for Immortality*, FIN. TIMES (September 13, 2021), https://www.ft.com/content/681fa287-f9ff-47f3-9f44-c0736ee0ab53 [https://perma.cc/YA96-9CVQ]; Andrew Hill, *'CEO Speak' on Show in the Billionaire Space Race'*, FIN. TIMES (Sept. 8, 2021), https://www.ft.com/content/3c4023ac-19ee-4e0f-a76f-5df118e82b41 [https://perma.cc/C24H-M9DS]; James Fontanella-Khan, Mark Vandevelde & Simeon Kerr, *Bill Gates Vehicle Buys $2.2bn Stake in Four Seasons from Saudi Royal in Dubai*, FIN. TIMES (Sept. 8, 2021), https://www.ft.com/content/3889fdcd-b151-4540-ae29-3a0f54216c1c [https://perma.cc/YB9D-2NLK]; Anjana Ahuja, *Silicon Valley's Billionaires Want to Hack the Ageing Process*, FIN. TIMES (Sept. 7, 2021), https://www.ft.com/content/24849908-ac4a-4a7d-b53c-847963ac1228 [https://perma.cc/6GAQ-L9XB].

170. Consider, for example, empirical work that demonstrates that "patent assertion entities" do indeed generally act as patent trolls, extracting rents from potential defendants, rather than acting as more benign innovation intermediaries as some scholars had claimed. Lauren Cohen, Umit Gurun & Scott Duke Kominers, *Empirical Evidence on the Behavior and Impact of Patent Trolls: A Survey*, *in* PATENT ASSERTION ENTITIES AND COMPETITION POLICY (D. Daniel Sokol ed., 2017); *see also* Mark A. Lemley & A. Douglas Melamed, *Missing the Forest for the Trolls*, 113 COLUM. L. REV. 2117 (2013) (arguing that patent trolls are merely symptomatic of larger failings of the patent system).

another. Concomitantly, policy makers need to be willing to abandon policy instruments and programs when the evidence shows that they are not producing the intended results. At present, this is not occurring. For example, consider the introduction of "patent box" regimes, that is, a lower corporate tax rate for income derived from patent royalties.[171] These began life as a good faith attempt by policy makers to incentivize research and development, but they continue to proliferate despite increasing evidence that they do little to promote innovation.[172]

A call for experimentation and acceptance of risk does not, however, mean that we start with a blank sheet of paper. As discussed in the first part of this Article, there is already a good deal of evidence about interventions that are most likely to be successful—namely, those that preserve space for scientific and technical freedom, and avoid centralization. This needs to be kept in mind if there is a move towards greater use of public procurement as an innovation policy lever. It is also, however, something that needs to be borne in mind when designing prize competitions. As has already been intimated, there has been a resurgence of interest in prizes over recent years. In the United Kingdom, in addition to Longitude 2014 discussed above, the National Health Service has experimented with Innovation Challenge Prizes to improve outcomes for patients suffering from dementia and other serious diseases.[173] In the United States, there has been a significant increase in the use of prize competitions since the passage of the America COMPETES Reauthorization Act of 2010,[174] which enables federal agencies to run prize competitions related to the agency's mission.[175] It has been reported that in the first ten years or so following

171. GARY GUENTHER, CONG. RSCH. SERV., R44829, PATENT BOXES: A PRIMER 2 (2017) https://sgp.fas.org/crs/misc/R44829.pdf [https://perma.cc/TV2Z-ZPB7] ("In general, a patent box is a tax break for business income arising from the commercial exploitation of qualified IP. The break consists of taxing a company's qualified IP at a relatively low rate. This reduction in taxation can be achieved directly by imposing a low tax rate on a company's income from royalties or licensing fees related to eligible IP or from the sale of such property, and indirectly by imposing the same low rate on the income a company receives from the sale of goods and services with embedded IP owned by the company.").

172. *See, e.g.*, Fabian Gaessler, Bronwyn H. Hall & Dietmar Harhoff, *Should There Be Lower Taxes on Patent Income?*, RSCH. POL'Y, Jan. 2021, at 1, 1 (arguing that their "results call into question whether the patent box is an effective instrument for encouraging innovation in a country, rather than simply preventing or facilitating the shifting of corporate in-come to low tax jurisdictions").

173. *See, e.g.*, DEP'T OF HEALTH & SOC. CARE, *NHS Innovation Challenge Prize for Dementia: Winners* Announced, GOV.UK, https://www.gov.uk/government/news/nhs-innovation-challenge-prize-for-dementia-winners-announced [https://perma.cc/2S85-VDEL] (Sept. 10, 2014).

