Democratic Engagement and the Republic of Science

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The election of Donald Trump, who has been characterized as "the first anti-science president," provides a fruitful opportunity to examine federal science policy. Following World War II, federal policy prioritized significant research funding and scientific autonomy, contributing to what Michael Polanyi called a "Republic of Science." In subsequent decades, science policy shifted toward encouraging applied research, commercialization, and greater interaction among the "triple helix" of academia, government, and industry. For some observers, the Trump administration portends a new chapter in federal science policy characterized by decreased funding and increased politicization. At this potential inflection point, this brief Article makes two claims. First, contrary to prevailing political trends, it argues for robust federal funding for science. In addition to long-term and unpredictable benefits, publicly funded research enhances human capital, drives private-sector innovation, and advances immediate policy objectives of job creation and economic growth. Second, this Article argues for both significant autonomy and greater democratic engagement on the part of the scientific community. While the federal government has legitimate claims on the research it funds, the scientific community should largely determine its own agenda according to its own norms and peer review processes. However, this Article rejects the notion of an insular republic of science, arguing that the scientific community should more actively communicate with and incorporate input from the broader society in which it operates.

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INTRODUCTION

The most foundational aspect of regulating future technologies is determining whether they come to exist in the first place. Accordingly, this Article assesses federal science and technology policy, which plays a critical role in generating new innovations. The emergence of the Trump administration holds significant implications for the development of science and technology, and scientists and engineers are grappling with the prospect of an administration perceived to have an anti-science bias.[1] Trump has famously rejected scientific consensus on climate change, appointed several senior officials with similar views,[2] and has generally deprioritized science in his proposed budget and policymaking.[3] This Article examines science and technology policy through the lens of a Trump presidency and in doing so explores broader themes and challenges in the federal government's relationship with science.

This Article focuses on two central aspects of science policy: the amount of public funding available for science and the degree of control the government exercises over publicly funded research. Throughout its history, federal science policy has evolved along both of those dimensions. From relatively modest beginnings, the federal government massively increased funding for scientific research following World War II, supporting what philosopher and physicist Michael Polanyi called a "Republic of Science."[4] In addition to significant funding, the federal government granted significant autonomy to scientists to pursue curiosity-driven research. Over recent decades, however, funding has declined, and federal policy has shifted toward emphasizing downstream, applied research and commercialization.[5] It remains to be seen if Trump's election signals

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[1] This is not the first time that a presidential administration has been perceived as hostile to science. *See, e.g.*, CHRIS MOONEY, THE REPUBLICAN WAR ON SCIENCE 238-61 (2005) (exploring the politicization of science during the George W. Bush administration).

[2] *See* Coral Davenport, *Climate Change and the Incoming Trump Government*, N.Y. TIMES (Dec. 19, 2016), https://www.nytimes.com/interactive/2016/12/19/us/politics/climate-change-trump-administration.html.

[3] *See* Chris Mooney, *85 Percent of the Top Science Jobs in Trump's Government Don't Even Have a Nominee*, WASH. POST (June 6, 2017), https://www.washingtonpost.com/news/energy-environment/wp/2017/06/06/trump-has-filled-just-15-percent-of-the-governments-top-science-jobs/?utm_term=.7580270bcb2f; *infra* notes 57–67 and accompanying text.

[4] Michael Polanyi, *The Republic of Science: Its Political and Economic Theory*, 1 MINERVA 54, 54 (1962).

[5] *See infra* notes 34–45 and accompanying text.

yet another chapter in the federal government's relationship with science.

This Article makes two claims. First, contrary to current political trends, it argues for robust federal funding for science. In addition to long-term and unpredictable benefits, federally funded research drives private sector innovation and advances immediate policy objectives of job creation and economic growth. Second, this Article argues for reorienting the relationship between the scientific community and the polity at large, including the federal government that significantly funds it. On the one hand, the dynamics of scientific progress and principles of individual and communal freedom weigh strongly in favor of insulating publicly funded scientists from undue political influence. While the federal government and market imperatives can legitimately influence research agendas, publicly funded scientists should enjoy significant autonomy to determine their own priorities. On the other hand, this Article also argues for greater democratic engagement by the scientific community. Rather than subsisting as an insular republic, the research community should more actively respond to the needs of society, seek greater public input into its work, and communicate its value and goals to the wider polity.

This Article unfolds in three parts. Part I offers a historical overview of federal science and technology policy, revealing evolution both in levels of public funding and the degree of government control over research agendas. Part II argues for robust federal funding for science, which provides both long-term, unpredictable benefits and tangible short-term gains. Part III argues for significant autonomy for the scientific community while also urging scientists and engineers to engage more intensively with the larger public in which they operate.

I. HISTORICAL CONTEXT

Although history resists categorization, the federal government's support for scientific research has roughly spanned three phases. Early on, the government's role was relatively modest and focused on building scientific institutions, including universities. The history of American scientific research is significantly intertwined with the history of universities, as they play a dominant role in conducting research. Higher education has long been a regional rather than national endeavor, and early American universities overwhelmingly relied on local funds rather than substantial federal support.[6] During

[6] *See* Nathan Rosenberg & Richard R. Nelson, *American Universities and Technical Advance in Industry*, 23 RES. POL'Y 323, 325 (1994).

the Civil War, however, the federal government began significantly subsidizing university research by establishing land-grant colleges under the Morrill Act of 1862.[7] Importantly, the land-grant statutes supported a highly practical kind of education emphasizing agriculture and the mechanical arts.[8] Indeed, until the early twentieth century, most university research was oriented toward "'hands-on' problem solving."[9] The federal government further developed scientific institutions by funding Agricultural Experiment Stations, which operated at land-grant colleges.[10] As another example of institution building, in 1887, the federal government established a bacteriological laboratory at the Marine Hospital in Staten Island, N.Y., which ultimately evolved into the National Institutes of Health ("NIH").[11] Federal research funding increased sharply during World War I, during which the government established the National Research Council.[12]

The second phase of federal science policy started with World War II.[13] Technological advances such as the atomic bomb and the mass

[7] Morrill Act, 7 U.S.C. §§ 301–309 (1862); *see* Jennifer L. Croissant & Laurel Smith-Doerr, *Organizational Contexts of Science: Boundaries and Relationships Between University and Industry*, *in* THE HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES 691, 692-93 (Edward J. Hackett et al. eds., 3d ed. 2007); *see also* Joshua B. Powers, *Commercializing Academic Research: Resource Effects on Performance of University Technology Transfer*, 74 J. HIGHER EDUC. 26, 45 (2003) ("[T]he economic development role for America's research universities had historically centered on the land-grant institutions . . . ."). Even before the Morrill Act of 1862, ch. 130, 12 Stat. 503 (codified as amended at 7 U.S.C. §§ 301–305, 307–309), the federal government granted land for the creation of public universities. Vernon Carstensen, *A Century of the Land-Grant Colleges*, 33 J. HIGHER EDUC. 30, 30 (1962).

[8] Yong S. Lee, *'Technology Transfer' and the Research University: A Search for the Boundaries of University-Industry Collaboration*, 25 RES. POL'Y 843, 850 (1996) ("American higher education can be said to have roots in the landgrant philosophy embodied in the Morrill Act of 1862 and the Hatch Act of 1887, which emphasize service to industry and agriculture."); *see* Peter Lee, *Patents and the University*, 63 DUKE L.J. 1, 8-9 (2013) [hereinafter Lee, *Patents*]; Richard R. Nelson & Paul M. Romer, *Science, Economic Growth, and Public Policy*, 39 CHALLENGE 9, 11 (1996).

[9] Rosenberg & Nelson, *supra* note 6, at 324.

[10] *See* 7 U.S.C.A. § 361a (West 1998); Carstensen, *supra* note 7, at 34-35.

[11] *See* Bhaven N. Sampat, *Mission-Oriented Biomedical Research at the NIH*, 41 RES. POL'Y 1729, 1730 (2012).

[12] *See* GARY W. MATKIN, TECHNOLOGY TRANSFER AND THE UNIVERSITY 18 (1990).

[13] Rosenberg & Nelson, *supra* note 6, at 334 ("World War II was a watershed in the history of American science and technology and, in particular, led to a dramatic change in the roles played by American universities in scientific and technical enterprises."); *see* MATKIN, *supra* note 12, at 20; JENNIFER WASHBURN, UNIVERSITY, INC.: THE CORPORATE CORRUPTION OF AMERICAN HIGHER EDUCATION 121 (2005); David C. Mowery & Bhaven N. Sampat, *University Patents and Patent Policy Debates in the USA,*

production of antibiotics were critical to winning the war, revealing to policymakers the value of massive public funding of science.[14] Vannevar Bush, who had served as President Franklin D. Roosevelt's chief science advisor, argued strongly for expansive federal science funding to continue after the war.[15] While there was wide consensus in favor of significant funding, debates arose over how much the government should control the research agendas of federally funded scientists. On one side, Senator Harley Kilgore (D-W. Va.) and other left-leaning politicians argued that the government should directly manage publicly funded science to satisfy social needs.[16] On the other side, Bush and others argued for significant autonomy for scientists receiving federal funds, including freedom to pursue theoretical and abstract inquiries without immediate practical application.[17] Ultimately, Bush's vision won out. While Bush highlighted particular research areas for emphasis, such as medicine and public health,[18] he also argued that science evolves in an unpredictable manner and that the most robust scientific gains would emerge from minimal government interference.[19] Consistent with scientific autonomy, government agencies began adopting peer review to select projects for federal funding.[20] As an outgrowth of Bush's vision, the federal government established the National Science Foundation ("NSF") in

1925–1980, 10 INDUS. & CORP. CHANGE 781, 789 (2001).

[14] *See* VANNEVAR BUSH, SCIENCE, THE ENDLESS FRONTIER: A REPORT TO THE PRESIDENT ON A PROGRAM FOR POSTWAR SCIENTIFIC RESEARCH 11 (1945); Henry Etzkowitz & Loet Leydesdorff, *The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University-Industry-Government Relations*, 29 RES. POL'Y 109, 116 (2000).

[15] BUSH, *supra* note 14, at 11, 31; *see* Nelson & Romer, *supra* note 8, at 9.

[16] *See* Richard R. Nelson, *The Advance of Technology and the Scientific Commons*, 361 PHIL. TRANSACTIONS ROYAL SOC'Y A 1691, 1698-99 (2003) [hereinafter Nelson, *Advance of Technology*]; Sampat, *supra* note 11, at 1729.

