Towards better science: More innovative and robust academic research

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This briefing explores ways in which government policy can address two great challenges facing academic science: falling research productivity and the trustworthiness of its findings.

KEY POINTS

Academic science faces two major issues:

- **Research productivity appears to be declining**. Scientific progress appears to be fairly constant, but maintaining this rate of progress is becoming increasingly costly. If the trend continues, we may face a choice between devoting increasingly large proportions of our national income to maintain technological progress, or accepting slower technological progress and a corresponding decline in economic growth.
- **There are issues with the replicability, reproducibility, and robustness** of large parts of the academic scientific literature. The same incentives push scientists towards pursuing more incremental and less potentially transformative research agendas that encourage bias, hype, fraud and negligence.

RECOMMENDATIONS

- **Create shared research infrastructure, such as shared repositories for data, code and papers.**
- **Enforce UKRI's Open Research policy, publishing data on the accessibility of publicly-funded research and setting a deadline for full compliance.**
- **Diversify UKRI funding mechanisms**, exploring innovative approaches such as:
  - Funding people not projects, with fellowships to promising young researchers
  - Giving reviewers 'golden tickets' to fund radical ideas
  - Run trials of funding mechanisms, such as assigning funding by lottery
- **Establish the 'National Institute for Scientific Replicability'**, which would sponsor replication projects and develop tools to predict replicability
- **Establish the 'Atlas Institute'**: an organisation which maps scientific progress and encourages scientific productivity and interdisciplinary research.

TWO PROBLEMS WITH ACADEMIC SCIENCE

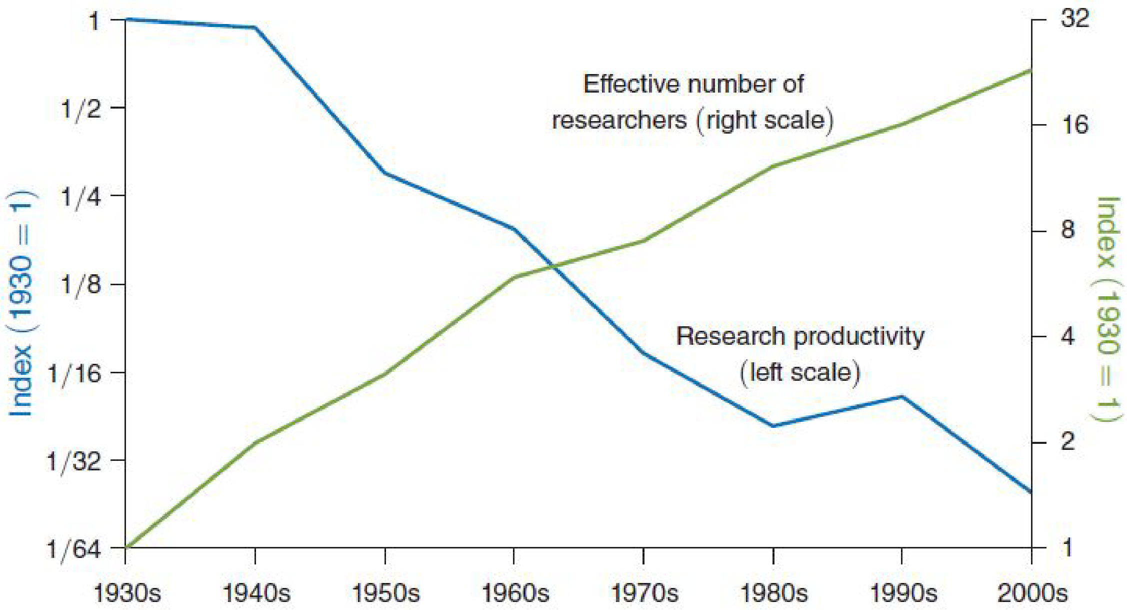
Academic science, consisting of academic researchers, commercial researchers, funders, and publishers, is supposed to facilitate the pursuit of knowledge. However, science is a social phenomenon, and as such the incentives and structures can create unintended side effects.

