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INNOVATION POLICY AND CHRONIC EMERGENCIES

ROBERT BURRELL* AND CATHERINE KELLY**

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 policymakers 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 accompanies acute emergencies, there is a risk that mission-oriented approaches may fail to deliver the 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 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 awarded post hoc with relatively little prescription as to the problems at which

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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 we should be open to reconsidering the way in which we 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 that proponents of mission-oriented innovation policies often advocate.

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INTRODUCTION

By September 2021, the COVID-19 pandemic was estimated to have killed roughly 4.6 million people.¹ Over the period that we have been living with COVID-19, global deaths from Anti-Microbial Resistance (“AMR”) have totalled approximately 1.16 million,² and ambient air pollution has killed around 6.3 million people.³ The latter killers have been a problem 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 was dramatic, and it is a problem that demands resolution so that life can return to “normal.” Faced with this emergency, governments around the world have swung into action and have played a critical part in the progress that has been made in turning the tide of the pandemic.⁷ As Joseph Stiglitz has observed, “[the] government had a central role in the victory—from investments in basic science that enabled the rapid genomic characterization of

¹ <https://coronavirus.jhu.edu/> (last visited Sep. 15, 2021).

² As reported by The World Health Organisation (“WHO”): <https://www.who.int/news/item/29-04-2019-new-report-calls-for-urgent-action-to-avert-antimicrobial-resistance-crisis> (last visited Sep. 15, 2021).

³ The WHO reports that ambient air pollution kills 4.2 million people annually: https://www.who.int/health-topics/air-pollution#tab=tab_1 (last visited Sep. 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 BIOMED* 157 (2020). At the time of writing, slightly more than 18 months later, this suggests that ambient air 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.

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, opened for signature November 13, 1979, 1302 UNTS 217 (entered into force March 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 & ENVIRONMENT* 671, 678 (1999). For brief history of AMR, see Scott H. Podolsky, *The Evolving Response to Antibiotic Resistance (1945–2018)* 4 *PALGRAVE COMMUNICATIONS* 124 (2018) (noting that by the 1950s antibiotic resistant strains of *Staphylococcus aureus* were causing deaths worldwide).

⁵ Jim O’Neill, *Review on Antimicrobial Resistance Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations* (UK Government’s Review on Antimicrobial Resistance, 2014), 6: https://amr-review.org/sites/default/files/AMR%20Review%20Paper%20-%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf ions.

⁶*Id.*⁶

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

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 the 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 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 paper 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 accompanies acute emergencies, there is a real risk that mission-oriented approaches may fail to deliver in other situations. The suggestion that a mission-

⁸ *Id.* At 1797.

⁹ Cf. Jakob Edler, Paul Cunningham, Abdullah Gök & Philip Shapira, *Impacts of Innovation Policy: Synthesis and Conclusion* (Nesta Working Paper No. 13/21, November 2013), 1. For further discussion of the definition of “innovation policy” see, e.g. Jan Fagerberg, *Innovation Policy: Rationales, Lessons and Challenges* 31 JOURNAL OF ECONOMIC SURVEYS 497 (2017).

¹⁰ See, e.g., MARIANA MAZZUCATO, *THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE MYTHS IN INNOVATION* (2013).

¹¹ This is true for both the current pandemic and climate change. See *Countries in Special Situations Hardest Hit by Climate Crisis, Pandemic, Delegates Say, as Second Committee Continues Session* (United Nations Meetings Coverage and Press Releases, GA/EF/3551, Oct. 7, 2021): <https://www.un.org/press/en/2021/gaef3551.doc.htm> (last visited Dec. 9, 2021). It is also true for AMR: Sunil Pokharel, Shristi Raut & Bipin Adhikari, *Tackling Antimicrobial Resistance in Low-income and Middle-income Countries* 4 BMJ GLOBAL HEALTH 002104 (2019) (noting at 1 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* (Overseas Development Institute, Dec. 20, 2010, Available at SSRN: <https://ssrn.com/abstract=2782323>).

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 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 I, we develop our 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 II, we look at 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. We 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 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, they fed into and helped create a culture of innovation. In the final part of this Article, we draw on these observations to make a proposal for change, namely, that we should reconsider the way in which we 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 that are often advocated by proponents of mission-oriented innovation policies.

I. 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, led by India and South

¹² See *infra* Part II.

¹³ *Id.*

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., the resolution passed by the Chilean Chamber of Deputies on March 17, 2020. An English translation of this resolution is available at: <https://www.keionline.org/chilean-covid-resolution> (last visited Sep. 8, 2021).