[17] *See* Nelson & Romer, *supra* note 8, at 9; *see also* Rosenberg & Nelson, *supra* note 6, at 333 (noting that increased federal funding coincided with movements in U.S. universities away from an excessive focus on practical application toward investigating the fundamental sciences).

[18] STEPHEN P. STRICKLAND, POLITICS, SCIENCE, AND DREAD DISEASE: A SHORT HISTORY OF UNITED STATES MEDICAL RESEARCH POLICY 22 (1972); *see also* David Blumenthal, *Academic-Industrial Relationships in the Life Sciences*, 349 NEW ENG. J. MED. 2452, 2452 (2003) (noting the substantial increase in federal support for biomedical research following World War II).

[19] *Cf.* BERNARD BARBER, SCIENCE AND THE SOCIAL ORDER 98 (1953) ("[I]n the long run, 'basic' research in industry is also 'applied' research. So also, of course, although in the somewhat longer run, is research done in the university, for all research ultimately has some application . . . .").

[20] Etzkowitz & Leydesdorff, *supra* note 14, at 116.

1950,[21] and the share of academic research supported by federal funds increased from about twenty-five percent in the mid-1930s to over sixty percent by 1960.[22]

The debates over federal science funding had deeper political and philosophical dimensions as well. The specter of fascism and communism left many observers skeptical of direct government control of scientific and technological research. Commentators were particularly wary of the perversion of science wrought by Nazi racism and eugenics as well as Soviet Lysenkoism.[23] In the postwar era, arguments for scientific freedom dovetailed with a strong drive to protect political freedom. Along these lines, Michael Polanyi argued for an autonomous "Republic of Science" that would receive public funding yet remain largely insulated from political, social, and economic influences.[24] Sociologist Robert Merton's famous characterization of scientific norms, which emphasized objectivity and universalism, further bolstered this normative vision of the autonomous scientist insulated from political and financial pressure[25] — what later scholars would characterize as "Mode 1" science.[26] Bush's policy proposals reflected and actualized this conception of scientific autonomy.[27] While the federal government would establish broad funding priorities, scientists retained significant discretion in their research programs.[28] Notably, this policy prescription rested upon a particular vision of scientific progress — called the "serendipity hypothesis" — in which unpredictable pathways drove scientific advances, thus discouraging direct governmental control of science.[29]

So began a period marked by massive federal investment in basic scientific research and significant autonomy for federally funded

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21 *See* Rosenberg & Nelson, *supra* note 6, at 334.

22 *Id.*

23 *See* Etzkowitz & Leydesdorff, *supra* note 14, at 116.

24 *See* Polanyi, *supra* note 4, at 54, 68. *But see* Yaron Ezrahi, *The Political Resources of American Science*, 1 SCI. STUD. 117, 117-18 (1971) (arguing that Polanyi's conception of scientific autonomy more accurately described science before its massive expansion due to political and market forces).

25 *See* ROBERT K. MERTON, THE SOCIOLOGY OF SCIENCE: THEORETICAL AND EMPIRICAL INVESTIGATIONS 270-78 (Norman W. Storer ed., 1973).

26 *See* MICHAEL GIBBONS ET AL., THE NEW PRODUCTION OF KNOWLEDGE: THE DYNAMICS OF SCIENCE AND RESEARCH IN CONTEMPORARY SOCIETIES 2-3 (1994).

27 *See* Rosenberg & Nelson, *supra* note 6, at 335 (describing the "major shift in the nature of university research towards the basic end of the spectrum").

28 Nelson, *Advance of Technology*, *supra* note 16, at 1698.

29 Sampat, *supra* note 11, at 1730.

scientists.[30] This model reflected a "linear" or waterfall approach to science policy in which the government invested in upstream academic research to create a "reservoir of knowledge," which would ultimately (through unpredictable pathways) flow into downstream technological advances.[31] Even during this period, however, policy tensions persisted between funding upstream versus downstream research. In parallel to open funding for curiosity-based research, the government also sponsored highly centralized, "mission-based" initiatives, such as the Apollo program. Likewise, while NIH allocated significant funds for open grants, pragmatic imperatives impacted its funding. For instance, enthusiasm about the Apollo program and a practical desire to minimize heart disease led to NIH's Artificial Heart program in the mid-1960s.[32] Similarly, a desire for greater tangible payoff from public science investments contributed to President Nixon's War on Cancer.[33]

This emphasis on tangible payoffs informed the third phase of federal science policy, which began in the 1970s and '80s. During that period, economic stagnation and decreased competitiveness relative to Europe and Japan led policymakers to seek more "return on investment" from federal science funding. At the same time, the linear model of public science funding proved to be incomplete,[34] as policymakers recognized that innovation was best served by strong, multidirectional relationships among the "triple helix" of government, academia, and industry.[35] This "cooperative model" of research rejected Bush's conception of an upstream reservoir of knowledge flowing into downstream applications and emphasized more give and

[30] *See* Thomas M. Jorde & David J. Teece, *Innovation, Cooperation and Antitrust*, 4 BERKELEY TECH. L.J. 1, 34 (1989).

[31] Timothy L. Faley & Michael Sharer, *Technology Transfer and Innovation: Reexamining and Broadening the Perspective of the Transfer of Discoveries Resulting from Government-Sponsored Research*, 3 COMP. TECH. TRANSFER & SOC'Y 109, 111 fig.1 (2005). *See generally* Lee, *Patents*, *supra* note 8, at 28-29 (discussing postwar U.S. science policy).

[32] *See* Sampat, *supra* note 11, at 1737.

[33] *See id.* at 1737-38.

[34] *See* Nelson & Romer, *supra* note 8, at 10.

[35] *See* Etzkowitz & Leydesdorff, *supra* note 14, *passim*; John M. Golden, *Biotechnology, Technology Policy, and Patentability: Natural Products and Invention in the American System*, 50 EMORY L.J. 101, 132 (2001); Elias A. Zerhouni, *NIH in the Post-Doubling Era: Realities and Strategies*, 314 SCIENCE 1088, 1090 (2006) ("In this model, research institutions take the risk of building and developing our national scientific capacity; the federal government, through a competitive peer-review process, funds the best science; and industry plays the critical role of bringing new, safe, and effective products to the public.").

take between academic and industrial research.[36] Policy and funding began to shift from supporting Mode 1 research, which is governed by theory-building and the academic interests of specific communities, to Mode 2 research, which is characterized by multidisciplinary collaboration oriented toward practical, real-world applications.[37]

As such, federal science and technology policy began increasingly supporting downstream research, collaboration, and commercialization.[38] Two statutes from 1980 illustrate this evolution. First, the Bayh-Dole Act permitted federal grantees to take title to patents arising from taxpayer-funded research.[39] The Act encouraged universities to patent federally funded inventions and then license them to private firms for commercialization. In addition to spurring technology transfer, the Act contributed to rapid increases in university patenting[40] and a shift in academic culture toward commercialization.[41] Second, the Stevenson-Wydler Technology Innovation Act directed government laboratories to transfer technology to the private sector.[42] Both statutes reoriented federal science policy toward commercializing the outputs of federally funded science. Congress further pursued this policy objective by amending the Stevenson-Wydler Act with the Federal Technology Transfer Act of 1986,[43] which established cooperative research and development agreements ("CRADAs") that allowed private companies to contract to

[36] *See* Golden, *supra* note 35, at 119-21.

[37] *See* Lutz Bornmann, *What Is Societal Impact of Research and How Can It Be Assessed? A Literature Survey*, 64 J. AM. SOC'Y FOR INFO. SCI. & TECH. 217, 218 (2013); Etzkowitz & Leydesdorff, *supra* note 14, at 116 (noting that commentators posit that Mode 2 was the original configuration of science before its academic institutionalization in the nineteenth century and that Mode 1 is a political construct aimed at justifying scientific autonomy, especially from industrial interests that funded nineteenth century universities).

[38] *See* Etzkowitz & Leydesdorff, *supra* note 14, at 116.

[39] *See* Bayh-Dole Act, Pub. L. No. 96-517, 94 Stat. 3015 (1980) (codified as amended at 35 U.S.C. §§ 200–211 (2006)); *see also* Lee, *Patents*, *supra* note 8, at 31-32.

[40] *See* DAVID C. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT IN THE UNITED STATES 104 (2004) (noting that university patenting was on the rise even before the Bayh-Dole Act and increased sharply after its enactment).

[41] *See* Lee, *Patents*, *supra* note 8, at 36-38.

[42] *See* Stevenson-Wydler Technology Innovation Act of 1980, Pub. L. No. 96-480, 94 Stat. 2311 (1980) (codified as amended at 15 U.S.C. § 3710); Golden, *supra* note 35, at 120.

[43] Federal Technology Transfer Act of 1986, Pub. L. No. 99-502, 100 Stat. 1785 (codified as amended at 15 U.S.C. §§ 3710a–3714).

use federal research resources.[44] These developments have led to a greater mix of "the market and the state, private and public sectors, science and values, producers and users of knowledge."[45]

While federal science policy has evolved over time in response to broad social and economic developments, it has also been the site of partisan battles within particular political administrations. For instance, on the eve of 9/11, the most significant policy issue facing the country was the controversy over federal funding of stem cell research. President George W. Bush withdrew federal funding for research on human embryonic stem cells derived after August 9, 2001, based on ethical concerns over the destruction of human embryos.[46] This episode cast into stark relief the deeply political nature of science funding. It also prompted other governmental entities to act. California voters, for instance, approved an ambitious state referendum to fund human embryonic stem cell research to help fill the gap left by the federal government's funding constraints.[47]

Science again became politicized during the Obama administration, particularly with its stimulus package. During the George W. Bush administration, inflation-adjusted funding for scientific and medical research decreased steadily.[48] Furthermore, during that period, the policy priorities of the Bush administration and budgetary constraints impacted NIH's research agenda, which increased funding for bioterrorism research and decreased support for tropical disease research.[49] Following the crash of global markets and the election of Barack Obama, Congress enacted the American Recovery and

[44] *Id.*

[45] Rémi Barré, *S&T Indicators for Policy Making in a Changing Science-Society Relationship*, *in* HANDBOOK OF QUANTITATIVE SCIENCE AND TECHNOLOGY RESEARCH: THE USE OF PUBLICATION AND PATENT STATISTICS IN STUDIES OF S&T SYSTEMS 115, 117 (Henk F. Moed et al. eds., 2005).