174. America Competes Reauthorization Act of 2010, Pub. L. No. 111-358, 124 Stat. 3983 (codified as amended in scattered sections of 5, 15, 20, 33, 42, 51 U.S.C.).

175. *Id.*

the passage of this legislation, federal agencies conducted nearly one thousand prize competitions, and by 2018, the total amount of prize money offered exceeded $37 million.[176] Alongside these public initiatives, a number of private innovation prizes have been established over recent years, including the XPrize for carbon removal and sequestration backed by a $100 million donation from Elon Musk and the Musk Foundation.[177] Experimentation with prizes is to be welcomed. Moreover, to be meaningful, any evaluation of the impact of prizes ought to seek to quantify their role in publicizing innovation challenges and channeling attention and expertise towards a problem.

Nevertheless, it is notable that recent prizes have tended to be defined by relatively rigid victory criteria.[178] This is an approach that finds favor in much of the literature on prize design.[179] For example, in one influential paper, Thomas Kalil emphasizes the importance of establishing "a specific objective and a clear definition of the victory conditions."[180] Yet Kalil also notes that "enunciating the most productive set of conditions is an art, not a science, and prize sponsors have sometimes had problems articulating the criteria."[181] In a similar vein, other respected scholars in the field are generally supportive of using specific victory criteria, despite noting that a factor likely to increase governance and management costs is "the difficulties in specifying ex ante all that can happen," such that "rule modifications and adaptations along the way are to be expected."[182]

In contrast, the authors are wary of prize competitions built around rigidly defined criteria. By defining very specific goals, prize competitions of this type may restrict the natural creativity of scientists and discourage exploration of tangential ways of tackling the underlying problem. Moreover, rigidly defined prize competitions may be particularly unhelpful when we are looking to tackle a complex,

176. MARCY E. GALLO, CONG. RSCH. SERV., R45271, FEDERAL PRIZE COMPETITIONS 7 (2020), https://sgp.fas.org/crs/misc/R45271.pdf [https://perma.cc/S5Z7-39DZ].

177. *$100m Prize for Carbon Removal*, XPRIZE, https://www.xprize.org/prizes/elonmusk [https://perma.cc/N7QN-UQAJ] (last visited Sept. 15, 2021).

178. *See, e.g.*, *Prize Rules*, LONGITUDE PRIZE, https://longitudeprize.org/prize-rules/ [https://perma.cc/3YTG-E64Q] (last visited Jan. 27, 2022) (requiring that tests must be able to give a result to the user in "less than 30 minutes").

179. *See infra* notes 180–82 and accompanying text.

180. Thomas Kalil, *Prizes for Technological Innovation* 20 (The Brookings Inst., Discussion Paper 2006–08, 2006), https://www.brookings.edu/wp-content/uploads/2016/06/200612kalil.pdf [https://perma.cc/SLF3-MSJM].

181. *Id.*

182. Fiona Murray, Scott Stern, Georgina Campbell & Alan MacCormack, *Grand Innovation Prizes: A Theoretical, Normative, and Empirical Evaluation*, 41 RSCH. POL'Y 1779, 1791 (2012).

multifaceted, or "wicked" problem since they may lead to undue attention being given to some facets of the problem or cause us to look in entirely the wrong direction for the best solution.

A model worthy of further study is one that seeks to combine the mission-focused steer of prizes with the expansive culture of a rewards system. As a preliminary point, it is important to note that the distinction between prizes and rewards is one that needs to be handled with care. The more the subject of "a prize" is described in broad terms, and the more there is discretion to adjust the size of the prize after the revelation of the nature of the invention, the closer a prize is to a reward.[183] Consideration ought to be given to establishing a small number of prize funds targeted at broad areas of public concern, with prizes to be awarded by a panel of experts based entirely on an ex post assessment of the contribution made by the claimant's breakthrough, including the scalability of any new technology. A prize fund modeled on these lines could be empowered to make interim payments to help enable and encourage further development of promising ideas whilst eschewing the award of formal milestone prizes that have found favor in some recent prize competitions.[184]

There is, moreover, a historical analog for this sort of system.[185] It lies in the Board of Longitude, but it does so in the period after the resolution of Harrison's timepiece controversy.[186] Over time the Board's mandate was expanded to allow it to make payments in relation to a broad range of nautical inventions.[187] The Board's very existence sent a signal as to the types of inventions that were important, and the Board could give further guidance as to research priorities, but the attempt to prescribe narrow criteria for the award of a prize was largely abandoned.[188] A modern version of this system might see the

183. *See Public Rewards and Innovation Policy*, *supra* note 43, at 874.

