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Crisis Innovation: Historical Evidence, Insights, and Open Questions

Daniel P. Gross and Bhaven N. Sampat

The COVID-19 pandemic has brought into focus the potential value of innovation in a crisis: big, new, urgent problems may demand novel solutions. Early on in the pandemic, there were calls from both scientists and policymakers for a focused R&D effort to combat the disease, many invoking past R&D efforts like the Manhattan Project as strategic metaphors for a wartime approach to the pandemic response.¹

Over the past several years, we have been immersed in studying crisis innovation, primarily through the lens of World War II, when the United States mobilized the country's fledgling innovation system to tackle dozens of urgent wartime R&D needs, resulting in outputs as varied as radar, mass-produced penicillin, malaria treatments, and atomic fission. This effort was primarily organized and led by a

new government agency, the Office of Scientific Research and Development (OSRD), which identified military research priorities and contracted with firms and universities across the country to perform the necessary research, prototyping, and early-stage manufacturing before new technologies could be produced at scale. In addition to supporting research and development, OSRD actively promoted diffusion. The OSRD-sponsored effort was a watershed moment in innovation policy, marking the federal government's first significant investment in research and supporting advances that were instrumental to the Allied victory and transformed civilian life after the war ended.

As perhaps the largest single shock in the history of the US innovation system and the most expansive crisis R&D effort,

we were drawn to studying it more closely. The long historical lens, together with rich detail from primary records from the National Archives present an opportunity to examine the nature of crisis R&D problems, organizational and policy approaches to crisis innovation, and the short- and long-run impacts of crisis R&D investments. Our research complements other studies of large, government-directed R&D projects like the Apollo program² and of other settings in which innovation may be valuable, such as environmental catastrophes.³

Mobilizing Research for War

To gain a deeper understanding of crisis R&D problems, we first analyze the wartime research effort.⁴ Initially formed in June 1940 as the National Defense



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Recurring themes in Gross' work include crisis innovation and its impacts on the innovation system; automation and its effects on firms, workers, and labor markets; and incentives and other tools for managing creative workers within organizations. His work frequently uses historical examples of industries undergoing significant technological change as contexts to investigate recurrent or modern economic questions.

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In addition to his work on World War II and crisis innovation, his current research studies pharmaceutical patent policy, innovation, and access to medicines in the United States and globally; the roles of the government in pharmaceutical innovation; and the history and political economy of the National Institutes of Health.

Research Committee, proposed by and led throughout the war by Vannevar Bush, OSRD grew from an eight-person nucleus to a 1,500-person, multibillion-dollar research funding agency enlisting and coordinating civilian science to address wartime R&D problems. Even before the US formally entered the war, it operated with urgency, but what began as a steady grind turned into a sprint after the bombing of Pearl Harbor.

Lacking precedent for an operation of this scale, OSRD improvised much of its structure and procedures as it evolved. The apparatus that emerged had several notable features. Its organizational form and routines balanced structure with flexibility. It had an explicitly applied focus, working closely with military partners to identify research priorities and contractors — primarily universities and privately owned companies — to work on them. It devised novel incentive mechanisms around patent policy and indirect cost recovery to encourage contractors' participation, and where necessary set up new research centers. Urgency also led OSRD to take on a major role in coordinating research efforts, hand-offs to manufacturing, and diffusion. As Bush deputy James Conant wrote, "The basic problem of mobilizing science during World War II was the problem of setting up rapidly... organizations which would connect effectively the laboratory, the pilot plant, and the factory with each other and with the battlefield."⁵

Under this end-to-end approach, OSRD and its partners produced major advances in dozens of areas. These included foundational progress in radar, electrical communication and computing, jet propulsion, and atomic energy; antibiotics and applications to infectious

disease; influenza and other vaccines; the malaria treatment chloroquine; new approaches to managing wartime hardships such as sleep and oxygen deprivation, cold temperatures, nutrient deficiency, and psychological stress; and new techniques for treating injuries and wounds. The most important innovation, however, may have been organizational: a new approach to harnessing science and technology to tackle big problems, to which we return below.

dence suggests they were a result of self-reinforcing agglomerative forces rather than sustained postwar federal R&D investments, as they do not seem to vary with the intensity of local postwar government-funded patents.