[46] *See* Press Release, Nat'l Inst. of Health Comm. Office, NIH Statement on the President's Stem Cell Address (Aug. 9, 2001), https://web.archive.org/web/20011030104932/http://www.nih.gov/news/pr/aug2001/od-09.htm; Press Release, Office of the Press Sec'y, President George W. Bush Discusses Stem Cell Research (Aug. 9, 2001), https://georgewbush-whitehouse.archives.gov/news/releases/2001/08/print/20010809-2.html (explaining that the federal government would continue to fund research on the sixty embryonic lines already in existence, but that no subsequent embryonic lines would receive funding).

[47] *See* Peter Lee, *Contracting to Preserve Open Science: Consideration-Based Regulation in Patent Law*, 58 EMORY L.J. 889, 932-33 (2009) [hereinafter Lee, *Open Science*].

[48] Haitham M. Ahmed, *Obama's Research-Funding Stimulus*, 9 LANCET INFECTIOUS DISEASES 653, 653 (2009).

[49] *See id.*

Reinvestment Act of 2009. The stimulus vastly increased federal spending and provided an opportunity to advance the policy objectives of the new administration. The stimulus package granted $21 billion in research funds to several agencies.[50] Significant science funding reflected President Obama's promise to "restore science to its rightful place," a critique of the George W. Bush administration's perceived deprioritization of science.[51]

II. ARGUMENTS FOR ROBUST SCIENCE FUNDING

The 2016 election may represent a watershed moment in federal science and technology policy, as Trump's victory has caused significant concern within the scientific community. Michael Lubell, former public affairs director for the American Physical Society, warned that "Trump will be the first anti-science president we have ever had . . . . The consequences are going to be very, very severe."[52] Robin Bell, president-elect of the American Geophysical Union, added, "There's a fear that the scientific infrastructure in the U.S. is going to be on its knees."[53] Researchers around the country in politically sensitive fields such as climate change are worried about decreased federal funding under a Trump administration.[54] These developments are particularly concerning given that while science funding has remained approximately ten percent of nondefense discretionary spending for several decades,[55] federal investment in basic science as a percentage of GDP is at its lowest level in fifty years.[56]

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[50] Jeffrey Mervis, *Scientists Start to Parse a Trump Presidency*, 354 SCIENCE 811, 812 (2016) [hereinafter Mervis, *Parse*].

[51] *See* Editorial, *Science Scorned*, 467 NATURE 133, 133 (2010). Ironically, even with the increased budget, many scientists found it was harder to obtain funding due to the significant increase in new applicants and applications. Zerhouni, *supra* note 35, at 1088. Research capacity had expanded dramatically starting around 1999, which vastly increased the demand for research dollars. *Id.*

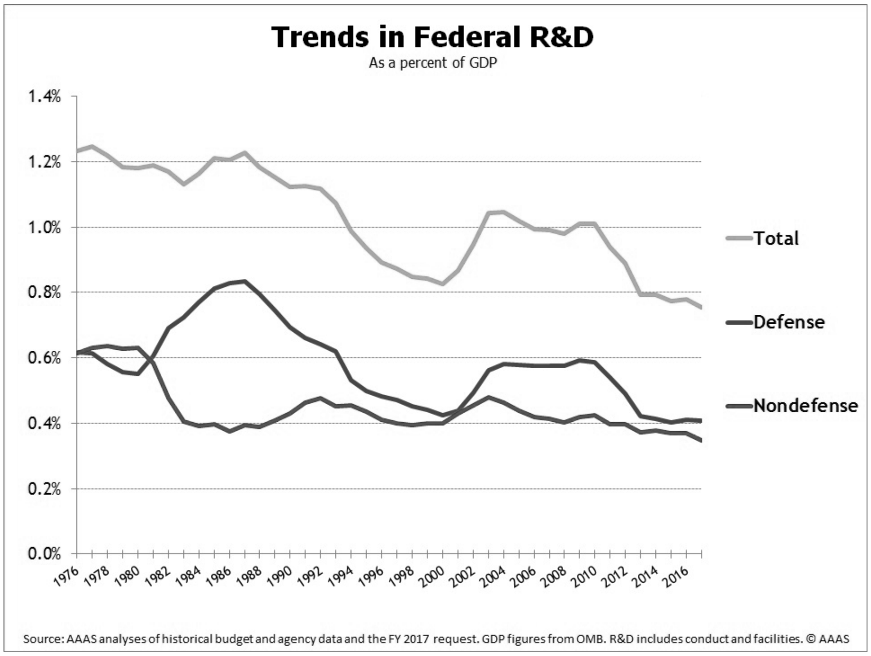
[52] Sarah Kaplan, *What Will President Trump Mean for Science?*, WASH. POST (Nov. 9, 2016), https://www.washingtonpost.com/news/speaking-of-science/wp/2016/11/09/what-will-president-trump-mean-for-science.

[53] *Id.*

[54] *See* Eric Niiler, *Scientists Prepare to Fight for Their Funding Under Trump*, WIRED (Nov. 15, 2016, 3:00 PM), https://www.wired.com/2016/11/scientists-preparing-defend-research-funding.

[55] Mervis, *Parse*, *supra* note 50, at 811.

[56] Marc Tessier-Lavigne, *In Defense of Basic Science Funding: Today's Scientific Discovery Is Tomorrow's Medical Advance*, 3 COLD SPRING HARBOR PERSP. MED. 1, 1 (2013).



Part of the fear arises from uncertainty, as Trump has not said much about science and technology policy. One notable exception, of course, is Trump's denial that human activity causes climate change and his recent withdrawal of the United States from the Paris Agreement.[57] Curiously, while Trump has famously doubted climate change and circulated debunked theories that vaccines cause autism, he has spoken favorably about space research.[58] During the campaign, candidate Trump said rather little about NIH, NSF, and gene and cell therapy,[59] though he stated in a radio interview that "I hear so much

[57] *See* Michael D. Shear, *Trump Will Withdraw U.S. from Paris Climate Agreement*, N.Y. TIMES (June 1, 2017), https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html; Donald J. Trump (@realDonaldTrump), TWITTER (Nov. 6, 2012, 11:15 AM), https://twitter.com/realdonaldtrump/status/265895292191248385?lang=en (tweeting that "[t]he concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive"). *But see* Miranda Green, *Haley: 'President Trump Believes the Climate Is Changing*,' CNN (June 4, 2017, 9:33 AM), http://www.cnn.com/2017/06/03/politics/nikki-haley-donald-trump-climate-change-cnntv/index.html ("President Donald Trump does believe in climate change and that humans have a role in it . . . .").

[58] *See* Kaplan, *supra* note 52.

[59] Terence R. Flotte, *The Science Policy Implications of a Trump Presidency*, 28 HUM. GENE THERAPY 1, 1 (2016).

about the NIH, and it's terrible."[60] Candidate Trump consistently expressed an intention to cut both government spending and taxes dramatically, which many fear would detrimentally impact federal research funding.[61]

Early indications from the Trump administration reveal a significant deprioritization of support for science. President Trump's first proposed budget[62] included drastic cuts to science funding, including cutting $6 billion from NIH, which constitutes about a fifth of the agency's budget.[63] Additionally, it proposed a general cut of about eighteen percent of the Department of Energy's ("DOE's") budget, including a decrease of $900 million for the DOE's Office of Science.[64] It further proposed eliminating the Advanced Research Projects Agency-Energy, which funds research on biofuels and batteries, and the Advanced Technology Vehicle Manufacturing Program.[65] The budget also proposed cutting $2.6 billion from the EPA (comprising 31.5% of the agency's budget), $250 million from the National Oceanic and Atmospheric Administration, and $102 million from NASA Earth Science.[66] While Congress pushed back and ultimately passed a budget that maintains and sometimes even increases science funding, Trump's proposed cuts generated major consternation in the scientific community and foreshadow future battles over science funding.[67]

In a broader sense, the Trump administration is a useful lens through which to examine general currents in federal science funding. While commentators often characterize Republican administrations as decreasing science funding,[68] that is not necessarily the case.[69] Indeed,

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60 Kaplan, *supra* note 52.

61 *See* Flotte, *supra* note 59, at 1-2; Kaplan, *supra* note 52.

62 OFFICE OF MGMT. & BUDGET, AMERICA FIRST: A BUDGET BLUEPRINT TO MAKE AMERICA GREAT AGAIN (2017), https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/2018_blueprint.pdf.

63 Joel Achenbach, *Trump's Budget Calls for Seismic Disruption in Medical and Science Research*, WASH. POST (Mar. 16, 2017), https://www.washingtonpost.com/national/health-science/trumps-budget-would-slash-scientific-and-medical-research/2017/03/15/d3261f98-0998-11e7-a15f-a58d4a988474_story.html.

64 *Id.*

65 *Id.*

66 *Id.*

67 *See* Joel Achenbach et al., *Science Funding Spared Under Congressional Budget Deal, but More Battles Ahead*, WASH. POST (May 1, 2017), https://www.washingtonpost.com/news/speaking-of-science/wp/2017/05/01/science-funding-spared-under-congressional-budget-deal-but-more-battles-ahead.

68 *See* Sidita Kushi, *Breaking Science Stereotypes: Examining the Effects of Party Politics on Federal R&D Funding*, 7 J. SCI. POL'Y & GOVERNANCE 1, 1 (2015); *cf.*

empirical research reveals that overall science funding *increases* under Republican presidents, most likely because of greater defense-related research.[70] More accurately, Republican and Democratic administrations prioritize different kinds of science funding. Democratic administrations tend to favor agencies like NASA, the EPA, the Department of Commerce, and the Department of Transportation, while Republican administrations tend to favor agencies such as NSF, the Department of Agriculture, and NIH.[71] The funding priorities of particular administrations vary as well; the George W. Bush administration was particularly supportive of NIH.[72] Some research areas are highly partisan: a 2013 survey found that sixty-six percent of Democrats versus twenty-four percent of Republicans believed there was solid evidence that human activity was the primary cause of increasing global temperatures.[73] Other areas, however, enjoy broad bipartisan support, such as biomedical research.[74]

At this potential inflection point for science policy, this Article argues for robust federal funding for scientific research and development. While publicly funded science confers several benefits, numerous empirical studies demonstrate a strong link between federal science funding and economic growth.[75] Published estimates of the return on investment for publicly funded research and development range from twenty to sixty-seven percent.[76] Federally funded scientific

Elizabeth Suhay & James N. Druckman, *The Politics of Science: Political Values and the Production, Communication, and Reception of Scientific Knowledge*, 658 ANNALS AM. ACAD. POL. & SOC. SCI. 6, 10 (2015) (noting the conventional wisdom that scientific beliefs vary with party affiliation).