184. *See, e.g.*, *$100m Prize for Carbon Removal*, *supra* note 177.

185. *See infra* notes 186–88 and accompanying text.

186. That is, after 1773. *See* Peter Johnson, *The Board of Longitude 1714-1828*, 99 J. BRITISH ASTRONOMICAL ASS'N 63, 68 (1989) ("With the award of the main prize to Harrison . . . the Board had fulfilled its role under the 1714 Act. However, it was kept in being under a new Act of 1774 which moved the emphasis away from longitude to navigation in general. The scope of the Board became much wider.").

187. *Id.*

188. This is an oversimplification of a complex topic, but the gradual expansion of the Board's remit is clear. *See id.*; *see also* Sophie Waring, *The Board of Longitude and the Funding of Scientific Work: Negotiating Authority and Expertise in the Early Nineteenth Century*, 16 J. MAR. RSCH. 55 (2014) (exploring how the Board of Longitude negotiated researchers' needs and wants while leveraging its authority to judge scientific expertise). The flexible role of the Board in granting monetary awards meant that after 1800, the Board and Parliament presented alternative avenues by which inventors might seek recompense and recognition for their efforts. *See Public Rewards and Innovation Policy*, *supra* note 43, at 868. The Board had a number of ways of

establishment of flexible and open-ended prize funds in the areas of AMR and climate change. This would provide an opportunity to assess the performance of flexible-prize funds against those of the more targeted Longitude 2014 and X prize for carbon removal (albeit at the cost of creating some overlap and duplication of effort).[189] The creation of prize funds modeled along these lines would mark a willingness to experiment with the widest possible range of methods of incentivizing innovation.

V. CONCLUSION

Serious challenges beset the world. The United Nation's Intergovernmental Panel on Climate Change (IPCC) report published in August 2021 has warned that it is already too late to avoid serious impacts from climate change;[190] the current pandemic is far from over in most of the world;[191] and AMR is already killing hundreds of thousands of people each year.[192] In the face of these challenges, it takes an almost religious commitment to the idea of a small state to rule out a greater role for a mission-oriented approach to innovation policy. But getting a mission-oriented approach right is no simple task, particularly outside the context of an acute emergency. It is also important to avoid the complacent assumption that once a chronic emergency becomes sufficiently serious, it will be reclassified in popular and political imagination as an acute emergency and thereby become capable of galvanizing the type of commitment to collective action seen during wartime or a pandemic. The relationship between innovation and adversity is complex.[193] Innovation ecosystems are multifaceted and vary significantly between technology sectors. Innovation policy pluralism and a willingness to experiment with new and rediscovered

signaling its priorities, including by establishing sub-committees (although the history of these sub-committees is itself complex). *See* Johnson, *supra* note 186, at 63–65. We also acknowledge that the 1819 prize for discovering the north-west passage was run on the basis of precise navigational criteria, but this does not detract from the general thrust of the point being made here. *Id.* at 66.

189. See *supra* notes 86–87, 177 and accompanying text.

190. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 47.

191. At the time of preparing the final revisions to this paper, the United Kingdom has hit its highest ever number of daily cases thanks to the Omicron variant that is sweeping the country. Philip Georgiadis, Jasmine Cameron-Chileshe & Laura Hughes, *UK Hits Record Number of Daily Coronavirus Cases*, FIN. TIMES (Dec. 15, 2021), https://www.ft.com/content/21f34dca-362d-499f-afbd-a608ef44d211 [https://perma.cc/NB6Y-ZS4Q].

192. *Supra* notes 2, 5–6 and accompanying text.

193. For an important recent article developing this theme, see Clark D. Asay & Stephanie Plamondon Bair, *Innovation in Adversity*, 49 FLA. STATE U. L. REV. (forthcoming).

policy levers are therefore essential.[194] History can offer some useful insights but not easy answers.

194. The language of "innovation policy pluralism" is taken from Daniel J. Hemel & Lisa Larrimore Ouellette, *'Beyond the Patents-Prizes Debate'*, 92 TEX. L. REV. 303 (2013) (arguing for "innovation policy pluralism").