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From Discovery to Impact: A Comparative Case Study of Publicly Funded Scientific Programs

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ABSTRACT

Governments remain the world's largest funders of scientific research and exercise significant influence over its direction. In doing so, they must make consequential choices about the scale, focus, and momentum of research investment. While debates over public science funding have traditionally contrasted curiosity-driven research with socially directed innovation, there is a more important question to be answered. What conditions enable publicly funded discoveries to translate into lasting societal impact?

This paper examines that question directly: ***What factors shape the successful translation of large-scale publicly funded scientific research programs into societal impact?*** Drawing on Nelson and Rosenberg's national innovation systems framework, a comparative qualitative case study is conducted across three landmark research programs — the Human Genome Project, mRNA vaccine development, and the European Graphene Flagship. These cases examine how differences in institutional arrangements, public-private linkages, and national innovation systems shaped whether scientific discovery translated into broader societal outcomes. Across the three cases, institutional coordination, protection of public knowledge, sustained support through periods of uncertainty, and effective public–private linkages emerged as critical conditions to generate enduring impact.

The analysis suggests that the societal value of publicly funded science depends less on the ambition of individual programs than on the institutional ecosystems that sustain discovery and carry it to widespread adoption. Governments should therefore evaluate public science not only by the breakthroughs it produces but by the capacity of the institutions that enable such discoveries to generate lasting societal benefit.

INTRODUCTION

In 2013, economist Mariana Mazzucato argued in defense of the entrepreneurial state, observing that every core technology underpinning the iPhone originated from publicly funded research (Mazzucato 23). At the time, governments accounted for nearly one-third of global research and development (R&D) expenditure. Over the following decade, total global R&D almost doubled to US$2.87 trillion, while the

government's share declined to 26% and public R&D spending across OECD countries fell in real terms ("R&D Spending Growth"). Recent trends clearly show that private R&D has increasingly become concentrated within a handful of technology firms, that are oriented towards commercial outcomes. Geopolitical tensions are directing more public funds towards the defense sector. In the US alone, the Department of Defense accounted for approximately 46% of all requested federal R&D funding in FY2025 (Gallo 3). Put together, these circumstances have intensified the question of how governments should prioritize spending on research.

Interestingly, the debate over the role of government in science funding has historically been shaped by two competing philosophies. In *Science, the Endless Frontier*, Bush argued that governments should fund curiosity-driven basic research without demanding predetermined outcomes, because scientific discovery is inherently unpredictable (Bush 10). Earlier, Bernal contended that publicly funded science should be directed towards solving socially important problems, a position later reinforced by Sarewitz, who argued that ambitious scientific programs do not automatically generate societal benefit (Bernal 382; Sarewitz 11). Nelson and Rosenberg, however, offered a different perspective. Drawing on a comparative study of fifteen countries, they argued that innovation emerges not from either model alone, but from the interactions among universities, firms, governments, and other institutions whose relationships determine which discoveries are explored, sustained, and ultimately translated into impact (505–15).

Building on Nelson and Rosenberg's national innovation systems framework, this paper examines a question that neither the curiosity-driven nor the mission-oriented tradition fully addresses: What factors shape the successful translation of publicly funded scientific research into societal impact?

To investigate this question, the paper conducts a comparative qualitative case study of three landmark programs: the Human Genome Project, mRNA vaccine development, and the European Graphene Flagship. These cases were selected because they represent contrasting paths through which publicly funded research originated, developed, was financed, and ultimately translated into real-world applications. The Human Genome Project and mRNA vaccine development are both biomedical innovations with far-reaching scientific and public health consequences, but they followed very different institutional trajectories. In contrast, the European Graphene Flagship represents a physics-led program that achieved significant scientific success but more limited commercial translation. Together, the three cases span different scientific disciplines, institutional settings, and innovation systems, enabling comparison of how
institutional conditions shaped their translation into broader societal outcomes.

RESEARCH DESIGN AND METHODOLOGY

This paper employs a comparative qualitative case study approach to examine how publicly funded scientific programs translate into societal impact. To structure the comparison, each case is examined using a common analytical framework comprising six observable dimensions that capture how publicly

funded scientific programs originate, evolve, and ultimately generate societal outcomes. Together, these dimensions provide a consistent basis for comparing the three cases.