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, including 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 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

¹⁹ IP/C/W/669 *Waiver from Certain Provisions of the TRIPS Agreement for the Prevention, Containment and Treatment of Covid-19. Communication from India and South Africa* (Oct. 2, 2020), <https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:IP/C/W669.pdf> (last visited Sep. 8, 2021). See also IP/C/W/669/Rev.1 *Waiver from Certain Provisions of the TRIPS Agreement for the Prevention, Containment and Treatment of Covid-19 Revised Decision Text, Communication from The African Group* (May 25, 2021), <https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:IP/C/W669R1.pdf> (last visited Sep. 8, 2021).

²⁰ Marrakesh Agreement Establishing the World Trade Organization, opened for signature April 15, 1994, 1867 UNTS 3 (entered into force January 1, 1995) annex 1C ‘Agreement on Trade-Related Aspects of Intellectual Property Rights’ (TRIPS Agreement).

²¹ 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. However, in the conditions of the pandemic, many Western governments have entered into such arrangements with potential suppliers of vaccines. For example, the European Commission concluded eight advanced purchase agreements with pharmaceutical companies as part of the EU’s strategy to tackle COVID. See *Communication from The Commission to The European Parliament, The European Council, The Council and The European Investment Bank, EU Strategy for COVID-19 vaccines* COM (2020) 245 final (noting at 3 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., UK RESEARCH AND INNOVATION, <https://www.ukri.org/our-work/tackling-the-impact-of-covid-19/> (last visited Sep. 8, 2021); SCIENCE FOUNDATION IRELAND, <https://www.sfi.ie/funding/funding-calls/covid19-rapid-response/> (last visited Sep. 8, 2021).

²³ Wellcome describes itself as “a politically and financially independent global charitable foundation, funded by a £29.1 billion investment portfolio”: <https://wellcome.org/who-we-are> (last visited Sep. 8, 2021). For details of Wellcome’s Covid programmes, see <https://wellcome.org/what-we-do/our-work/coronavirus-covid-19> (last visited Sep. 8, 2021).

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

²⁵ DANIEL GROSS & BHAVEN SAMPAT, ORGANIZING CRISIS INNOVATION: LESSONS FROM WORLD WAR II (2020). For discussion of the development of vaccines during the Second World War, see KENDALL HOYT, LONG SHOT: VACCINES FOR NATIONAL DEFENSE, Ch. 3 (2012).

²⁶ See, e.g. Filippo Reale, *Mission-oriented Innovation Policy and the Challenge of Urgency: Lessons from Covid-19 and Beyond*, 107 TECHNOVATION 102306 (2021) (arguing at 1 “finding a vaccine against SARS-CoV-2 (and

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

The resurgence of interest in the role of the state 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

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* 123-4 (2021).

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?*, THE CONVERSATION, February 3, 2020.

³⁰ INNOVATION AND SCIENCE AUSTRALIA, *AUSTRALIA 2030: PROSPERITY THROUGH INNOVATION*, <https://www.industry.gov.au/sites/default/files/May%202018/document/pdf/australia-2030-prosperity-through-innovation-full-report.pdf> (last visited Sep. 8, 2021).

³¹ In 2014 the European Union introduced ‘innovation partnerships’, the main feature of which is that innovation occurs during the performance of the contract. See Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC, in particular, recital 47 and Art. 31. Over more recent years the European Commission has been pushing for the use of these partnerships to mobilise procurement expenditure as a driver of innovation. These efforts can be traced back to the 2017 *Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions, Making Public Procurement work in and for Europe* COM/2017/0572 final. This led to the publication in 2018 of the *Guidance on Innovation Procurement*, and its revision in 2021. See *Commission Notice, Guidance on Innovation Procurement* C (2021) 4320 final.

³² See *infra* notes 33–49 and accompanying text.

³³ This language has been used by both the Australian and UK governments: *ibid.* and see, in the UK, DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY, <https://www.gov.uk/government/news/new-plans-to-put-uk-at-front-of-global-innovation-race> (last visited Sep. 8, 2021).

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 legitimizes 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 betting on races that the private sector avoids altogether.³⁸ Subsequent scholarship has, *inter alia*, demonstrated the importance of support of the Federal Government and the 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 There has even been a re-evaluation of

³⁴ As to the importance of the rise of China to the shift in Western thinking See, e.g., Eric Schmidt, *I Used to Run Google. Silicon Valley Could Lose to China*, NEW YORK TIMES, February 27, 2020, arguing: “in 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 For detailed discussion see, e.g., ORVILLE SCHELL & JOHN DELURY, *WEALTH AND POWER: CHINA'S LONG MARCH TO THE TWENTY-FIRST CENTURY* (2016).