When people say 'science is broken', they are typically referring to two closely associated problems. First, scientific productivity appears to be declining – we are getting less bang for our buck. [1] Secondly, fraud, bias, negligence, and hype are undermining the search for truth. [2]

Declining research productivity

Whilst the rate of technological progress – measured by, for example, agricultural crop yields and computer chip density – doesn't appear to be slowing down, the amount of effort we need to put in to maintain this rate of progress is increasing. [3] Scientific productivity, measured by citations for recent papers compared with older ones or development of new topics, also appears to be declining. [4]

Figure 1: Aggregate evidence on research productivity



Source: Bloom et al, Are ideas getting harder to find? [5]

Explanations for this stagnation fall into two non-mutually exclusive categories: either this is an unavoidable consequence of scientific and technological progression, or our scientific institutions have changed in a way that is detrimental to scientific progress.

In the first category, there are two explanations for declining scientific productivity. First, if new discoveries are a result of the application of previous discoveries to problems, then researchers will need an increasing amount of knowledge to reach the frontier in order to be able to push it forwards. Researchers must spend more time training, which slows down the rate of discovery. This is often referred to as the "burden of knowledge".[6] There is good evidence backing this explanation: discoveries are made by increasingly older researchers, suggesting that more training is required before researchers can innovate; researchers are increasingly specialised, in order to reduce the amount of knowledge required; and research is done in increasingly large teams to spread the burden of knowledge across multiple researchers. By increasing the size of teams required, the burden of knowledge may further reduce the rate of scientific breakthroughs – larger teams tend to develop existing ideas whereas smaller teams are more likely to produce breakthroughs.[7]

Second, it could be that ideas get harder to find because they become increasingly costly, in terms of time and equipment required, to discover. An analogy for this is mining a seam of gold – the first few layers are easy to find, however extracting the gold gets harder as the layers are deeper and more specialised equipment is required.

There are many possible explanations for ways in which our scientific institutions have changed that have reduced scientific productivity. Many point to the increasing competition for academic positions, which create incentives for researchers to publish as many papers as they can. This pressure, referred to as 'publish-or-perish', often leads researchers to choose 'safer' research projects (which are less likely to find breakthrough results) as they are more likely to produce positive results which are more likely to be published.[8]

Another potential reason for reduced scientific productivity is the staggering 40% of their time that scientists spend applying for grants,[9] leaving less time for research. The grant peer review processes are not worth the time that scientists put into them: novel[10] and interdisciplinary research[11] is less likely to receive funding, even though these types of research are more likely to produce breakthroughs.[12]

In addition to this, entire scientific fields and subfields can be caught up in groupthink, preventing exploration of multiple lines of enquiry. Stanley Prusiner, who eventually won the Nobel Prize for the discovery of prions, faced vicious resistance from virologists after his research challenged their "slow virus theory". His vital discovery was almost prevented by this resistance.[13]

Finally, the decline in R&D carried out by large industrial labs, often funded by profits from monopoly power, may have contributed to decreasing scientific productivity. As Ben Southwood recently described,[14] industrial labs such as AT&T's Bell Labs and Xerox's Palo Alto Research Centre have historically produced a huge number of transformative breakthroughs.

Scientific productivity is 1/32 of what it was in the 1930s.[15] We don't know how much of the decline in scientific progress is due to controllable institutional factors, and how much due to the increasing difficulty of scientific discovery, which is clearly beyond our control. But we owe it to ourselves to do what we can to improve the improvable.

Replicability, reproducibility and robustness

For the last twenty years, scientists and policymakers who depend on science have been increasingly concerned by the large proportion of scientific research which doesn't replicate. In 2005, John Ioannidis published 'Why Most Published Research Findings Are False'.[16] The term 'replication crisis' was coined in the 2010s as part of a growing awareness of the problem.[17]

At first glance, the goal of producing replicable research is in tension with the goal of increasing the rate of innovation in science. Indeed, at a meeting on scientific reproducibility hosted by the White House Office of Science and Technology Policy in 2020, respondents were asked to consider: would efforts to improve reproducibility risk harming the creativity and innovation of federally-funded research?[18]

This is simply a result of defining the goal too narrowly. If scientists are producing ostensible breakthroughs at a greater rate but these breakthroughs aren't replicable, they aren't really contributing to scientific progress. And upon investigation, many of the perverse incentives which are partly responsible for scientific stagnation are also to blame for the replication crisis.