Comparison Dimension	Purpose in Analysis
Origin of the program	Examines whether research was initiated through scientific curiosity, a societal mission, strategic priorities, or individual initiative.
Timing and stage of public investment	Assesses when public funding was provided and whether support extended across the research and translation stages.
Institutional configuration	Compares the roles of universities, government agencies, industry, and research organizations.
Mechanisms of translation	Examines how discoveries moved from research to application, including public-private partnerships, venture capital, and other institutions.
Governance of knowledge	Evaluates how scientific knowledge was managed, shared, or protected.
Societal outcomes	Compares broadly the scientific, economic, and societal consequences of each program.

These dimensions draw on Nelson and Rosenberg's insight that innovation outcomes are shaped not by individual programs in isolation but by the broader systems they operate in (505–15). Rather than treating each program as an isolated success or failure, this framework examines the interactions among public institutions, universities, industry, and governance structures. Applying this framework consistently across three contrasting cases, this paper examines how differences in institutional conditions influenced whether publicly funded research generated enduring societal impact.

COMPARATIVE CASE STUDIES

The Human Genome Project: Institutional Discovery and the Protection of Public Knowledge

The origins of the Human Genome Project (HGP) can be traced to the United States Department of Energy (DoE), which sought to understand the long-term genetic effects of radiation exposure among survivors of the atomic bombings of Hiroshima and Nagasaki. In 1985, Charles DeLisi, a senior official at the DoE, recognised that detecting radiation-induced mutations would require first mapping the entire human genome. He then redirected approximately US$4.5 million from the DoE's existing research budget to initiate the program (Cook-Deegan 94–112).

DeLisi further understood that genome mapping would require sustained federal support. He secured the backing of Senator Pete Domenici, whose political support proved instrumental in obtaining Congressional approval. As funding expanded, the National Institutes of Health joined the Department of Energy in leading what eventually became an international research effort. While the DoE and NIH financed and coordinated the project, the genome sequencing itself was undertaken by networks of scientists working across several countries in universities, national laboratories, and specialised genome centres. By the project's completion in 2003, researchers had produced the first complete sequence of the human genome, creating an openly accessible reference for future research.

Public investment in HGP spanned the full research pipeline, from basic sequencing through to data infrastructure. But the defining moment for knowledge governance came in 1998 when Celera Genomics, a private company, claimed it could sequence the genome faster and cheaper than the public project. In response, Francis Collins and NIH Director Harold Varmus testified before Congress that the human genome must remain a public good. The state's critical role was to protect foundational knowledge from becoming private intellectual property, a critical governance decision that shaped every subsequent use of genomic data.

The institutional set-up that carried HGP to impact reflects the pluralism of the American innovation system. University-based research produced the foundational science while government agencies provided sustained funding and coordination. Entrepreneurs subsequently integrated the research and genomic knowledge into commercially scalable applications. The Battelle Institute estimated that private enterprise generated $141 for every public dollar invested (*Economic Impact* 1) - a return that depended not on the program's original ambition but on the institutional linkages that translated sequencing data into pharmaceuticals, diagnostics, and biotechnology.

HGP's translation path was neither linear nor predictable. The project cost nearly $3 billion and progressed slowly. It does not fit neatly into Bush's model of curiosity leading to application, nor into Bernal's model of socially directed research producing targeted outcomes. What it demonstrates is Nelson and Rosenberg's core insight: that the interactions among institutions, namely, government agencies protecting public access, universities producing foundational research, and private enterprise scaling applications are defining. These interactions determined the programme's ultimate societal impact, not the scale or design of the program itself.

mRNA Vaccine Development: Individual Persistence and Institutional Failure

If HGP illustrates how institutional arrangements can carry a programme to impact, mRNA vaccine development reveals what happens when those arrangements fail — and how societal impact can emerge despite, rather than because of, the system.

In the late 1980s, Katalin Karikó, a researcher at the University of Pennsylvania, began working on mRNA therapeutics to investigate whether mRNA could instruct cells to produce therapeutic proteins. She applied for numerous NIH grants but each application was rejected after peer reviews. The reviewers considered the approach too unstable, too impractical and too far away from clinical application. In 1995, Karikó was demoted from the tenure track but chose to continue her work (Garde and Saltzman). The programme's origin therefore was driven by an individual champion pursuing a line of research that no established institution was willing to fund.