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

³⁷ MARIANA MAZZUCATO, *THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE MYTHS IN INNOVATION* (2013).

³⁸ *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* (2019).

⁴⁰ See, e.g., Dylan Gerstel & Matthew P. Goodman, *From Industrial Policy to Innovation Strategy Lessons from Japan, Europe, and the United States* (Center for Strategic & International Studies, A Report of the CSIS Economics, September 2020), https://www.wita.org/wp-content/uploads/2020/09/200901Gerstel_InnovationStrategy_FullReport_FINAL_0.pdf. 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* (European Bank for Reconstruction and Development, Working Paper No. 216, June 2018). For further analysis of the history and modern operation of Russia’s science cities, see, e.g., Igor A. Monakhov, *Science Cities within Innovative Environments of Russia and Great Britain: Cross-Country Comparison* 174 *AKTUAL’NI PROBLEMY EKONOMIKY = ACTUAL PROBLEMS IN ECONOMICS* (2015) 220, 221 (“The history of Russian science cities can be traced back to the Soviet period, when the USSR was making enormous

Britain's industrial revolution, long 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

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

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 (2014) (focusing, in particular, on the complex system of prizes and rewards that were used to incentivise innovation during this period); ANTON HOWES, *ARTS AND MINDS: HOW THE ROYAL SOCIETY OF ARTS CHANGED A NATION* (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 defence of the traditional view see B. ZORINA KHAN, *INVENTING IDEAS: PATENTS, PRIZES, AND THE KNOWLEDGE ECONOMY* (2020).

⁴⁴ 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 organisations such as the IMF, World Bank and western governments. See John Williamson, *The Strange History of the Washington Consensus* 195 (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 *JOURNAL OF ECONOMIC SURVEYS* 350 (2009). The shift in meaning has been most pithily captured by Joseph E. Stiglitz, *The Post Washington Consensus Consensus* (Initiative for Policy Dialogue Working Paper Series, April 2007): http://policydialogue.org/files/publications/papers/Ch_4.pdf (“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 organised in 2009 to co-ordinate the international responses to the still unfolding global financial crisis. See *Today's G20 Deal will Solve Financial Crisis, Claims Gordon Brown*, *GUARDIAN*, April 2, 2009.

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

⁴⁶ See, e.g., in the UK, the Labour Party's policy paper, *Medicines for the Many: Public Health before Private Profit* (2019): <https://labour.org.uk/wp-content/uploads/2019/09/Medicines-For-The-Many.pdf>. See also, Bhaven N. Sampat & Frank Lichtenberg, *What are the Respective Roles of The Public and Private Sectors in Pharmaceutical Innovation?* 30 *HEALTH AFFAIRS* 332 (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).

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 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 role of the state 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 our 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 where the necessary “leaps”

⁴⁷ See, e.g., Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021 – The Physical Science Basis* (August 2021): <https://www.ipcc.ch/report/ar6/wg1/> (this sobering report sets out the seriousness of the challenge of anthropogenic climate change and makes a compelling case for urgent action).

⁴⁸ Naomi Oreskes, *We Need a New Manhattan Project to Deal with Climate Change*, NEW YORK TIMES, November 14, 2013.

⁴⁹ Mazzucato, *supra* note 27, ch. 6.

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).

⁵² *Id.*

⁵³ As to the Apollo missions, see, e.g., Mazzucato, *supra* note 27, ch. 4.

⁵⁴ For a comparative analysis of the success and failure of different mission-oriented policies, see Deborah D. Stine, *The Manhattan Project, the Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis* (Congressional Research Service, Report RL34645, 2009): <https://sgp.fas.org/crs/misc/RL34645.pdf> (last visited Dec. 10, 2021) (discussing the relative failure of the federal energy technology R&D programs of the 1970s, and noting at 8 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 emphasised, *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* (Centre for Comparative Economics, UCL SSEES, Economics and Business Working Paper No.131, November 2014) (noting at 13 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). To similar effect, see Stine, *id.* (arguing, “The Manhattan project had

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 has 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 that 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 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-

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, e.g., Lauran Neergaard, *Years of Research Laid Groundwork for Speedy COVID-19 Vaccines*, PBS NEWS HOUR, December 7, 2020: <https://www.pbs.org/newshour/health/years-of-research-laid-groundwork-for-speedy-covid-19-vaccines> (last visited Oct. 8 2021).