69 *See* Kushi, *supra* note 68, at 11.

70 *See id.*

71 *Id.*

72 *See* Achenbach, *supra* note 63.

73 *See* Coral Davenport, *Miami Finds Itself Ankle-Deep in Climate Change Debate*, N.Y. TIMES (May 7, 2014), https://www.nytimes.com/2014/05/08/us/florida-finds-itself-in-the-eye-of-the-storm-on-climate-change.html.

74 Mervis, *Parse*, *supra* note 50, at 811.

75 *See, e.g.*, David Korn & Stephen Heinig, *Recoupment Efforts Threaten Federal Research*, 20 ISSUES SCI. & TECH. 26, 29 (2004); Ammon J. Salter & Ben R. Martin, *The Economic Benefits of Publicly Funded Basic Research: A Critical Review*, 30 RES. POL'Y 509, 509 (2001). *But see* Colin Macilwain, *Science and Democracy*, 32 ISSUES SCI. & TECH. 40, 42 (2016) [hereinafter Macilwain, *Science and Democracy*] (expressing skepticism at the link between scientific research and economic growth).

76 NAT'L ACAD. SCIS. ET AL., RISING ABOVE THE GATHERING STORM 48 (Nat'l Acads. Press ed., 2007); Edwin Mansfield, *Academic Research and Industrial Innovation*, 20 RES. POL'Y 1, 11 (1991) (finding a twenty-eight percent social rate of return on

research contributes to substantial job and revenue growth.[77] Additionally, starting in the 1990s, U.S. productivity increased sharply because of investments in computers and information technology, which arose in significant part from federal science funding.[78] More broadly, technological innovation is linked to three-fourths of the United States' economic growth rate since World War II.[79]

While direct economic effects are certainly valuable, publicly funded research also contributes to better health outcomes (which indirectly bolsters economic growth) and technologies that enhance social welfare.[80] Increases in life expectancy and public health are due significantly — though not exclusively — to federal investments in science.[81] For instance, forty years of federal funding of biomedical research have helped cut mortality from heart disease and stroke in half.[82] Federal funds have driven the development of numerous technologies that enhance quality of life, including the Google search engine, the Global Positioning System, the Internet, Magnetic Resonance Imaging, AIDS drugs, reverse auctions, and hybrid corn.[83]

Of course, evaluating the causal chain linking federal science funding, enhanced innovation, economic growth, and social welfare poses several challenges.[84] For instance, the relevant time horizons may be quite long. One study found an average time lag of seventeen years between research funding and health impacts for cardiovascular research.[85] Furthermore, while it is well established that innovation

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research). *But see* Salter & Martin, *supra* note 75, at 526 (critiquing the Mansfield methodology).

[77] *See* NAT'L ACAD. SCIS. ET AL., *supra* note 76, at 49-51.

[78] *Id.* at 47-48; *see* Rosenberg & Nelson, *supra* note 6, at 331-32 (describing the emergence of practical, electronic, digital computers from university research); *see also* ARTI RAI ET AL., PATENT REFORM: UNLEASHING INNOVATION, PROMOTING ECONOMIC GROWTH & PRODUCING HIGH-PAYING JOBS 1 (2010).

[79] RAI ET AL., *supra* note 78, at 2.

[80] *See* Korn & Heinig, *supra* note 75, at 29.

[81] *See* NAT'L ACAD. SCIS. ET AL., *supra* note 76, at 51-57.

[82] Tessier-Lavigne, *supra* note 56, at 1.

[83] *See* PETER L. SINGER, FEDERALLY SUPPORTED INNOVATIONS: 22 EXAMPLES OF MAJOR TECHNOLOGY ADVANCES THAT STEM FROM FEDERAL RESEARCH SUPPORT 10-30 (2014).

[84] *See* Professor Ben R. Martin, Assessing the Impact of Basic Research on Society and the Economy, Invited Presentation at the FWF–ESF International Conference on "Science Impact: Rethinking the Impact of Basic Research on Society and Economy" (May 11, 2007), https://www.researchgate.net/publication/228894032_Assessing_the_Impact_of_Basic_Research_on_Society_and_the_Economy (noting the difficulties of causality, attribution, internationality, and evaluation timescale).

[85] Martin Buxton, *The Payback of "Payback": Challenges in Assessing Research Impact*, 20 RES. EVALUATION 259, 260 (2011).

drives productivity growth, the link between publicly funded research and innovation is less clear.[86] Further complicating such analyses, it is admittedly more difficult to assess the social rather than scientific impact of research.[87] According to one commentator, foundational studies in the field "were undertaken with the explicit aim of building support for research investment, rather than being objective assessments."[88] Relatedly, economic analyses of federal science funding tend to focus more on benefits rather than costs, such as increased healthcare expenditures due to longer lifespans, the opportunity costs of talented individuals pursuing science over other endeavors, and the environmental harms of technological advances.[89] Ultimately, however, a 2001 review concluded that "the limited evidence gathered to date indicates that publicly funded basic research does have a large positive payoff, although this is perhaps smaller than the social rate of return on private R&D."[90]

While studies tend to neglect the costs of federal science funding, they may also underestimate its substantial benefits. In evaluating the benefits of academic science, it is important to consider the various direct and indirect ways by which publicly funded research increases economic and social welfare. In general, public funding of academic science provides at least six kinds of benefits: (1) an expanded knowledge base available for firms to exploit; (2) well-educated graduates that contribute to the labor force; (3) new equipment, laboratory techniques, and analytical methods that increase productivity for both public and private entities; (4) an entry point for companies and other institutions to access networks of expertise; (5) solutions for particularly complex problems that firms may not be able to solve; and (6) a source for creating new firms.[91] While an earlier generation of economists regarded knowledge as the primary payoff of federally funded science, recent commentators have focused on the contribution of publicly funded science to developing the "capabilities" of individual researchers, organizations, and communities, such as Silicon Valley.[92] Indeed, an important output of

[86] *See* Colin Macilwain, *What Science Is Really Worth*, 465 NATURE 682, 682 (2010) [hereinafter Macilwain, *Worth*].

[87] Bornmann, *supra* note 37, at 230.

[88] Macilwain, *Worth*, *supra* note 86, at 682.

[89] *Id.* at 684.

[90] Salter & Martin, *supra* note 75, at 514.

[91] *Id.* at 520.

[92] Korn & Heinig, *supra* note 75, at 29; Salter & Martin, *supra* note 75, at 512, 522.

federally funded science is talented scientists, engineers, and technicians who serve industry needs.[93]

Given the link between science, innovation, and human capabilities, areas of regulation that are not ordinarily recognized as science policy — such as immigration — deeply impact science and innovation in this country. Foreign scientists are present at every level of the U.S. science education infrastructure, particularly the graduate ranks.[94] Furthermore, immigrants play an outsize role in driving American innovation, and altering immigrant-friendly policies could deleteriously impact the U.S. technology sector.[95] One study found that immigrants or children of immigrants founded over forty percent of Fortune 500 companies.[96] Accordingly, the Trump administration's various orders to restrict immigration from predominantly Muslim countries could "hinder research, affect recruitment of top scientists and dampen the free exchange of scientific ideas."[97] Furthermore, business leaders have criticized Trump's proposed immigration restrictions as undermining technological innovation and economic growth.[98]

In addition to producing long-term benefits, robust science funding would serve some of the Trump administration's immediate policy goals. For instance, substantial science funding is consistent with Trump's proposal for investments in domestic infrastructure.[99] Trump's calls for increased infrastructure reflect a recognition that private-sector productivity rests upon public investments in "enabling" assets like roads, bridges, and communication networks. Similarly, a significant portion of private innovation draws upon a broad foundation of publicly funded science. To take just one example, "while American industry plays a crucial role in turning inventions into marketable products, publicly funded research still plays a dominant role in fostering the basic scientific and

93 Mervis, *Parse*, *supra* note 50, at 812.

94 Henry Fountain, *Science Will Suffer Under Administration's Travel Ban, Officials Say*, N.Y. TIMES, Jan. 31, 2017, at A18.

95 *See* Farhad Manjoo, *Why Silicon Valley Booed Trump's Immigration Ban*, N.Y. TIMES, Feb. 9, 2017, at B1.

96 *Id.*

97 Fountain, *supra* note 94.

98 *See* David Streitfeld et al., *Tech World Denounces Move to Bar Immigrants*, N.Y. TIMES, Jan. 30, 2017, at B1.

99 *See* Carla Fried, *The Muni Market Turns Toward Washington*, N.Y. TIMES, (Apr. 14, 2017), https://www.nytimes.com/2017/04/14/business/mutfund/trump-municipal-bonds.html (discussing Trump's proposal for $1 trillion in infrastructure spending).

technological advances that drive biotechnology forward."[100] Robust science funding would thus bolster the public infrastructure necessary to drive private innovation. In addition, science funding would also advance another immediate policy objective: jobs. In very pragmatic terms, NIH funding supports 300,000 researchers at more than 3,000 universities, medical schools, teaching hospitals, and other research institutions.[101] Beyond just creating jobs, federal science funding creates particularly high-paying jobs. Technological innovation — to which federal science funding contributes significantly — produces jobs with an average compensation of two and a half times the national average.[102]

Expanded science funding, particularly for biomedical research, would also support the new administration's plans to reform the U.S. healthcare system. While the exact shape and scope of healthcare reform remains to be seen, healthcare spending represents an enormous share of the economy, accounting for about 17.8% of GDP.[103] Considering just one disease, in the absence of a therapy, the cost of treating Alzheimer's disease is estimated to cost a trillion dollars per year by 2050.[104] Given that the federal government spends more on healthcare than any other area, even noted conservative Newt Gingrich has argued that "[i]t's irresponsible and shortsighted, not prudent, to let financing for basic [medical] research dwindle."[105] In the 1990s, Gingrich spearheaded the efforts of the Republican-led Congress to double NIH's budget, even amidst significant tax cuts.[106] He has recently argued for another doubling of NIH's budget.[107] Increased funding for scientific research promises to generate lower-cost, more effective treatments. Furthermore, such funding can also offset major losses to academic medical centers, which provide substantial medical services to low-income individuals, from the

[100] Golden, *supra* note 35, at 110.

[101] ASS'N OF AM. MED. COLLS., ACADEMIC MEDICINE INVESTMENT IN MEDICAL RESEARCH 4 (2015).