For example, in addition to pushing scientists into pursuing less risky projects, a culture of 'publish-or-perish' pushes researchers to use less robust methodology or generally produce lower quality research in order to maximise the number of positive results.[19] Other scientists are aware of the prevalence of poor quality research coming out of academia. One study found that industrial scientists were 23% less likely to cite academic research than industrial research because they view it as lower quality compared with research produced by industry, which is incentivised to advance commercial aims rather than optimising for publications.[20]

Because only positive results create the hype and the prestige required for academic career progression, researchers typically don't publish null (negative) results, creating publication bias.[21] This creates inefficiency if researchers try the same experiments, being unaware of the null result obtained by other scientists, and if enough negative results are left in the file drawer instead of being published, false claims can become canonised as fact.[22] Failures to replicate aren't always because of fraud or bias. Researchers using the same data to answer the same questions can get different answers, based on the methodology they use.[23]

RECOMMENDATIONS

Researchers and policymakers have been aware of both of these problems for a number of years. Accordingly, there is already a lot of good work being carried out from within government (such as UK Research and Innovation's (UKRI) Open Research policy and the establishment of the UK Committee on Research Integrity)[24] and by scientists (such as the UK Reproducibility Network and the Center for Open Science[25]), and through independent scrutiny (such as the House of Commons Science and Technology Committee's inquiry into reproducibility and research integrity).[26]

Scientific progress is not well understood, but there are clear problems. The recommendations below aim to address these problems, and are worth implementing as they may well improve the rate of scientific advance. These recommendations below go beyond the work already done in government.

Create shared research infrastructure

Research institutions compete with each other for funding, researchers, and other resources. However, there are many instances where greater cooperation would be beneficial. One particularly ripe area for cooperation is shared research infrastructure, including repositories and public datasets.

Currently, research institutions tend to have their own repositories. These repositories allow researchers to access data, code, pre-prints and papers from other researchers at their institution. Initiatives like the UK Data Archive try to collect datasets for researchers to share, but are limited to particular disciplines and do not tend to cover code or articles. This is inefficient.

A shared repository, accessible by all researchers in the UK would make it much easier to access data, code, and pre-prints from other institutions. A shared repository would also enable recognition for scientific work that has not (yet) made it into an academic journal, and may not ever be appropriate to be published in such a format. This would loosen the grip of publish-or-perish. The repository would require data stewards both within each institution and centrally to ensure research outputs are properly stored. A shared repository is a step towards replacing our current artisanal scientific production model with a more industrial model,[27] with increased specialisation and all outputs openly published with real-time peer review (similar to Wikipedia). Research institutions and UKRI should jointly fund the repository.

The UK has a history of creating high-value public datasets, such as the UK Biobank and the NHS Genomic Medicine Service. The government could use Focused Research Organisations (see below) to produce these datasets where identified by the Atlas Institute (see below), and make sure that the data is available on the common repository.

Enforce UKRI's Open Research policy

UKRI has a world-leading Open Research policy, including an Open Access policy which aims to make all UKRI-funded research freely accessible and an Open Data policy which aims to ensure that all data from UKRI-funded research is "findable', accessible, interoperable and re-useable".[28]

However, these policies are currently largely unenforced. As a first step, UKRI should begin collecting and publishing data on compliance with each of these policies. It should then announce a date by which all research institutions must be in compliance with all open research policy.

A shared repository would make compliance easier, as researchers could upload their research outputs to the repository in order to fulfil the conditions of the Open Access and Open Data policies. A shared repository would also enable automatic compliance enforcement for many parts of the Open Access and Open Data policies.

Diversify UKRI funding mechanisms

Currently, the majority of UKRI funding is distributed by peer reviewed grant applications on a project-by-project basis. As Matt Clancy wrote in a recent essay for The Entrepreneurs Network, there is good reason to think that different funding mechanisms could mitigate some of the issues associated with academic science, for example by freeing researchers from the need to continually apply for grants.[29]

Of course, new funding mechanisms may solve existing issues but create new ones. Even if this were to happen, there is value in introducing diversity in the funding mechanisms available. Diversity of funding mechanisms would create diversity in the types of project and researcher that are given funding, increasing the rate of innovation and breakthrough.

UKRI's 2022-27 Strategy recognises this: "In research and innovation, one size will never fit all. A toolbox of funding mechanisms is needed to ensure the right mix of ideas thrive."[30] ."[31] There are already many instances of innovation, such as the Natural Environment Research Council awarding funding for its Exploring the Frontiers of Environmental Science scheme by lottery within scoring bands,[32] the National Institute for Health and Care Research's FAST funding scheme, [33] the establishment of the Innovation and Research Caucus,[34] and the Creating Opportunities Trial Accelerator Fund[35] and Evaluation Development Fund.[36] Yet more could be done to diversify the mechanisms through which UKRI funds research.