We find similar long-run impacts in the biomedical sciences. Though medical research accounted for less than 5 percent of OSRD's budget, it set the stage for a postwar surge in drug development and changes in medical practice.⁷ Both here and elsewhere, OSRD's work

supported the incubation of new industries, from a research-intensive pharmaceutical industry to radar and microwave communications. In additional work with Maria P. Roche of Harvard Business School, we have examined the effects of OSRD's radar research program — operated primarily through a large new organization created during World War II to lead this effort, the MIT Radiation Laboratory — on industry develop-

ment.⁸ The Rad Lab created new collaborative structures that persisted long after the war ended, pioneering a new approach to science at scale ("Big Science") through large central laboratories. This project also set in place building blocks of emergent high-tech industries around radar and electronics, incubating a deep well of new technical knowledge, extensive human and organizational capital in a new field, manufacturing capabilities, and — crucially — an anchor customer in the military.

The war presented myriad other challenges to the US innovation system, among them protecting wartime technology from foreign enemies. To this end, Congress in 1940 gave the US Patent and Trademark Office authority to order that an invention in a patent applica-

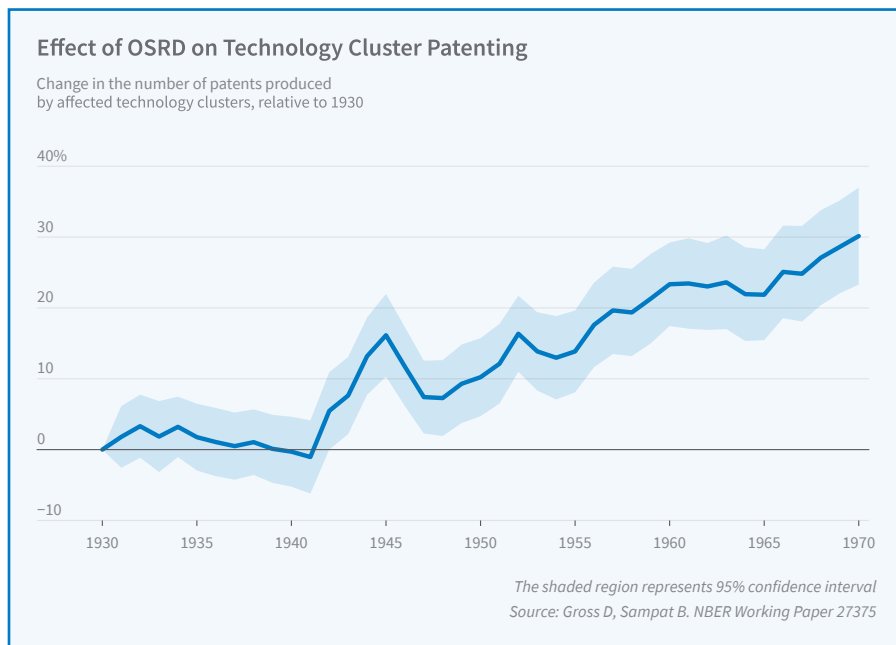


Figure 1

Enduring Impacts on Innovation

Though its first-order impact was to help bring the war to a successful end, OSRD's impacts were broad and long lasting. One was its effect on the economic geography of American innovation. We find, and illustrate in Figure 1, that OSRD catalyzed technology hubs around the country, triggering decades-long growth in inventive output as well as downstream entrepreneurship and job growth in regions that were heavily engaged in wartime research — including the Boston/Route 128 and Silicon Valley high-tech regions, among others.⁶

A key residual question is why these effects were so long lived. Preliminary evi-

tion be kept secret, and to withhold patent rights and prohibit disclosure until that secrecy order was rescinded—an authority it retains today. Such orders were issued widely during the war, particularly in areas important to the war effort, including atomic energy, radar, cryptography, synthetic materials, and petroleum refining. At the war's height, more than half and in some cases 90 percent of patents in these technology areas were "going dark." Gross has examined the effects of compulsory secrecy on the functioning of the innovation system and found that it had wide-ranging impacts, driving implicated firms that were not government suppliers to pivot away from patenting in affected subjects, precluding commercialization, and impeding follow-on innovation—bringing into relief the key functions of intellectual property and openness in the US innovation system.⁹ On the other hand, a range of evidence indicates that this policy achieved its intended effect of keeping sensitive technology out of the public view, underscoring basic tradeoffs between security and technological progress, whether in hot wars, cold wars, or peacetime.