Public investment in mRNA was minimal and intermittent at precisely the stage where it was most needed. The NIH peer review system — the primary mechanism for allocating early-stage public funding in the United States — repeatedly assessed Karikó's work and judged it unworthy of support. This is not an isolated failure. Campanario documented that 24 Nobel Prize-winning discoveries were initially rejected during peer review (549–65). The institutional configuration that successfully carried HGP to impact — government agencies providing sustained funding while universities generated foundational research — failed to support mRNA development at the translational stage.

The breakthrough came in 2005 when Karikó and Drew Weissman discovered that modified mRNA could evade the immune system. Yet this finding was considered narrow and sat in obscurity for years. The mechanism of translation to widespread impact was Karikó's decision to join BioNTech in 2013, transferring publicly generated knowledge into a private firm. When COVID struck in 2020, BioNTech and Pfizer rapidly produced a vaccine using this research. In 2023, Karikó and Weissman won the Nobel Prize.

The governance of knowledge in the mRNA case followed a path quite different from HGP. Where HGP's defining institutional act was protecting genomic data as a public good, mRNA's critical knowledge transfer happened when Karikó joined BioNTech in 2013 — carrying publicly generated research into a private firm not through a deliberate decision but because no public institutional path existed to carry it forward.

It can be argued that all institutions in the mRNA story acted according to established conventions. The NIH peer reviewed through well-established criteria that were arguably incremental in nature. The university demoted a researcher whose work did not attract funding. Peer reviewers exercised the conservatism that Campanario documented. The mRNA story is therefore the inverse of the Human Genome Project. HGP succeeded because institutions sustained discovery and translation, while mRNA succeeded because of extraordinary individual determination, robust research facilities, and some serendipity.

The European Graphene Flagship: Strong Science Without Translation

With 15 European economies ranked in the Global Innovation Index top 25, Europe offers a third model with a highly networked and scientifically productive research system (*Global Innovation Index* 14). The

Graphene Flagship, built on a Nobel Prize-winning discovery by Andre Geim and Konstantin Novoselov at the University of Manchester in 2004, provides an opportunity to examine the scientific innovation from origination to translated outcomes.

In 2004, two physicists at the University of Manchester isolated graphene, a material stronger than steel and more conductive than copper, by peeling graphite with scotch tape during a Friday night experiment. As Geim later reflected, these sessions were driven by pure curiosity — something random and playful (Geim). The technique was so absurdly simple that many journals declined their paper before it was published in the journal *Science* in 2004, and six years later it won the Nobel Prize in Physics in 2010.

Right after the Nobel Prize, Graphene was called the "wonder material" and Europe recognized the opportunity to commercialize at scale and not cede commercialisation to others, as it had with the World Wide Web (invented in Europe but commercialized in Silicon Valley). In 2013, Europe selected Graphene as a flagship proposal through a competitive process evaluated by an independent review panel. Graphene Flagship was launched with a budget of €1 billion — one of the largest research programmes of its kind with 170 academic and industrial partners from 22 countries. This coalition had to be pan-European and represent member states balancing diplomacy and scientific ambition. On the dimensions of origin, funding, and institutional breadth, therefore, the Graphene Flagship appears the strongest of the three cases.

A decade later, the Flagship had produced over 5,000 publications and generated thirteen times more patent applications per euro invested than comparable EU research projects (*Graphene Flagship 10 Years Assessment*). Critics argued it was a research programme that had promised commercialization but fell short. The Flagship's director, Jari Kinaret, countered that the impact of public research can only be measured ten to fifteen years after a project ends. Both may be right. But the structural observation remains: the EU built a coalition optimised for diplomatic inclusion and research output — not for the harder, messier work of translating a discovery into a product.

The contrast with Switzerland is instructive. With two world-class universities, ETH Zürich and EPFL Lausanne, alongside universities of applied sciences and industry research networks, and an exceptionally high 60% of Swiss venture capital directed into deep technology (*Swiss Deep Tech Report 2025*), Switzerland has ranked among the world's most innovative economies for over a decade (*Global Innovation Index* 14). Switzerland proves the critical variable is not size of spend, but how well national institutions carry discoveries successfully to impact — precisely the translation pathway the Graphene Flagship lacked.

What the Graphene case demonstrates is that neither scientific ambition, sustained public funding, nor broad institutional participation is sufficient on its own. Without the mechanisms that bridge discovery to application, even well-funded and well-coordinated programmes can produce strong science that fails to generate proportionate societal impact.