Innovation could take the form of running trials, tweaking existing programs, or introducing new programs with theoretical or empirical backing.[37] Below are a few suggestions:

(1) **Introduce a HHMI-style fellowship, awarded to a small number of promising young researchers every year.[38]** Funding people, not projects allows researchers to pursue a longer-term, more transformative research agenda, without the need to constantly re-apply for grants. The European Research Council and Marie Skłodowska Curie Actions grants made up more than half of the person-based funding in the UK,[39] and it is encouraging that the government's alternative to Horizon Association would aim to recreate these fellowships. Supplementing these with additional stable funding for younger researchers would address issues around researchers getting progressively older.[40]

(2) **Modify the review process for 5% of UKRI grants to promote more radical ideas**. Grants should be assessed blinded, and each reviewer should be given a 'golden ticket' that allows them to fund any proposal they assess to be particularly promising, regardless of the other reviewers' views on the proposal. Similar schemes have been set up at the Volkswagen Foundation, and the Villum Fonden.

Reforms to funding processes are likely to face resistance from scientists – globally, 78% of researchers believe that peer review remains the best way to ensure that the highest quality proposals are funded.[41] This is not sufficient reason to not try and improve our scientific institutions. By experimenting with public scientific funding, and by learning from philanthropic efforts to improve science,[42] we can move towards a better scientific system. Small amounts of experimentation will inculcate appetite for greater experimentation with scientific institutions in general.

Diversifying UKRI funding mechanisms would supplement the diversification of research institutions such as the creation of the Advanced Research and Innovation Agency and Focused Research Organisations.[43]

Establish the National Institute for Scientific Replicability

This organisation, originally proposed by Stuart Buck,[44] would be tasked with 'red-teaming' science – mimicking the practice from cyber-security of intentionally seeking out vulnerabilities and testing them. It would do this by:

(1) Sponsoring independent replication projects
(2) Funding alternative lines of enquiry on important scientific questions where the traditional sources of funding are arguably affected by groupthink and confirmation bias
(3) Developing tools for predicting replicability in scientific literature to guide replication efforts[45]

This institute would have a separate budget and would be independent from UKRI and other scientific bodies.

Establish the Atlas Institute

As the Tony Blair Institute proposed previously,[46] the 'Atlas Institute' would be an applied, interdisciplinary laboratory where scholars in these fields work directly with researchers to map scientific progress. Scholars would:

(1) Map all fields of social and natural science, identifying research gaps and challenging conclusions about the current body of knowledge
(2) Develop tools to increase scientific productivity (e.g., better search tools, machine learning models to inform experiment design etc.)[47]
(3) Study interdisciplinary research at the meta-level, and train researchers to work in an interdisciplinary manner
(4) Identify valuable datasets that are yet to be produced but that would be valuable public goods[48]

ENDNOTES

[1] Collison, Patrick, and Michael Nielsen. "Is Science Stagnant?" The Atlantic, November 28, 2018. https://www.theatlantic.com/science/archive/2018/11/diminishing-returns-science/575665/

[2] Ritchie, Stuart. Science Fictions: Exposing Fraud, Bias, Negligence and Hype in Science. Random House, 2020.

[3] Bloom, Nicholas, Charles I. Jones, John Van Reenen, and Michael E. Webb. "Are Ideas Getting Harder to Find?" The American Economic Review 110, no. 4 (April 1, 2020): 1104–44. https://doi.org/10.1257/aer.20180338

[4] Clancy, Matt. "Science Is Getting Harder." New Things Under the Sun, May 31, 2022. https://www.newthingsunderthesun.com/pub/17ygmn8w/release/4

[5] Bloom, Nicholas, Charles I. Jones, John Van Reenen, and Michael E. Webb. "Are Ideas Getting Harder to Find?" The American Economic Review 110, no. 4 (April 1, 2020): 1104–44. https://doi.org/10.1257/aer.20180338

[6] Clancy, Matt. "Are Ideas Getting Harder to Find Because of the Burden of Knowledge?" New Things Under the Sun, August 10, 2021. https://www.newthingsunderthesun.com/pub/zsc23qxz/release/16

[7] Wu, Lingfei, Dashun Wang, and James Evans. "Large Teams Develop and Small Teams Disrupt Science and Technology." Nature 566, no. 7744 (February 1, 2019): 378–82. https://doi.org/10.1038/s41586-019-0941-9