[102] RAI ET AL., *supra* note 78, at 1.

[103] *Historical*, CTRS. FOR MEDICARE & MEDICAID SERVS. (Dec. 6, 2016, 8:00 AM), https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nationalhealthaccountshistorical.html.

[104] Tessier-Lavigne, *supra* note 56, at 1.

[105] Newt Gingrich, Opinion, *Double the N.I.H. Budget*, N.Y. TIMES, Apr. 22, 2015, at A23.

[106] *See* Flotte, *supra* note 59, at 2; *see also* Sara Reardon et al., *The Trump Experiment*, 539 NATURE 337, 337 (2016) (providing that "Gingrich supported a plan to double the budget for the [NIH] over 10 years").

[107] *See* Gingrich, *supra* note 105, at A23 ("Doubling the [NIH's] budget once again would be a change on the right scale . . . .").

Republicans' intended repeal of the Affordable Care Act.[108] Here, history offers an illustrative lesson; in the mid-twentieth century, the failure of nationalized health insurance led disease advocates to lobby for increasing funds for NIH to improve public health.[109]

Increasing science funding would also advance one of Trump's signature policy objectives: resurrecting American manufacturing.[110] Amidst global outsourcing of American jobs, policymakers have sought to reinvigorate domestic manufacturing. The Obama administration sponsored the Manufacturing USA initiative,[111] and Trump has sought to curtail outsourcing and preserve American manufacturing jobs. Such outsourcing reflects a broad trend toward vertical disintegration of global supply chains,[112] in which developed countries typically focus on "high value" activities such as research, development, and design while outsourcing "low value" activities such as manufacturing overseas. Recent commentary, however, has revealed the synergies of vertical integration and close proximity of research, design, and manufacturing.[113] While design certainly informs manufacturing, the reverse is true, too. For instance, Nokia recently reintegrated design with manufacturing to accelerate innovation and has opened its research operations to promote more collaboration.[114] Thus, American manufacturing would benefit from close proximity to a vibrant domestic research base.

In sum, robust federal funding of science both promises long-term, significant payoffs and advances the current administration's immediate policy objectives. Empirical research underscores the

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108 *See* Flotte, *supra* note 59, at 2 (discussing how the repeal of the ACA would diminish funding for low-income health insurance and challenging the Trump administration to make healthcare more affordable by increasing NIH funding to facilitate medical breakthroughs).

109 *See* Sampat, *supra* note 11, at 1730.

110 *See* Flotte, *supra* note 59, at 1.

111 *See Manufacturing USA – the National Network for Manufacturing Innovation*, ADVANCED MANUFACTURING NAT'L PROGRAM OFF., https://www.manufacturing.gov/nnmi (last visited Aug. 7, 2017); Richard A. McCormack, *Obama Will Unveil $1-Billion National Manufacturing Innovation Network Initiative Based on Germany's Fraunhofer Institute*, MFG. & TECH. NEWS (Feb. 28, 2012), http://www.manufacturingnews.com/news/national-network-for-manufacturing-innovation-228112.html; *see also* Daniel Sarewitz, *Science and Innovation Policies for Donald Trump*, 539 NATURE 331, 331 (2016).

112 *See, e.g.*, Jonathan M. Barnett, *Intellectual Property as a Law of Organization*, 84 S. CAL. L. REV. 785, 843-50 (2011) (discussing global vertical disintegration in the semiconductor industry).

113 *See* Annie Lowrey, *Ideas on an Assembly Line*, N.Y. TIMES, Dec. 13, 2012, at B1.

114 Ronald J. Gilson et al., *Contracting for Innovation: Vertical Disintegration and Interfirm Collaboration*, 109 COLUM. L. REV. 431, 501 (2009).

strong link between science funding and economic growth, and the past seventy years of funding have helped generate countless technologies that enhance productivity and social welfare. In addition to the knowledge gains of public science funding, government support also cultivates creative individuals, organizations, and communities that drive innovation. Furthermore, federal science funding advances the political objectives of enhancing infrastructure, preserving jobs, reforming healthcare, and strengthening American manufacturing.

III. THE SCIENTIFIC COMMUNITY'S ENGAGEMENT WITH SOCIETY

While providing robust financial support is an important plank in federal science policy, it leads to another important question: what is the appropriate relationship of the scientific community with the government that funds it and with society at large? This dynamic has at least two dimensions: the extent to which the government should influence scientific agendas and the degree to which the scientific community should engage with politics and the broader society in which it operates. Turning to the first issue, this Article argues for a high degree of scientific autonomy. While the federal government can legitimately shape scientific agendas in some contexts, it should leave ample room for curiosity-driven, scientist-determined research, and it should never seek to control scientific conclusions. Relatedly, this Article contends that sensitivity to communal self-determination and the global nature of the republic of science also counsel in favor of significant scientific autonomy. Turning to the second issue, this Article argues that autonomy should not mean insularity; while the scientific community should remain independent, it should also actively engage the polity at large, communicating its value and receiving input into its work. This Article draws on concepts from political theory, federalism, and democratic dialogue to argue for autonomy, decentralization, and public engagement in the governance of scientific activities.

A. The Federal Government's Control over Scientific Inquiry

U.S. science policy has long grappled with the extent to which the government should exercise control over the research it funds. A half-century ago, Vannevar Bush advocated for significant unrestrained funding for scientific research (though with pockets of targeted funding for particular fields).[115] Bush's policy proposals, supported by

[115] *See* BUSH, *supra* note 14, at 7.

Polanyi's philosophical conception of the republic of science,[116] extolled the virtues of a largely self-directed scientific community that received significant public support with minimal governmental interference.[117] Key to this policy prescription was a theory of scientific progress predicated on serendipity; given the unpredictable nature of science, attempts to direct scientific progress may ultimately stifle it.[118] This prescription also drew support from principles of self-determination and political freedom; within the republic of science, researchers themselves were well suited to organize themselves and pursue the most promising lines of inquiry. As discussed above, this model of research funding favoring significant scientific autonomy and curiosity-driven research has yielded impressive results.[119]

However, as national policy priorities have evolved, the federal government has legitimately exercised the "power of the purse" to shape the science that it funds. First, as noted above, the federal government has engaged in "mission-based" scientific initiatives, usually to great effect.[120] The Manhattan Project, the Apollo program, the War on Cancer, and the Human Genome Project represent mission-based initiatives that yielded remarkable scientific insights and valuable technologies. Such government-directed programs have continued more recently in the cancer "moonshot" program spearheaded by former Vice President Joe Biden.[121] These mission-based programs, which respond to pressing national priorities, certainly shape scientific agendas and are a legitimate exercise of federal science dollars. However, even here there is reason for caution. The federal government is better suited to supporting the upstream, public-good research that private actors are likely to neglect rather than participating directly in the market. The Obama administration's support for solar panel maker Solyndra, which was part of a broader effort to advance clean technologies,[122] offers a cautionary tale about

[116] *See* Polanyi, *supra* note 4, *passim*.

[117] *See supra* notes 23–29 and accompanying text.

[118] *See* Sampat, *supra* note 11, at 1729-30. It bears recognizing, however, that there is little large-sample evidence on the amount and prevalence of serendipity in NIH-funded discoveries. *Id.* at 1739 n.24.

[119] *See supra* notes 75–93 and accompanying text.

[120] *See supra* notes 32–33 and accompanying text.

[121] *See* Harris Gardiner, *$1 Billion Planned for Cancer 'Moonshot*,*'* N.Y. TIMES, Feb. 2, 2016, at A13.

[122] Rachel Weiner, *Solyndra, Explained*, WASH. POST: THE FIX (June 1, 2012), https://www.washingtonpost.com/blogs/the-fix/post/solyndra—explained/2012/06/01/gJQAig2g6U_blog.html?utmterm=.8442e5bd4aaa.

direct government subsidy of individual companies and the politicization of research and development funding.[123]

Second, the government has legitimately shifted science policy toward encouraging downstream research and commercialization of applied technologies. Again, while Solyndra illustrates the pitfalls of subsidizing individual companies, a more appropriate role for government involves broad-based policy decisions that may encourage shifts in research emphasis. Along these lines, in the 1980s the government utilized patent policy and funding to encourage more downstream research and technology transfer arising from publicly supported science. Statutes such as the Bayh-Dole Act and the Stevenson-Wydler Technology Innovation Act emerged in significant part from Congress's desire to increase the return on public investment in science and accelerate its translation into marketable goods and services.[124] In this manner, the federal government utilized patent policy and science funding to enhance national competitiveness.

These are legitimate exercises of federal science policy, and they could go even further. Recent research has highlighted the difficulties of transferring federally funded, academic research to the private sector for commercialization.[125] Patenting by universities and national laboratories is perceived as critical to technology transfer, but patents do not disclose and licenses do not transfer valuable invention-related tacit knowledge critical to effective commercialization of academic inventions.[126] Such knowledge remains "sticky" to the faculty inventors,[127] and federal policy can better encourage its transfer to private sector partners. For instance, policy makers can increase funding for boundary spanning organizations, such as technology transfer offices ("TTOs"), incubators, and proof of concept centers, where federally funded academic and industry scientists collaborate

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[123] *See* Joe Stephens & Carol D. Leonnig, *Solyndra: Politics Infused Obama Energy Programs*, WASH. POST (Dec. 25, 2011), https://www.washingtonpost.com/solyndra-politics-infused-obama-energy-programs/2011/12/14/gIQA4HllHP_story.html?utm_term=.9e807b2e0b18.

[124] *See supra* notes 38–45 and accompanying text.

[125] *See* Peter Lee, *Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer*, 100 CALIF. L. REV. 1503, 1523-34 (2012) [hereinafter Lee, *Tacit Dimension*].

[126] *See id.* at 1524-30.

[127] Eric von Hippel, *"Sticky Information" and the Locus of Problem Solving: Implications for Innovation*, 40 MGMT. SCI. 429, 429 (1994) (defining "sticky information" as information that is costly to transfer or acquire).

side by side.[128] In this manner, federal policy can advance the aims of Bayh-Dole and Stevenson-Wydler by accelerating the translation of publicly supported inventions into tangible goods and services.

Here as well, however, the federal government must be cautious in utilizing patent policy and science funding to influence research priorities. While encouraging the translation of publicly funded research into marketable products is a legitimate objective, policy makers must be wary of overly distorting research agendas.[129] The aim of accelerating technology transfer is part and parcel of the increasing "corporatization" of university research, which may shift research agendas to more financially profitable rather than scientifically meritorious lines of inquiry.[130] Such research may decrease scholarly productivity,[131] introduce bias into academic investigations,[132] and decrease public confidence in universities.[133] These policy interventions thus threaten the independent, curiosity-driven model of scientific inquiry that has proven so productive, and policy makers must be cautious about overly shifting research activities toward commercialization.