⁵⁷ See, e.g., David C Mowery, *Defense-Related R&D as a Model for “Grand Challenges” Technology Policies* 41 RESEARCH POLICY 1703 (2012).

⁵⁸ John Kay, *Mission Economy by Mariana Mazzucato – Could Moonshot Thinking Help Fix the Planet?*, FINANCIAL TIMES, January 13, 2021.

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 (R.R. Dynes, B. De Marchi and C. Pelanda eds., 1987).

⁶⁰ Tom Morgan, *Toast of Wimbledon: Standing Ovation for the Vaccine Scientist Who Smashed It*, THE TELEGRAPH, June 28, 2021.

⁶¹ Nicola Slawson, *Vaccinologist Barbie: Prof Sarah Gilbert Honoured with a Doll*, THE GUARDIAN, August 4, 2021. Of course, this emergency has also seen some sectors of the community express extreme distrust of scientists and other experts. As we have noted previously, the anti-vaxxer movement presents significant challenges to the successful role out of public health responses, see Robert Burrell & Catherine Kelly, *The COVID-19 Pandemic and the Challenge for Innovation Policy* 71(1) NORTHERN IRELAND LEGAL QUARTERLY 89 (2020).

⁶² See, e.g., ‘Covid-19 Portfolio: In the Media’ detailing the radio, television and podcast contributions of academics in Yale University’s Program in the History of Science and Medicine: <https://hshm.yale.edu/covid-19-portfolio/in-the-media> (last visited Sep. 15, 2021).

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 accompanies acute emergencies also increases 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 UK'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

⁶³ For 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 PUBLIC OPINION QUARTERLY 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: Josh Dawsey, *Poor Handling of Virus Cost Trump his Reelection, Campaign Autopsy Finds*, WASHINGTON POST, February 1, 2021.

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, in particular, her presentation at the Jackson Square Ventures book club, Dec 11, 2019: <https://www.youtube.com/watch?v=Zt14lSOzLIs> (“there was no one in Washington [asking] aren't you spending too much?” at 19mins, 31secs).

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

⁶⁶ Gross & Sampat, *supra*.

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

⁶⁸ See *infra* notes 66–70 and accompanying text.

⁶⁹ <https://www.britannica.com/biography/James-B-Conant> (last visited Sep. 15, 2020).

⁷⁰ Mark Landler & Benjamin Mueller Benjamin, *Vaccine Rollout Gives U.K. a Rare Win in the Pandemic*, THE NEW YORK TIMES, JANUARY 29, 2021.

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 perhaps 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 accompanies 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 mission-oriented intervention that some scholars would like to see more of and, in form at least, is largely indistinguishable from the strategic expedition of research related to the current pandemic. Absent, however, the impetus provided by an acute emergency, scientists and other researchers are 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

⁷¹ Karsten Werth, *A Surrogate for War—The U.S. Space Program in the 1960s*, 49 *AMERICAN STUDIES* 563, 586 (2004).

⁷² See *infra* notes 73–74 and accompanying text.

⁷³ Andrew Chaikin, *Bob Gilruth, the Quiet Force Behind Apollo*, *AIR & SPACE MAGAZINE*, February 2016.

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

⁷⁵ See, e.g., in the UK, UKRI’s “Strategic Priorities Fund”: <https://www.ukri.org/our-work/our-main-funds/strategic-priorities-fund/> and, in Australia, the Australian Research Council’s list of “National Research Priorities”: <https://www.arc.gov.au/grants/grant-application/science-and-research-priorities>.

⁷⁶ See generally Jochen Gläser & Grit Laudel, *Governing Science: How Science Policy Shapes Research Content*, 57 *EUROPEAN JOURNAL OF SOCIOLOGY* 117–168 (2016).

⁷⁷ *Id.* at 126–127 (in discussing the incorporation of public policy goals in science policies, the authors note, “Scientists responded to this new funding strategy by casting their fields and topics as particularly promising”, but also note that that “in 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(4) *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 UK).

To reiterate, none of this is a call for inaction, but it is a call for caution. There is now a body of scholarship that takes seriously the limits and possibilities of mission-oriented approaches.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 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, if any, can be learned from Britain in the eighteenth and nineteenth centuries, particularly regarding the approach to solving chronic challenges.

II. THE REWARDS OF HISTORY

⁷⁸ An excellent overview is provided by Richard R. Nelson, *The Moon and the Ghetto Revisited* 38 SCI PUBLIC POLICY 681 (2011). 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”. 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’” (at 687), but this observation by itself does not tell us when and how government intervention can produce meaningful results.