Table 1: Comparative Analysis of Three Publicly Funded Scientific Programmes

Dimension	Human Genome Project	mRNA Vaccine	Graphene Flagship
Origin	Institutional initiative within DoE; scaled into coordinated NIH–DoE program	Individual researcher (Karikó) pursuing a line of research no institution would sustain	Nobel Prize discovery fueled by curiosity followed by a large pan-European program
Timing of public investment	Sustained across full research pipeline, from basic sequencing to data infrastructure	Early-stage public funding largely absent; NIH peer review repeatedly rejected grant applications	Strong and sustained public investment across research pipeline after scientific discovery
Institutional configuration	Strong coordination among NIH, DoE, universities, and industry	University research strong; public funding weak at translational stage; private sector eventually enabled translation	Broad academic collaboration across 22 countries; weaker industry integration and venture capital linkages
Mechanism of translation	Open genomic data combined with public–private innovation ecosystem; entrepreneurs scaled applications	Transfer of knowledge to BioNTech (2013) followed by rapid industry scale-up under pandemic pressure	Translation from research to commercial application remained limited despite significant research outputs
Knowledge governance	Genome protected as a public good through deliberate institutional action	Knowledge transferred to private sector through Karikó's move to BioNTech	Collaborative research with IP distributed across institutions
Societal outcome	Major biotechnology ecosystem; estimated $141 return per public dollar invested	COVID-19 vaccines and broader mRNA therapeutic platform; Nobel Prize (2023)	Significant scientific output, publications, and patents; modest commercial impact relative to investment

Source: Author's analysis based on comparative case study framework.

Across the three cases, the comparative analysis reveals that societal impact was shaped less by the scale or ambition of the original programme than by the institutional conditions surrounding it. The Human Genome Project succeeded because government agencies sustained discovery across the full research pipeline, protected foundational knowledge as a public good, and created the conditions for private enterprise to scale applications. mRNA vaccine development achieved impact despite the institutional system rather than because of it. It was carried forward by individual persistence and a transfer of publicly generated knowledge into the private sector when no institutional path existed to support it. The Graphene Flagship, despite sustained funding and broad academic participation, lacked the public–private linkages and translational mechanisms needed to carry scientific discovery into commercial application. What the three cases demonstrate, taken together, is Nelson and Rosenberg's core insight: that the interactions among institutions - how knowledge is governed, how funding is sustained through uncertainty, and how discoveries are carried across the gap between research and application - determine the societal value of publicly funded science more than the design of any individual programme.

CONCLUSION

This paper began by asking what factors shape the successful translation of publicly funded scientific research into societal impact. Through a comparative analysis of the Human Genome Project, mRNA vaccine development, and the European Graphene Flagship, it argues that scientific achievement emerges not from isolated innovations alone, but from institutional systems capable of sustaining discovery and translating it into broader societal benefit. Across all three cases, differences in institutional coordination, knowledge governance, and mechanisms of translation shaped outcomes as much as — and often more than — the ambition or scale of the original programme.

These findings extend the debate between Bush's defence of curiosity-driven science and Bernal's call for socially directed research. Both perspectives remain important, but the evidence presented here suggests that they are incomplete when considered in isolation. Consistent with Nelson and Rosenberg's national innovation systems framework, the societal value of public science depends not only on what governments choose to fund, but on the institutions, relationships, and pathways that enable discoveries to move from laboratories to society.

The policy implication is therefore not that governments should fund fewer ambitious scientific programmes, but that they should give equal attention to building the institutional capacity that allows those programmes to succeed. Sustained investment in universities, research laboratories, translational infrastructure, long-horizon funding, and effective public–private collaboration can strengthen the pathways through which scientific discoveries generate lasting public value. As public R&D faces growing fiscal pressure and the infrastructure for modern science becomes increasingly concentrated within a small number of institutions, the ability to build and sustain these pathways becomes more, not less, important.

Ultimately, the challenge for governments is not only to support scientific discovery but to build institutions capable of governing it wisely. As Jasanoff argues, science policy requires "technologies of humility" — institutions that continually ask who benefits, who bears the risks, and how societies should respond when innovation no longer serves human welfare ("Technologies" 227). By shifting attention from individual breakthroughs to the systems that sustain them, this paper argues that the enduring success of public science lies not in the discoveries it produces alone, but in the institutions that enable those discoveries to improve society.

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