While discussing the government's role in shaping scientific agendas, it is appropriate to address another institution that could, in theory, shape funding priorities: the market. Against criticism that the government is "politicizing" science policy, officials may be tempted to allocate research funds to serve commercial interests. After all, allocating research dollars to areas of high commercial importance

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[128] *See* Lee, *Tacit Dimension*, *supra* note 125, at 1554.

[129] This section draws substantially on Lee, *Tacit Dimension*, *supra* note 125, at 1563-67.

[130] *See* Eyal Press & Jennifer Washburn, *The Kept University*, ATLANTIC MONTHLY, Mar. 2000, at 39, 39-40; *see also* Brett M. Frischmann, *Commercializing University Research Systems in Economic Perspective: A View from the Demand Side*, *in* UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER: PROCESS, DESIGN, AND INTELLECTUAL PROPERTY 155, 176-78 (Gary D. Libecap ed., 2005). *But see* Jerry G. Thursby & Marie C. Thursby, *University Licensing and the Bayh-Dole Act*, 301 SCIENCE 1052, 1052 (2003) (stating that empirical evidence suggests no shift toward more applied research in response to patent royalties).

[131] *See* David Blumenthal et al., *Participation of Life-Science Faculty in Research Relationships with Industry*, 335 NEW ENG. J. MED. 1734, 1738 (1996).

[132] *See* MARTIN KENNEY, BIOTECHNOLOGY: THE UNIVERSITY-INDUSTRIAL COMPLEX 115 (1986) (describing a potential conflict of interest wherein Herbert Boyer, a Genentech cofounder, obtained a $200,000 research grant from Genentech); David J. Triggle, *Patenting the Sun: Enclosing the Scientific Commons and Transforming the University—Ethical Concerns*, 63 DRUG DEV. RES. 139, 143-44 (2005) (describing conflicts of interest between faculty members and universities).

[133] *See* Triggle, *supra* note 132, at 144-45.

seems to be a neutral, politically defensible approach to science policy. But this would constitute a dangerous missed opportunity. Recall that in Polanyi's normative conception, the republic of science was insulated from not just political demands but also market influences.[134] Certainly, the market can usefully guide science policy (and sometimes correct its missteps).[135] But while federal science spending provides a valuable foundation for private enterprise,[136] advancing the aims of industry should not unduly determine federal research expenditures. While public science funding clearly plays a central role in supporting market actors and national economic imperatives, one of its primary functions is to fill the gaps of market failure.[137] A classic justification for government science funding is that it provides a public good — basic scientific knowledge — that the market underproduces.[138] After all, the nonrival, nonexcludable nature of technical knowledge depresses market actors' incentive to invest in basic research, even though such research is highly valuable to society. Given that one of the functions of government science funding is to fill the gaps of market failure, it would be ill-advised simply to allocate public funds to areas of established market value.

On the contrary, this Article argues that the federal government should allocate public funds toward research and development initiatives that the market overlooks. This approach justifies expenditures on upstream research that generates significant spillovers but that individual companies have inadequate incentives to pursue. It also justifies research and development in areas of high social value relative to market value, such as treatments for diseases that affect poor and marginalized communities.[139] For such areas of research and innovation, market signals (prices) may be weak proxies for social value,[140] but maximizing social value should be the overriding

[134] *See* Ezrahi, *supra* note 24, at 117-18.

[135] Even if the Trump administration is hostile to climate science, industry may still care about climate risk and lobby for more research in that field. *Cf.* Niiler, *supra* note 54 (providing an analogous example of industry stepping in to guide science policy in the climate change arena).

[136] *See supra* notes 99–102 and accompanying text.

[137] *See* Barry Bozeman, *Technology Transfer and Public Policy: A Review of Research and Theory*, 29 RES. POL'Y 627, 632 (2000).

[138] *See* Richard R. Nelson, *The Market Economy, and the Scientific Commons*, 33 RES. POL'Y 455, 462 (2004).

[139] *See* Peter Lee, *Toward a Distributive Agenda for U.S. Patent Law*, 55 HOUS. L. REV. (forthcoming 2017) (manuscript at 18-19) (on file with UC Davis School of Law) [hereinafter Lee, *Distributive Agenda*].

[140] *Cf.* Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents-Prizes*

objective of science policy. The federal government has already pursued this approach by funding research on neglected diseases.[141] Similarly, the government has utilized exclusive rights to encourage the development of treatments for rare diseases that affect small populations with the Orphan Drug Act, which promotes research and development for treatments for diseases that affect less than 200,000 Americans.[142]

While market value may not be the appropriate metric for determining public investments in science, the government can reasonably expect some tangible return on its investments. Toward the end of the 1990s, NSF became one of the first science funding agencies to ask peer reviewers to evaluate not just the scientific merit of applications but also their social impact.[143] As Lutz Bornmann observes, "Mode 2 research is characterized by an environment of increasing financial stringency in which science (like many other areas of society) must prove that government investments in R&D have been effective and employed for the benefit of society."[144] As with the push toward greater emphasis on commercialization, there are downsides to such public accountability. Given the recent emphasis on return on investment, scientists and universities may shift research toward activities that lead to greater documentable impact,[145] as compared to those with more long-term, unpredictable benefits.

One innovative mechanism for balancing scientific autonomy and specific research goals is the "challenge" model of funding research. For instance, the Gates Foundation has provided significant funding for its Grand Challenges in Global Health.[146] Such initiatives define a concrete goal yet provide researchers with significant freedom and flexibility to

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Debate, 92 TEX. L. REV. 303, 328 (2013) ("[F]or example, the social value of a malaria or tuberculosis vaccine may be enormous, but potential beneficiaries in developing countries lack the ability to pay high prices.").

141 *See Therapeutics for Rare and Neglected Diseases (TRND)*, NAT'L CTR. FOR ADVANCING TRANSLATIONAL SERVS., https://ncats.nih.gov/trnd (last visited Aug. 7, 2017).

142 Orphan Drug Act of 1983, Pub. L. No. 97-414, 96 Stat. 2049 (codified as amended in various sections of 21 U.S.C. and 42 U.S.C.); *see also* Lee, *Distributive Agenda*, *supra* note 139 (manuscript at 18-19).

143 Bornmann, *supra* note 37, at 223.

144 *Id.* at 229.

145 *See* Erik Ernø-Kjølhede & Finn Hansson, *Measuring Research Performance During a Changing Relationship Between Science and Society*, 20 RES. EVALUATION 131, 136 (2011).

146 *See* Harold Varmus & Ed Harlow, *Science Funding: Provocative Questions in Cancer Research*, 481 NATURE 436, 436 (2012).

pursue it in the manner they see fit. These initiatives draw from a long history of inducement prizes, which historically played a prominent role in funding scientific and technological research.[147] For instance, in the eighteenth and nineteenth centuries, European scientific societies frequently offered awards for solutions to theoretical and applied problems.[148] More recently, the XPRIZE Foundation has spearheaded a resurgence of prizes, such as one to encourage suborbital space flight.[149] As a variation on this model, the National Cancer Institute has advanced a Provocative Questions initiative, which "asks investigators to propose intriguing questions in cancer research that need attention."[150] These initiatives establish broad goals of high social importance but allow potential grant recipients freedom to craft individual, creative solutions for achieving them.

Given the importance of scientific autonomy in federal science policy, the Trump administration's actions and statements about science have been quite troubling. Trump has regularly rejected well-established scientific consensus, particularly on climate change. In November 2012, Trump tweeted, "The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive."[151] During the campaign, Trump advisers stated that NASA should focus more on exploring deep space and less on what they called "politically correct environmental monitoring."[152] Trump appointed prominent climate change denier Myron Ebell to lead his EPA transition team,[153] and several of Trump's key cabinet appointments have expressed skepticism about climate change.[154] Mike Pence's appointment as Vice President also caused alarm given his well-documented doubts about climate change and evolution as

147 *See, e.g.*, THOMAS KALIL, PRIZES FOR TECHNOLOGICAL INNOVATION 5-6 (2006), https://www.brookings.edu/wp-content/uploads/2016/06/200612kalil.pdf (citing notable examples of prizes throughout history, including those to induce the development of food preservatives, longitudinal measurements, and aviation advancements); Peter Lee, *Social Innovation*, 92 WASH. U. L. REV. 1, 52-53 (2014).

148 Toni Feder, *Incentive Prizes Reinvented to Solve Problems*, 63 PHYSICS TODAY 21, 22 (2010).

149 *See* Leonard David, *SpaceShipOne Wins $10 Million Ansari X Prize in Historic 2nd Trip to Space*, SPACE.COM (Oct. 4, 2004, 10:56 AM), https://www.space.com/403-spaceshipone-wins-10-million-ansari-prize-historic-2nd-trip-space.html.

150 *See* Varmus & Harlow, *supra* note 146, at 436.

151 Donald Trump (@realDonaldTrump), TWITTER (Nov. 6, 2012, 11:15 AM), https://twitter.com/realdonaldtrump/ status/265895292191248385?lang=en.

152 Reardon et al., *supra* note 106, at 337-38.

153 Niiler, *supra* note 54.

154 *See* Davenport, *supra* note 2.

well as his criticism of embryonic stem cell research.[155] Trump has followed through on his dismissal of climate change by eliminating environmental regulations and withdrawing the United States from the Paris Agreement.[156] Beyond climate change, Trump also created consternation by linking autism to childhood vaccinations and characterizing NIH as "terrible."[157]

Even more alarming, the Trump administration has acted upon its rejection of scientific consensus to influence and stifle climate change researchers. Quite ominously, the Trump transition team asked for the names of DOE employees involved in developing climate policy, a request which the agency refused.[158] The same questionnaire also targeted DOE's "integrated assessment models," which can forecast future changes in climate and energy use, thus raising speculation that the incoming administration was "trying to undermine the credibility of the science that DOE has produced, particularly in the field of climate science."[159] The Trump administration has also constrained scientific communication by prohibiting employees of the EPA and Department of Agriculture from discussing agency research with any outside parties, including the news media.[160] These episodes recall earlier complaints during the George W. Bush administration that officials edited scientific documents to cast doubt on climate change and prevented researchers from speaking openly with the media.[161] While questioning scientific orthodoxy is a valuable practice that may lead to greater scientific insight, intimidation and silencing of researchers is antithetical to scientific progress.