⁷⁹ See, e.g., Conant, *supra*, 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”.

⁸⁰ Kay, *supra*.

⁸¹ O’Mara, *supra*, 52.

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 policymakers. 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.

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

⁸² That the industrial revolution was characterised 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, most famously, ERIC HOBSBAWM, *INDUSTRY AND EMPIRE* (1974) (arguing that it was only once the UK 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 (at 60) 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 148–156 and accompanying text. For an excellent and accessible historiography of the industrial revolution, see JOSEPH E. INIKORI, *AFRICANS AND THE INDUSTRIAL REVOLUTION IN ENGLAND* (2002), 89–155. For an earlier, but still influential and important historiography, see R. M. Hartwell, *The Causes of the Industrial Revolution: An Essay in Methodology* 18 *ECONOMIC HISTORY REVIEW* 164 (1965).

⁸³ See, e.g., Khan, *supra*, 72-75; Mazzucato, *supra* note 27, at 125-126; M. Diane Burtona and Tom Nicholas, *Prizes, Patents and the Search for Longitude* 64 *EXPLORATIONS IN ECONOMIC HISTORY* 21 (2017); Jaison G. Morgan, *Inducing Innovation Through Prizes* 3 *INNOVATIONS: TECHNOLOGY, GOVERNANCE, GLOBALIZATION* 105 (2008).

⁸⁴ *Id.*

⁸⁵ *Id.*

⁸⁶ <https://longitudeprize.org/> (last visited Sep 14, 2021). The idea is that this will 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, 14 June 2013 <https://www.bbc.co.uk/news/uk-politics-22892443> (last visited Dec. 10, 2021) (noting, for example, that the Prime Minister stated “The original Longitude Prize stimulated a solution to a great technical problem of the time - and it was won by an 'outsider'”).

need to be careful about the lessons that history has to offer. As argued in detail elsewhere,⁸⁸ and as outlined below, it should at the very least 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 the period with which we are concerned, 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 centuries, and 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, 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

⁸⁸ Burrell and Kelly, *supra* note 27.

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

⁹⁰ Khan, *supra*, 74.

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: <http://www.who.int/mediacentre/factsheets/smallpox/en/> (last visited Dec. 15 2021). 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 medical 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 INTERNATIONAL JOURNAL OF 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. 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 “For 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”: Robert M. Feibel, *John Vetch and the Egyptian Ophthalmia* 28 SURVEY OF OPHTHALMOLOGY 128, 128 (1983). 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 CANADIAN BULLETIN OF MEDICAL HISTORY 321. 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), ch.3. 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 MEDICINE 1862 (2006). However, during the period with which we 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 romanticised image was complex and that 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 BULLETIN OF THE HISTORY OF MEDICINE 458 (2000).

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 we 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. Our research revealed a complex pattern of state intervention in science and technology in the eighteenth and nineteenth centuries.⁹⁴ State intervention came in diverse guises and was not by any means 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 We have argued elsewhere that post hoc rewards were such a prominent part of the innovation landscape during the industrial revolution that 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, with no ex ante guidance as to the categories of endeavor that might attract parliamentary approval.⁹⁹ These rewards were used by the British state 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

⁹² See HANNAH NEWTON, *RECOVERY FROM ILLNESS IN EARLY MODERN ENGLAND* (2018), in particular, 9-14.

⁹³ Burrell & Kelly, *supra* note 43.

⁹⁴ *Id.*

⁹⁵ *Id.*

⁹⁶ *Id.*

⁹⁷ *Id.* See also Robert Burrell & Catherine Kelly, *Parliamentary Rewards and The Evolution of the Patent System* 74(3) *CAMBRIDGE LAW JOURNAL* 423 (2015).

⁹⁸ Burrell & Kelly, *supra* note 43, at 886.

⁹⁹ *Id.* at 873-874.

¹⁰⁰ *Id.*

¹⁰¹ *Id.*

¹⁰² Providing the equivalent current value is complex. For example, if one takes this sum at 1800 (as representing more or less the mid-point in the system of Parliamentary payments) commonly accepted methods of conversion produce a range of slightly more than £14,000,000 to considerably in excess of £800,000,000. For current purposes, however, the most useful comparator is that of equivalent 'economic status' which in 2013 (when we

payment of £30,000 to Edward Jenner for developing the smallpox vaccine,¹⁰³ but smaller sums were awarded for improvements in textile manufacture,¹⁰⁴ dyes,¹⁰⁵ ship repair,¹⁰⁶ safety at sea,¹⁰⁷ paper making,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 the award of a lump sum, there were 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” canon 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 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 The only one of these bodies that is now remembered is the Board of Longitude, but there were also bodies charged with improving agriculture and with specific responsibility for Scotland.¹¹⁶

were creating our dataset) would have equated to £206,800,000: www.measuringworth.com (last visited Sep. 8, 2021).