[8] Joober, Ridha, Norbert Schmitz, Lawrence Annable, and Patricia Boksa. "Publication Bias: What Are the Challenges and Can They Be Overcome?" Journal of Psychiatry & Neuroscience 37, no. 3 (May 1, 2012): 149–52. https://doi.org/10.1503/jpn.120065

[9] Ness, Kirsten, Sara Rockwell, Kelly Shaver, and Randy Brutkiewicz. "2012 Faculty Workload Survey." Federal Demonstration Partnership, April 2014. https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_087667.pdf

[10] Boudreau, Kevin, Eva C. Guinan, Karim R. Lakhani, and Christoph Riedl. "Looking Across and Looking Beyond the Knowledge Frontier: Intellectual Distance, Novelty, and Resource Allocation in Science." Management Science 62, no. 10 (October 1, 2016): 2765–83. https://doi.org/10.1287/mnsc.2015.2285

[11] Bromham, Lindell, Russell Dinnage, and Xia Hua. "Interdisciplinary Research Has Consistently Lower Funding Success." Nature 534, no. 7609 (June 30, 2016): 684–87. https://doi.org/10.1038/nature18315

[12] Foster, Jacob G., Andrey Rzhetsky, and James Evans. "Tradition and Innovation in Scientists' Research Strategies." American Sociological Review 80, no. 5 (September 1, 2015): 875–908. https://doi.org/10.1177/0003122415601618

[13] Allen, David, and Elizabeth Reedy. "Seven Cases: Examples of How Important Ideas Were Initially Attacked or Ridiculed by the Professions." In Groupthink in Science. Springer Nature, 2020.

[14] Southwood, Ben. "Revitalising Research." The Entrepreneurs Network, April 2023. https://www.tenentrepreneurs.org/operation-innovation-1#5

[15] Bloom, Nicholas, Charles I. Jones, John Van Reenen, and Michael E. Webb. "Are Ideas Getting Harder to Find?" The American Economic Review 110, no. 4 (April 1, 2020): 1104–44. https://doi.org/10.1257/aer.20180338

[16] Ioannidis, John P. A. "Why Most Published Research Findings Are False." PLOS Medicine 2, no. 8 (August 30, 2005): e124. https://doi.org/10.1371/journal.pmed.0020124

[17] Pashler, Harold, and Eric-Jan Wagenmakers. "Editors' Introduction to the Special Section on Replicability in Psychological Science." Perspectives on Psychological Science 7, no. 6 (November 1, 2012): 528–30. https://doi.org/10.1177/1745691612465253

[18] Buck, Stuart. "Escaping Science's Paradox." Works in Progress, October 19, 2020. https://worksinprogress.co/issue/escaping-sciences-paradox.

[19] Clancy, Matt. "Publish-or-Perish and the Quality of Science." New Things Under the Sun, August 10, 2021. https://www.newthingsunderthesun.com/pub/9uk7xaj8/release/7

[20] Bikard, Michaël. "Made in Academia: The Effect of Institutional Origin on Inventors' Attention to Science." Organization Science 29, no. 5 (June 20, 2018): 818–36. https://doi.org/10.1287/orsc.2018.1206.

[21] Joober, Ridha, Norbert Schmitz, Lawrence Annable, and Patricia Boksa. "Publication Bias: What Are the Challenges and Can They Be Overcome?" Journal of Psychiatry & Neuroscience 37, no. 3 (May 1, 2012): 149–52. https://doi.org/10.1503/jpn.120065.

[22] Nissen, Silas Boye, Tali Magidson, Kevin C. Gross, and Carl T. Bergstrom. "Publication Bias and the Canonization of False Facts." ELife 5 (December 20, 2016). https://doi.org/10.7554/elife.21451.

[23] Clancy, Matt. "One Question, Many Answers." New Things Under the Sun, June 11, 2021. https://www.newthingsunderthesun.com/pub/rl99fcwj/release/9.

[24] UK Research and Innovation. "Open Research," March 21, 2023. https://www.ukri.org/what-we-offer/supporting-healthy-research-and-innovation-culture/open-research/.

[25] Center

[26] Science, Innovation and Technology Committee. "Reproducibility and Research Integrity: Sixth Report of Session 2022–23." UK Parliament, April 26, 2023. https://committees.parliament.uk/publications/39343/documents/193778/default/.

[27] Bechhofer, Nathaniel, and Saloni Dattani. "The Speed of Science." Works in Progress, February 8, 2021. https://worksinprogress.co/issue/the-speed-of-science.