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155 Jeff Tollefson, *Trump vs Clinton: Worlds Apart on Science*, 535 NATURE 473, 473 (2016).

156 *See id.* at 474; Kaplan, *supra* note 52.

157 Reardon et al., *supra* note 106, at 338.

158 David Malakoff et al., *Trump Team Targets Key Climate Metric*, 354 SCIENCE 1364, 1364 (2016); Steven Mufson & Juliet Eilperin, *Trump Transition Team for Energy Department Seeks Names of Employees Involved in Climate Meetings*, WASH. POST (Dec. 9, 2016), https://www.washingtonpost.com/news/energy-environment/wp/2016/12/09/trump-transition-team-for-energy-department-seeks-names-of-employees-involved-in-climate-meetings/?utm_term=.1192f5e62762.

159 Mufson & Eilperin, *supra* note 158 (quoting Professor Robert Jackson, climate and energy researcher at Stanford University).

160 Dina Fine Maron, *Trump Administration Restricts News from Federal Scientists at USDA, EPA*, SCI. AM. (Jan. 24, 2017), https://www.scientificamerican.com/article/trump-administration-restricts-news-from-federal-scientists-at-usda-epa.

161 *See* Mufson & Eilperin, *supra* note 158; *see also* Martin McKee & Thomas E. Novotny, Editorial, *Political Interference in American Science: Why Europe Should Be Concerned About the Actions of the Bush Administration*, 13 EUR. J. PUB. HEALTH 289, 289-90 (2003).

The history of science policy reveals the grave perils of overreaching government intervention in science. The most notorious example is the Soviet Union's disastrous support for Trofim Lysenko's political campaign against genetics-based agriculture. Supporters of Lysenkoism denounced Mendelian genetics as a "bourgeois pseudoscience,"[162] and Stalin approved the murder and exile of numerous geneticists.[163] Lysenko's failed agricultural programs worsened the Soviet Union's mass starvation and led to decades of lost scientific progress in genetics.[164] It was only in the mid-1960s that Lysenkoism was discredited and genetics research reinstated.[165] Although on a much different scale, political involvement in science has also negatively impacted research in this country. For example, the George W. Bush administration's opposition to human embryonic stem cell research delayed clinical trials for treatments for spinal cord injuries by eight years.[166]

Contrary to these instances of political influence, scientific autonomy serves several important values and interests. First, as mentioned, it allows the most robust science to develop. As Vannevar Bush argued in the aftermath of World War II, science unfolds in unpredictable ways, and attempts to direct scientific research may inhibit it.[167] As historian of science Thomas Kuhn observed, the most revolutionary scientific advances emerge when the orthodoxy of "normal science" frays at the edges, thus initiating a paradigm shift where a novel theory displaces the old one.[168] Within this model, excessive centralization and authoritarian control eliminate the radical theories and unorthodoxy that are critical to scientific progress. Commentators have observed that "'democratic' social structure provides the best possible conditions for acceptance and implementation of the scientific ethos."[169]

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162 Cliff Ollier, *Lysenkoism and Global Warming*, 20 ENERGY & ENV'T 197, 198 (2009).

163 *See id.*

164 Suzanna Sherry, *Democracy and the Death of Knowledge*, 75 U. CIN. L. REV. 1053, 1068 (2007); *see* Walter Hirsch, *The Autonomy of Science in Totalitarian Societies*, 40 SOC. FORCES 15, 20 (1961).

165 *See* Ollier, *supra* note 162, at 198.

166 *See* John A. Robertson, *Embryo Stem Cell Research: Ten Years of Controversy*, 38 J.L. MED. & ETHICS 191, 191 (2010).

167 *See* BUSH, *supra* note 14, at 19-20.

168 THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS 10 (4th ed. 2012); *see also id.* at 12, 19.

169 Hirsch, *supra* note 164, at 15.

Additionally, significant scientific autonomy also promotes political freedom and communal self-determination.[170] The scientific community, while not an insular republic of science, represents a community with a deep interest in self-determination. As such, heavy-handed attempts by the federal government to snuff out certain types of research (for instance, concerning climate change) are highly problematic. In the mid-twentieth century, sociologist of science Robert Merton characterized scientific norms as encompassing communism, universalism, disinterestedness, and organized skepticism.[171] Mode 1 scientific activity, which favored curiosity-driven research and prevailed after World War II, reflected this normative vision of science as internally determined and insulated from outside influence.[172] Notably, Mode 1 had a political dimension as well, as its emphasis on scientific autonomy directly responded to the racism and eugenics of Nazi science and Lysenko's attacks on genetics in the Soviet Union.[173]

One of the most valuable mechanisms for institutionally safeguarding scientific autonomy is funding research via peer review. Major funding agencies like NIH and NSF have historically embraced investigator-initiated research and should remain committed to independent, peer-review grant mechanisms.[174] Indeed, "the bulk of NIH funding is investigator-initiated and funded through a peer review process focused on science."[175] NIH developed its "dual peer review" process in 1947, in which "study sections" made up of scientists evaluate proposals based on scientific merit, and then Institute Advisory Councils comprised primarily of scientists review these applications and make recommendations to the Institute Director.[176] The resulting "peer review allocation process is mostly

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[170] *Cf.* Barry P. McDonald, *Government Regulation or Other "Abridgements" of Scientific Research: The Proper Scope of Judicial Review Under the First Amendment*, 54 EMORY L.J. 979, 1091 (2005) (noting that scientific research, which comprises both expressive and nonexpressive components, should receive appropriate First Amendment protection).

[171] *See* MERTON, *supra* note 25, at 270-78.

[172] *See id.*

[173] *See* Etzkowitz & Leydesdorff, *supra* note 14, at 116.

[174] *See* Zerhouni, *supra* note 35, at 1088; *see, e.g.*, *Division of Physics: Investigator-Initiated Research Projects (PHY)*, NAT'L SCI. FOUND., https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505058 (last visited Oct. 25, 2017) (providing access to list of investigator-initiated awards in the field of physics).

[175] Sampat, *supra* note 11, at 1730.

[176] *Id.* at 1733.

about identifying and funding the best science."[177] Turning to NSF, Lamar Smith (R-TX), chair of the House science committee, recently introduced legislation to revise that agency's peer review system.[178] The proposed legislation, which aimed in part to redirect funding from social science studies to research in the natural sciences and engineering,[179] would require NSF officials to certify that every grant funded research "in the national interest."[180] While President Obama thwarted this proposed legislation with a threatened veto,[181] such moves jeopardize scientific independence and chill valuable lines of inquiry.

Federalism, another key democratic principle, also supports scientific autonomy. The decentralized nature of American government provides opportunities for subnational governments to pursue their own scientific agendas. A historical example arose when President George W. Bush banned federal funds for significant lines of human embryonic stem cell research.[182] In response, California voters passed Proposition 71, which provided $3 billion for stem cell research in that state.[183] Several other states pursued similar plans to fund stem cell research.[184] State officials in California have already signaled their interest in pursuing aggressive climate change policies in response to the Trump administration's actions,[185] and it is possible that local preferences may also drive research funding. Of course, the federal government exerts significant leverage over states like California. For instance, it could limit federal research funds based on objectionable state policies.[186] Nonetheless, the decentralized nature of science policy in the United States affords greater opportunity to shore

177 *Id.*

178 *See* Jeffrey Mervis, *In a Turnabout, Key Congressional Critic Backs NSF Peer Review*, SCIENCEINSIDER (Mar. 12, 2015), http://www.sciencemag.org/news/2015/03/turnabout-key-congressional-critic-backs-nsf-peer-review [hereinafter Mervis, *Turnabout*].

179 160 CONG. REC. H4957-58 (daily ed. May 29, 2014) (statement of Rep. Smith) (proposing that Congress redirect funds cut from NSF's Social, Behavioral, and Economic Sciences directorate to the physical sciences and engineering).

180 Mervis, *Turnabout*, *supra* note 178.

181 *See* Mervis, *Parse*, *supra* note 50, at 811.

182 *See* Varnee Murgan, *Embryonic Stem Cell Research: A Decade of Debate from Bush to Obama*, 82 YALE J. BIOLOGY & MED. 101, 101 (2009).

183 *See* Lee, *Open Science*, *supra* note 47, at 932-33.

184 *See id.* at 932.

185 Adam Nagourney & Henry Fountain, *California, at Forefront of Climate Fight, Won't Back Down to Trump*, N.Y. TIMES (Dec. 26, 2016), https://www.nytimes.com/2016/12/26/us/california-climate-change-jerry-brown-donald-trump.html.

186 *See id.*

up scientific autonomy if one political regime behaves in an oppressive manner. Local and state governments may even partner with foreign governments to counter federal policy perceived to threaten science.[187]

On a wider scale, the global nature of the republic of science also weighs in favor of a high degree of scientific autonomy. In a globalized world where countries compete for talented individuals in international labor markets, such individuals will flow to jurisdictions most amenable to their interests. Trump's anti-science and anti-immigrant rhetoric may discourage foreign scientists from coming here,[188] and some foreign scientists working in this country are considering leaving.[189] This would be particularly harmful to U.S. competitiveness given that foreigners comprise about five percent of U.S. university students, encompassing about 380,000 individuals studying science, engineering, technology, or mathematics.[190] Thus, global competition to attract and retain the best scientists and engineers also favors affording researchers the freedom to pursue lines of research of interest to them. In sum, while the federal government can and should utilize its funding power to advance specific policy objectives, it should also continue to fund curiosity-driven research and afford significant autonomy to scientists.

B. Democratic Engagement and the Republic of Science

Autonomy, however, does not mean insularity. Polanyi's conception of a republic of science extolled a scientific community that was shielded from the broader polity in two ways. In addition to enjoying significant autonomy from political and market demands, the scientific community bore little responsibility to communicate with or consider input from the outside world. However, such "aloofness" can have deleterious consequences,[191] and this Article rejects this normative

[187] *Cf.* Hiroko Tabuchi & Henry Fountain, *Bucking Trump, These Cities, States and Companies Commit to Paris Accord*, N.Y. TIMES (June 1, 2017), https://www.nytimes.com/2017/06/01/climate/american-cities-climate-standards.html (describing a submission to the United Nations by several cities and states, as well as other entities, pledging to abide by the greenhouse gas emissions targets of the Paris Agreement).