¹⁰³ Burrell & Kelly, *supra* note 43, at 860, 863. *See also* JOHN BARON, THE LIFE OF EDWARD JENNER (1838) chs. 1–2; RICHARD B. FISHER, EDWARD JENNER 1749–1823 (1991), ch. 6.

¹⁰⁴ Burrell & Kelly, *id.* at 886.

¹⁰⁵ *Id.* at 861, 862, 863.

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.*

¹¹³ *Id.* at 865–868. As to the ordinary term of protection, *see* Statute of Monopolies 1624, 21 James I, c. 3 (Eng.) § 6.

¹¹⁴ Burrell & Kelly, *supra* note 43.

¹¹⁵ *Id.* at 868–869.

¹¹⁶ *Id.* at 870–871.

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, payments being made by the Admiralty to inventors of improved anchors and methods of raising ships on blocks.¹¹⁹

Moreover, 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, we have discovered that rewards were given to inventors in the early

¹¹⁷ *Id.* at 869.

¹¹⁸ *Id.*

¹¹⁹ *Id.*

¹²⁰ *See generally*, DEREK HUDSON & KENNETH LUCKHURST, *THE ROYAL SOCIETY OF ARTS, 1754–1954* 12 (1954).

¹²¹ *Id.* at 870.

¹²² *See infra* note 123 and accompanying text.

¹²³ Hudson & Luckhurst, *supra*, at 12.

¹²⁴ *See infra* note 124 and accompanying text.

¹²⁵ Burrell & Kelly, *supra* n 43, at 871.

¹²⁶ *See infra* notes 127-131 and accompanying text.

¹²⁷ Aaron Graham, *Patents and Invention in Jamaica and the British Atlantic before 1857* 73 *ECONOMIC HISTORY REVIEW* 954–957(2020).

Australian colonies,¹²⁸ where they were 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 with and intersected with rewards granted by other bodies, with the Royal Society of Arts 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 that was 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 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 that this money would be distributed in “premiums for essays on breaking up grasslands.”¹³⁴ Even when granting rewards directly,

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. The grant of land to Macarthur is noted, for example, in the obituary that was published to mark the centenary of his death, *John Macarthur* THE SYDNEY MORNING HERALD, April 7, 1934 and is recorded in his entry in the AUSTRALIAN DICTIONARY OF BIOGRAPHY, <https://adb.anu.edu.au/biography/macarthur-john-2390>. The right of King to acquire crown land at a reduced price is similarly recorded in the AUSTRALIAN DICTIONARY OF BIOGRAPHY, <https://adb.anu.edu.au/biography/king-james-2307>.

¹²⁹ As documented, for example, in ROBERT HUGHES THE FATAL SHORE: THE EPIC OF AUSTRALIA'S FOUNDING (1986).

¹³⁰ See generally, Henry Trueman Wood, *The Royal Society of Arts IV—The Society and the Colonies (1754-1847)* 59 JOURNAL OF THE ROYAL SOCIETY OF ARTS 1030 (1911). See also D. G. C. Allan, "Dear and Serviceable to Each Other": Benjamin Franklin and the Royal Society of Art 144 PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY 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, respectively, 40 TRANSACTIONS OF THE SOCIETY, INSTITUTED AT LONDON, FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES, AND COMMERCE 230 (1822); 51 TRANSACTIONS OF THE SOCIETY, INSTITUTED AT LONDON, FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES, AND COMMERCE 90 (1836-7).

¹³² See *infra* notes 134-135 and accompanying text.

¹³³ See *infra* notes 134-135 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* (31 May & 11 June, 1802).

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 these instances, the system remained entirely decentralized, with the maximum possible latitude being left for scientific creativity.

Against this background, it is ironic that it is the Longitude Prize that attracts so much attention in modern scholarship.¹³⁶ The Longitude Prize was not regarded as a success by contemporaries,¹³⁷ and it is notable that it 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 something both in the argument that Harrison was unfairly treated by the scientific establishment of the day because of his background,¹⁴⁰ and 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

¹³⁵ Burrell & Kelly, *supra* note 43, at 864 (discussing, for example, the payments to Sir William Congreve to enable him to continue his experiments with 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*, 72-75; Mazzucato, *supra* note 34, at 125-126.