[28] UK Research and Innovation. "Open Research," March 21, 2023. https://www.ukri.org/what-we-offer/supporting-healthy-research-and-innovation-culture/open-research/.

[29] Clancy, Matt. "Funding Fundamentals." The Entrepreneurs Network, April 2023. https://www.tenentrepreneurs.org/operation-innovation-1#3.

[30] "UKRI Strategy 2022 to 2027," March 17, 2022. https://www.ukri.org/publications/ukri-strategy-2022-to-2027/ukri-strategy-2022-to-2027/.

[31] "UKRI Strategy 2022 to 2027," March 17, 2022. https://www.ukri.org/publications/ukri-strategy-2022-to-2027/ukri-strategy-2022-to-2027/.

[32] "NERC to Trial a New Assessment Process for Funding Applications," July 15, 2022. https://www.ukri.org/news/nerc-to-trial-a-new-assessment-process-for-funding-applications/.

[33] NIHR. "A FASTer Way to Accelerate Innovation," n.d. https://www.nihr.ac.uk/blog/a-faster-way-to-accelerate-innovation/30079.

[34] "New network to maximise research and innovation funding impact," *UKRI*, 13 June 2023.

https://www.ukri.org/news/new-network-to-maximise-research-and-innovation-funding-impact/

[35] "UKRI Creating Opportunities Trial Accelerator Fund," *UKRI*, June 2023. https://www.ukri.org/opportunity/creating-opportunities-trial-accelerator-fund/

[36] "UKRI Creating Opportunities Evaluation Development Fund," *UKRI*, June 2023. https://www.ukri.org/opportunity/creating-opportunities-evaluation-development-fund/

[37] Bravo-Biosca, Albert. "Experimental Innovation and Growth Policy: Why Do We Need It?" Innovation Growth Lab, May 2016. https://www.innovationgrowthlab.org/sites/default/files/styles/experimental_innovation_and_growth_policy_why_do_we_need_it.pdf.

[38] Azoulay, Pierre, Joshua Graff Zivin, and Gustavo Manso. "Incentives and Creativity: Evidence from the Academic Life Sciences." The RAND Journal of Economics 42, no. 3 (September 1, 2011): 527–54. https://doi.org/10.1111/j.1756-2171.2011.00140.x.

[39] Forth, Tom, and Richard Jones. "The Missing £4 Billion." Nesta, May 2020. https://media.nesta.org.uk/documents/The_Missing_4_Billion_Making_RD_work_for_the_whole_UK_v4.pdf.

[40] Ricón, José Luis. "Was Planck Right? The Effects of Aging on the Productivity of Scientists." Nintil, December 16, 2020. https://nintil.com/age-and-science/.

[41] Clarivate. "Global State of Peer Review Report," 2018. https://clarivate.com/lp/global-state-of-peer-review-report/.

[42] Thompson, Derek. “Silicon Valley’s New Obsession: Science Funding.” The Atlantic, May 10, 2022. https://www.theatlantic.com/ideas/archive/2022/01/scientific-funding-is-broken-can-silicon-valley-fix-it/621295/.

[43] Fingerhut, Henry, and Benedict Macon-Cooney. “A New Model for Science.” Tony Blair Institute for Global Change, August 4, 2022. https://www.institute.global/insights/tech-and-digitalisation/new-model-science.

[44] Buck, Stuart. “Escaping Science’s Paradox.” Works in Progress, October 19, 2020. https://worksinprogress.co/issue/escaping-sciences-paradox.

[45] Altmejd, Adam, Anna Dreber, Eskil Forsell, Juergen Huber, Taisuke Imai, Magnus Johannesson, Michael Kirchler, Gideon Nave, and Colin F. Camerer. “Predicting the Replicability of Social Science Lab Experiments.” PLOS ONE 14, no. 12 (December 5, 2019): e0225826. https://doi.org/10.1371/journal.pone.0225826.

[46] “The Way of the Future: Supercharging UK Science and Innovation.” Tony Blair Institute for Global Change, July 16, 2021. https://www.institute.global/insights/tech-and-digitalisation/way-future-supercharging-uk-science-and-innovation.

[47] Sourati, Jamshid. “Accelerating Science with Human versus Alien Artificial Intelligences.” arXiv.org, April 12, 2021. https://arxiv.org/abs/2104.05188.

[48] Good Science Project. “A New Public Database for Chemistry,” June 14, 2022. https://goodscienceproject.org/articles/a-new-public-database-for-chemistry/.