[188] *See* Kaplan, *supra* note 52; Jeff Tollefson et al., *Donald Trump's US Election Win Stuns Scientists*, NATURE (Nov. 9, 2016), http://www.nature.com/news/donald-trump-s-us-election-win-stuns-scientists-1.20952.

[189] Tollefson et al., *supra* note 188.

[190] Reardon et al., *supra* note 106, at 339.

[191] Amy Harmon & Henry Fountain, *In Age of Trump, Scientists Show Signs of a Political Pulse*, N.Y. TIMES (Feb. 6, 2017), https://www.nytimes.com/2017/02/06/science/donald-trump-scientists-politics.html.

conception of an insular republic of science. While it argues in favor of substantial scientific autonomy, it also argues for a reciprocal obligation of democratic engagement on the part of researchers. Such engagement must be truly dialogic; in addition to communicating its successes to the public at large (and lobbying for more support), it should also meaningfully listen and integrate public input into its work.

As Yaron Ezrahi observed several decades ago, "contemporary American science is not a socially autonomous enterprise, nor is it insulated from politics."[192] For better or worse, given the centrality of public funding to the viability of scientific research, scientific institutions must lobby to justify their existence.[193] Focusing first on federal science agencies, institutional design is critical for balancing scientific autonomy with the desire for publicly funded science to respond to social needs. NIH offers an illustrative case study in striking this balance. NIH is the largest single funder of biomedical research in the world and provides sixty-five percent of all federal funds for academic research and development.[194] As noted, it enjoys unique bipartisan support,[195] and Congress doubled NIH's budget from 1997 to 2002.[196] While tensions have arisen between the agency's commitment to funding basic research and more health-related, applied research,[197] NIH has skillfully navigated this tension by leveraging its institutional design and political affiliations. While the agency prioritizes unplanned research based on the interests of grant applicants, it possesses "safety valves" that allow it to target funds for specific areas of disease research in response to political and social demands.[198] While peer review allocates the vast majority of NIH funds, alternate channels, such as cross-Institute funding decisions and requests for applications covering specific grants, clinical trials, and research and development contracts can direct funds to areas of immediate importance.[199] Throughout, the agency leverages relationships with members of Congress, academic medical centers, universities, and disease advocacy groups to build its political

192 Ezrahi, *supra* note 24, at 118.
193 *See id.* at 129.
194 Sampat, *supra* note 11, at 1731.
195 *Id.* at 1729.
196 *Id.*
197 *See id.*
198 *Id.* at 1720.
199 *Id.* at 1734-36.

support.[200] NIH, however, can do more. As Elias Zerhouni, former director of NIH, has stated, "NIH and the scientific community need to better educate the public about the extraordinary return on investment in the NIH."[201] This is particularly necessary in light of a 2005 survey finding that seventy-three percent of Americans were unable to identify NIH as the agency that funds most taxpayer-supported medical research in the United States.[202]

Beyond federal agencies like NIH, nonprofit scientific organizations and societies also play an important role in communicating the value and needs of scientific research to the public.[203] As Rush Holt, CEO of the American Association for the Advancement of Science ("AAAS") and a former Democratic member of Congress, has stated, "The public understands the value of science and technology. At least it does sometimes."[204] The AAAS and similar organizations can ensure greater public understanding of science. The time is ripe for such efforts following Trump's election and the establishment of an administration that has been hostile to scientific consensus. In the aftermath of the election, Jennifer Zeitzer, director of legislative relations at the Federation of American Societies for Experimental Biology, stated, "It's going to be critically important to stand up for science."[205]

At a more grassroots level, the Trump administration has also mobilized a higher degree of political consciousness among individual scientists.[206] In the aftermath of the election, thousands of researchers and several scientific organizations reached out to Trump's transition team to discuss the value of science.[207] On April 22, 2017 (Earth Day) over one million supporters participated in various March for Science protests across the world.[208] Concerned that an anti-science administration may delete valuable government data, various self-organized "data rescue" events have archived environmental and other

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200 *Id.* at 1730. For instance, many buildings on NIH's campus are named after supportive members of the House and Senate Appropriations Committees. *Id.* at 1732.

201 Zerhouni, *supra* note 35, at 1090.

202 *Id.*

203 *See* Roger A. Pielke, Jr., *Policy, Politics and Perspective*, 416 NATURE 367, 368 (2002).

204 Niiler, *supra* note 54.

205 Tollefson et al., *supra* note 188.

206 *See* Harmon & Fountain, *supra* note 191.

207 *See* Emma Marris, *Is Donald Trump Pushing More Scientists Toward Political Activism?*, NATURE (Dec. 13, 2016), https://www.nature.com/news/is-donald-trump-pushing-more-scientists-towards-political-activism-1.21130.

208 MARCH FOR SCI., https://satellites.marchforscience.com (last visited Oct. 21, 2017).

data from government websites.[209] 314 Action, a political action committee that encourages scientists and engineers to run for office, has seen a vast increase in interest, and prominent scientists have expressed their intention to seek office.[210] In sum, "it is no longer the political asceticism of scientists, but rather their conscious, adaptable and economic utilization of their political resources, which will best serve the advancement of science."[211]

Democratic engagement, however, must be a bidirectional dialogue and not simply a recitation of scientific achievements coupled with demands for money. There is significant consensus among scholars that the desires and interests of the public should inform scientific agendas,[212] namely the process of identifying which scientific questions to prioritize over others.[213] Relatedly, economists have argued for "induced innovation" models in which demand-side considerations inform the allocation of public money for science.[214] For its part, individual scientists may choose to reorient their work toward addressing practical problems. For instance, early work on apoptosis was widely heralded but has not led to measurable impacts on health.[215] In contrast, the development of cost-effective incontinence pads, which is not as scientifically interesting, has had an immediate and important impact on society.[216]

Such engagement will require cultural evolution on the part of scientists and the scientific community. Oftentimes, researchers conceive of public engagement as a "one-way street: they want to talk at the public, not hear from it."[217] Academic culture has traditionally focused on obtaining research funding or spinning out science-related businesses rather than engaging in dialogue with the public.[218] Furthermore, institutions can frame and co-opt "dialogue" so as to shore up trust for a predetermined agenda and suppress alternative

[209] Harmon & Fountain, *supra* note 191.

[210] *See id.*

[211] Ezrahi, *supra* note 24, at 133.

[212] *Cf.* ALBERT C. LIN, PROMETHEUS REIMAGINED 19-23 (2013) (advocating public participation in technological management and policy decision making).

[213] *Cf.* Suhay & Druckman, *supra* note 68, at 10 (noting the widespread perception that scientific stances are partisan).

[214] Sampat, *supra* note 11, at 1732. *But see supra* notes 134–42 and accompanying text.

[215] Bornmann, *supra* note 37, at 218.

[216] *Id.*

[217] Macilwain, *Science and Democracy*, *supra* note 75, at 40.

[218] *Id.* at 41.

views.[219] Scientists must be mindful of the manner in which they communicate and the power they exert over representations of science. As Alfred Moore observes, "the technical is political, the political should be democratic and the democratic should be participatory."[220] Additionally, continuing the theme of democratic engagement, there are important challenges of representation, for the republic of science is not a monolithic entity but comprised of diverse communities and individuals with sometimes differing opinions.[221]

Returning to the organizing theme of history, it bears emphasizing that scientists have always been firmly embedded in the politics, culture, and economics of the societies in which they operate.[222] From the Catholic Church, which sponsored Jesuit explorations into astronomy, to the Medici's patronage of Renaissance scientists,[223] science has always drawn from and informed society. Indeed, early modern thinkers such as Galileo and Descartes shifted from writing in Latin to the vernacular to appeal not just to learned experts but also to the reading public.[224] In the early nineteenth century, American astronomy was remade through patrons who funded the work of scientists while granting them significant autonomy.[225] Although Vannevar Bush advocated a largely autonomous republic of science supported by federal funds, this model grew in the shadow of the Manhattan Project, an enormous and highly centralized government research program aimed at a very specific end. At the same time, the scientific community possesses its own internal logic, interests, and values that wider society ignores at its peril. Accordingly, this Article has argued for democratic engagement in science policy. The federal government can legitimately advance specific policy objectives in its science funding, but it should create a wide space for curiosity-driven, communally-determined science. Certainly, attempts to quash areas of legitimate scientific research should be resisted. For its part, the

219 *See* Jack Stilgoe et al., *Why Should We Promote Public Engagement with Science?*, 23 PUB. UNDERSTANDING SCI. 4, 6 (2014).

220 Alfred Moore, *Beyond Participation: Opening Up Political Theory in STS*, 40 SOC. STUD. SCI. 793, 793 (2010).

221 Pielke, *supra* note 203, at 367.

222 *See* Anna Wesselink et al., *Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface*, 30 ENVTL. SCI. & POL'Y 1, 2 (2013).

223 *See* MARIO BIAGIOLI, GALILEO, COURTIER: THE PRACTICE OF SCIENCE IN THE CULTURE OF ABSOLUTISM 11-19 (1993).

224 H. BUTTERFIELD, THE ORIGINS OF MODERN SCIENCE 1300–1800, at 168-69 (rev. ed. 1966).

225 *See* Robert W. Smith, *Early History Space Astronomy: Issues of Patronage, Management and Control*, 26 EXPERIMENTAL ASTRONOMY 149, 150-51 (2009).

scientific community bears a responsibility to communicate its values and agenda to the wider polity and meaningfully incorporate input into its work. The result may be more science in politics and more political scientists.

CONCLUSION

The foundation for regulating technologies in the future is to ensure a robust science and technical base that allows them to come into existence. This Article has focused on the emergence of the Trump administration to explore broader challenges and prescriptions for U.S. science policy. At a time of skepticism of big government, it has argued for robust public funding for science and technology. In addition to serving long-term interests of economic growth, technological innovation, and enhanced social welfare, federal science funding extends human capabilities and serves immediate policy objectives. This Article has also argued for a significant degree of autonomy on the part of the scientific community. While federal science funding can legitimately serve specific national priorities, it should leave ample room for curiosity-driven research unencumbered by political influence. Within this framework, the Trump administration's vociferous rejection of widely held scientific consensus and its attempts to influence and silence researchers are highly disturbing. For its part, the scientific community can no longer exist as an insular "republic of science" divorced from the political and social context in which it operates. Accordingly, this Article has argued for greater democratic engagement on the part of scientists to both communicate the value of publicly funded science and incorporate public input into their work. In this manner, the republic of science can better serve the broader republic of which it is a critical part.