¹³⁷ Katy Barrett, “Explaining” themselves: *The Barrington Papers, the Board of Longitude, and the Fate of John Harrison* (2011) 65 NOTES AND RECORDS OF THE ROYAL SOCIETY OF LONDON 145 (2011) (examining the efforts of the Commissioners of the Board of Longitude to defend their actions to an increasingly skeptical Parliament).

¹³⁸ 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* (Marie N. Bourguet, Christian Licoppe and H. Otto Sibum eds., 2002).

¹⁴² Siegel, *supra* note 138.

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 recreation of a comprehensive system of post hoc financial rewards given modern controls on the dispersal of public funds.¹⁴⁴ Moreover, given the undoubted problems of political patronage that dogged the operation of the reward system,¹⁴⁵ it is far from clear that recreation 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

¹⁴³ Robin W. Spencer, *Open Innovation in the Eighteenth Century: The Longitude Problem* 55 RESEARCH TECHNOLOGY MANAGEMENT 39 (2012).

¹⁴⁴ See MICHAEL POWER, *THE AUDIT SOCIETY* (1997) (Power notes 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” (at 43). 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 Burrell & Kelly, *supra* n 43, at 875–876.

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* (Josh Lerner & Scott Stern, eds., 2012).

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

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

¹⁴⁹ Anton Howes, *The Spread of Improvement: Why Innovation Accelerated in Britain 1547-1851* (Working Paper, April 2017) https://www.antonhowes.com/uploads/2/1/0/8/21082490/spread_of_improvement_working_paper.pdf (last visited Oct. 8 2021, unpublished paper cited with the author’s permission).

¹⁵⁰ *Id.* 7.

¹⁵¹ *Id.* 12, 17-18.

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

Macleod has argued, the transformation of inventors into national heroes was more about domestic politics than the desire to promote science or technology per 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

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

¹⁵⁴ Meisenzahl & Mokyr, *supra*, 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 endeavour, particularly in an environment where such endeavours 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).

¹⁵⁷ 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 (2018) at 620-622.

¹⁵⁹ *Id.*

¹⁶⁰ In a similar vein, see JOEL MOKYR, *THE LEVER OF RICHES* 252 (1990) (discussing the impact of Britain’s admittedly flawed patent system during this period, and arguing “It 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. It is therefore 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 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

¹⁶¹ Spencer, *supra*, 40.

¹⁶² Fish Carriage Act 1762, 2 George III, 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: 15 March 1802, HC Deb (1802) 203 (UK).

¹⁶⁴ See, e.g., Kealey, *supra*; Meisenzahl & Mokyry, *supra*; Mokyry, *supra* note 160, in particular, ch. 5.

¹⁶⁵ See *supra* note 83.

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.

III. 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 we are concerned,¹⁶⁸ and as was noted in Part I of this paper, 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 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

¹⁶⁶ See *supra* notes 146–156 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 organising 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 AND RECORDS: THE ROYAL SOCIETY JOURNAL OF THE HISTORY OF SCIENCE 457 (2019).

¹⁶⁸ See, e.g., H. M. Scott, *The Second 'Hundred Years War', 1689–1815*, 35 THE HISTORICAL JOURNAL 443–469 (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").

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 potential value of the signaling effect, the challenge posed by the wicked problems of our time, and the increasing evidence of the problems that dog the patent system should make us welcome attempts to find alternative ways of incentivizing innovation.¹⁷⁰ One area in which we might productively emulate Georgian Britain is in a willingness to be adventurous when implementing such alternatives. Policymakers 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 well not work in another. Concomitantly, policymakers need to be willing to abandon policy instruments and programs when the evidence is 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 policymakers to incentivize research and development,

¹⁶⁹ See, e.g., the following in the FINANCIAL TIMES in the period September 1 – September 15, 2021: Tom Hannen, *This Tesla Co-founder has a Plan to Recycle your EV Batteries*, FINANCIAL TIMES, September 15, 2021; Fani Papageorgiou, *Peter Thiel, Jeff Bezos and the Quest for Immortality*, FINANCIAL TIMES, September 13, 2021; Andrew Hill, *‘CEO Speak’ on Show in the Billionaire Space Race*, FINANCIAL TIMES, September 9, 2021; James Fontanella-Khan, Mark Vandeveld & Simeon Kerr, *Bill Gates Vehicle Buys \$2.2bn Stake in Four Seasons from Saudi Royal in Dubai*, FINANCIAL TIMES, September 8, 2021; Anjana Ahuja, *Silicon Valley's Billionaires want to Hack the Ageing Process*, FINANCIAL TIMES, September 7, 2021.