The Birth of Modern Innovation Policy

OSRD also left a large imprint on innovation policy. This in part arose through a wide range of direct institutional legacies, including the seeds of postwar science-funding agencies and a network of federally funded research centers. Important, too, was Bush's vision. Near the end of the war President Franklin Roosevelt asked Bush to reflect on lessons from the wartime effort for postwar innovation policy, and Bush's response, a report to the president titled "Science, the Endless Frontier," famously made the case for government funding of basic research on the grounds of its high returns for economic growth, national security, and public health. Though many of the specific institutional features Bush advocated were not adopted—most notably his call for a single agency, a "National Research Foundation," focused on funding basic

research—the report has shaped innovation policy debates for the ensuing 75 years. It advanced a linear model of innovation—drawing a line from fundamental research to technology development to commercialization—and argued that research policy should focus on funding basic research, leaving applied endeavors to industry. The latter argument anticipated the Nelson-Arrow "market failure" rationale for funding basic research.¹⁰

Insights, Open Questions, and Unresolved Debates

Economics has a long tradition in studying innovation, but like the Bush report, this tradition emphasizes its role in advancing long-run economic growth and human welfare in peacetime through incremental technological progress. Yet crisis problems are big and immediate, and as World War II scientific leaders like Conant noted, crisis R&D must draw on "the basic knowledge at hand." Rather than promoting gains, crisis innovation policy aims to limit losses. Where modern peacetime R&D policy aims to address market failures by funding research that is unlikely to be efficiently provisioned in private markets, crisis R&D policy seeks technological solutions to specific problems. With distinct objectives, constraints, and time horizons, crises may require different economic and policy frameworks.¹¹

What can be learned from the OSRD example for crisis innovation and other big R&D problems? In Bush's words, it "brought into being a pattern of administration ... which stands as a richly suggestive guide for other undertakings."¹² One insight that emerged from comparing the problems for which the OSRD model may be relevant, and the problems for which it is incomplete or ill suited, is that OSRD was much broader than the Manhattan Project alone. More than a singular, focused moonshot, it was many moonshots pursued all at once, collectively managed from the center. Thus, though we agree with previous assessments that the Manhattan Project may only be relevant for specific classes of problems,¹³ the

OSRD approach may be more broadly applicable to crises and other challenges when multiple urgent problems need solving. One example may be the COVID-19 pandemic.¹⁴ The most successful piece of the COVID-19 response—the vaccine development effort under Operation Warp Speed—was explicitly modeled on the Manhattan Project. Yet the pandemic presented dozens of other problems that might have benefited from a coordinated R&D attack.

Many questions raised in and after World War II extend to peacetime. Postwar policy debates introduced a range of issues, including the role of government in basic versus applied research, the geographic distribution of research funding, and patent policy, motivated by concerns that OSRD had concentrated its programs too heavily in a handful of elite institutions and firms and had given away rights to taxpayer-funded invention. While Bush advocated funding basic research and the best science, with scientists guiding the funding choices, another camp—US Senator Harley Kilgore (D-WV) and his allies, for example—took a contrary view, including support for applied research, a broad geographic and institutional distribution of funding, and politicians and laypeople having a say in the research agenda.

These questions and tensions persist today. For example, the recently enacted CHIPS and Science Act adds an applied focus to the National Science Foundation, and earlier in 2022, Congress created the Advanced Research Projects Agency for Health, which may also provide funding for more applied research activities than the National Institutes of Health has typically supported. The CHIPS Act also aims to develop regional technology centers across the country, particularly in regions that have not historically been loci of research activity. Some critics of these efforts invoke arguments similar to those advanced by Bush, though an interesting question neither Bush nor Kilgore considered, but which has been raised by some scholars, is whether a broader distribution of resources might also broaden public support for science and govern-

ment R&D spending.¹⁵

A third set of unresolved questions relates to government patent policy. The rules governing intellectual property that were adopted by many agencies in the postwar era can be traced back to choices made by OSRD. While the 1980 Bayh-Dole Act universalized a policy of allowing recipients of government R&D funding to retain title to patents, Kilgorian criticisms of “giving away” government patent rights have resurfaced periodically since the war, including in current debates about high drug prices. These questions also came up during the pandemic around who should hold intellectual property rights on COVID-19 vaccines and therapeutics to which both the public and private sector had made contributions.¹⁶ That these and other questions remain contentious points to the continued need for research on the science of science policy, with distinct but complementary views of crises and ordinary times.

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