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 COLUMBIA LAW REVIEW 2117 (2013) (arguing that patent trolls are merely symptomatic of larger failings of the patent system).

¹⁷¹ Gary Guenther, *Patent Boxes: A Primer* (Congressional Research Service, Report R44829, 2017): <https://sgp.fas.org/crs/misc/R44829.pdf> (last visited Dec. 10, 2021) (noting at 2 “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”).

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 that 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 years following 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.

¹⁷² See, e.g., Fabian Gaessler, Bronwyn H. Hall & Dietmar Harhoff, *Should there be Lower Taxes on Patent Income?* 50 RESEARCH POLICY 104129 (2021) (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” at 1).

¹⁷³ See, e.g., <https://www.gov.uk/government/news/nhs-innovation-challenge-prize-for-dementia-winners-announced> (last visited Sep. 15, 2021).

¹⁷⁴ Pub. L. No. 111-358, 124 Stat. 3983.

¹⁷⁵ *Id.*

¹⁷⁶ Marcy E. Gallo, *Federal Prize Competitions* (Congressional Research Service, Report R45271, 2020): <https://sgp.fas.org/crs/misc/R45271.pdf> (last visited Sep. 15, 2021).

¹⁷⁷ <https://www.xprize.org/prizes/elonmusk> (last visited Sep. 15, 2021).

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 that is 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. It may be that by defining very specific goals, prize competitions of this type restrict the natural creativity of scientists and discourage exploration of tangential ways of tackling the underlying problem. Rigidly defined prize competitions may be particularly unhelpful when we are looking to tackle a complex, 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 system of rewards. 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 nature of the invention has been revealed, 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

¹⁷⁸ See, e.g., the prize rules governing Longitude 2014: https://longitudeprize.org/wp-content/uploads/sites/74/2021/05/Longitude_Prize_Rules-2020.pdf (requiring, for example, that “tests must be able to give a result to the user in less than 30 minutes”).

¹⁷⁹ See *infra* notes 218–220 and accompanying text.

¹⁸⁰ Thomas Kalil, *Prizes for Technological Innovation* 20 (The Brookings Institution, 2006), 20: <https://www.brookings.edu/wp-content/uploads/2016/06/200612kalil.pdf> (last visited Sep. 15, 2021).

¹⁸¹ *Id.*

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

¹⁸³ See further Burrell & Kelly, *supra* n 43, at 874.

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 controversy over Harrison's timepiece had been resolved.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 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.

CONCLUSION

Serious challenges beset the world. The U.N.'s Intergovernmental Panel on Climate Change (IPCC) report published in August 2021 has warned that it is already too late to avoid serious

¹⁸⁴ See, e.g., <https://carbon.xprize.org/prizes/elonmusk> (last visited Sep. 15, 2021).

¹⁸⁵ See *infra* notes 186-188 and accompanying text.

¹⁸⁶ That is, after 1773. See, Peter Johnson, *The Board of Longitude 1714-1828* 99 JOURNAL OF THE BRITISH ASTRONOMICAL ASSOCIATION 63 (1989); (noting at 68 that "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, Johnson, *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 JOURNAL FOR MARITIME RESEARCH 55 (2014). 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 Burrell and Kelly, *supra* note 43 at 868. The Board had a number of ways of signalling its priorities, including by establishing sub-committees (although the history of these sub-committees is itself complex). 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.

¹⁸⁹ See *supra* notes 86-87 and accompanying text, and note 177 and accompanying text, respectively.

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 to innovation policy 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 policy levers are therefore essential.¹⁹⁴ History can offer some useful insights, but not easy answers.

¹⁹⁰ *Supra* note 47.

¹⁹¹ At the time of preparing the final revisions to this paper, the UK has hit its highest ever number of daily cases thanks to the Omicron variant that is sweeping the country. See, e.g., Philip Georgiadis, Jasmine Cameron-Chileshe and Laura Hughes, *UK Hits Record Number of Daily Coronavirus Cases*, FINANCIAL TIMES, December 15.

¹⁹² *Supra* notes 2, 5-6 accompanying text.

¹⁹³ For an important recent article developing this theme, see Clark D. Asay & Stephanie Plamondon Bair, *Innovation in Adversity* 49 FLORIDA STATE UNIVERSITY LAW REVIEW (forthcoming).

¹⁹⁴ The language of "innovation policy pluralism" is taken from Hemel & Larrimore Ouellette, *supra*.