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America, Jump-Started: World War II R&D and the Takeoff of the US Innovation System[†]

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During World War II, the US government's Office of Scientific Research and Development (OSRD) supported one of the largest public investments in applied R&D in US history. Using data on all OSRD-funded invention, we show this shock had a formative impact on the US innovation system, catalyzing technology clusters across the country, with accompanying increases in high-tech entrepreneurship and employment. These effects persist until at least the 1970s and appear to be driven by agglomerative forces and endogenous growth. In addition to creating technology clusters, wartime R&D permanently changed the trajectory of overall US innovation in the direction of OSRD-funded technologies. (*JEL* H56, N42, N72, O31, O33, O38, R11)

A large literature in economics has studied the determinants of innovation (Cohen 2010; Bryan and Williams 2021), including government funding (Bloom, Van Reenen, and Williams 2019). The US innovation system is especially rich in specialized, regional technology clusters, which are thought to be important to overall technological progress (Chatterji, Glaeser, and Kerr 2014; Carlino and Kerr 2015) while also contributing to growing gaps in regional economic performance (Gruber and Johnson 2019). Yet this literature has few examples of systemic R&D shocks and underexplores issues such as (i) the long-run effects of public R&D investments; (ii) the impacts of large, actively managed applied research programs

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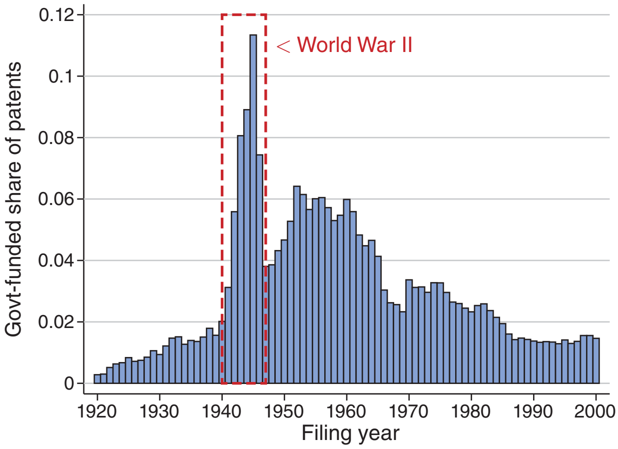

Figure 1. Government-Funded Share of US Patents, 1920 to 2000

Notes: The figure plots the government-funded share of annual US patenting (by filing year), using administrative data. World War II was the peak intensity of government-funded invention in US history. See the online Appendix for data details.

(Azoulay et al. 2019a); and (iii) to what degree, and how, these investments affect regional economic development—issues that are central to policy today.[1]

In this paper, we study the long-run effects of the largest R&D shock in US history. In World War II, the newly created Office of Scientific Research and Development (OSRD) led an expansive effort to develop technologies and medical treatments for the Allied war effort. From 1940 to 1945, OSRD engaged industrial and academic contractors in more than 2,200 R&D contracts at over US$(2022)9 billion, despite no prewar tradition of funding extramural (externally performed) R&D. At the height of the war, the US government was funding the research behind nearly one of every eight US patents—more than five times prewar and modern levels, and nearly twice the level at the peak of the Cold War in the 1950s and 1960s (Figure 1).

The immediate effect of these investments was a range of technological advances that were not only instrumental to the success of the Allied campaign but also of wide civilian value after the war ended.[2] Its longer-run impact was to reshape the US innovation system. We document four main findings. First, World War II R&D kicked off the postwar growth of technology clusters (counties × technologies) around the country: despite parallel trends prior to the war, the most heavily treated clusters were by 1970 producing another 40 percent to 50 percent more patents per

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[1] These gaps have recently become relevant: in August 2022, the US initiated its largest public investment in applied, use-oriented R&D since the Cold War (via the CHIPS and Science Act). Among its provisions, it adds a $20 billion technology directorate to the National Science Foundation (NSF) and a $10 billion investment in regional technology hubs, aiming to develop new domestic capabilities in frontier technologies and to create new capacity in regions that have not previously been major R&D centers (Gruber and Johnson 2019).

[2] OSRD itself existed only for the duration of the war, but in that time it was responsible for foundational technological developments in radar, electronic communication and early computing, underwater detection (sonar), rockets and jet propulsion, and atomic fission, as well as medical and pharmaceutical advances, such as mass-produced penicillin, influenza and other vaccines, new malaria treatments, new approaches to managing myriad human hardships from sleep and oxygen deprivation to nutrient deficiencies, and many more.

year than untreated clusters. Second, this sustained growth benefited from, but did not depend on, postwar federal R&D investment. Instead, our evidence suggests OSRD catalyzed self-sustained agglomeration, including firm in-migration, entry, and growing spillovers across inventors and technologies. Third, we find evidence that these changes were accompanied by growth in local industrial employment and firm creation in related high-tech industries. Finally, we show that wartime R&D had permanent effects on the direction of US innovation, which pivoted toward electronics and communications. By (rapidly) extending the frontier of key emerging technologies while stimulating agglomeration, the impacts of this shock were thus to enhance competitiveness but widen differences in inventive productivity, and in turn economic performance, across the country.

Making this analysis possible is a new dataset of the universe of OSRD contracts, which we have collected from archival records, including detailed information on the contractors, contracts, and patents they produced. We merge these records with the complete US patent record, new administrative data on postwar government-funded patenting, and SIC-level measures of local firm creation and industrial employment. We use these data to study the effects of the OSRD shock on postwar invention, local innovation ecosystems, and industrial activity from 1930 to 1970. Our empirical design compares pre- and postwar patenting in clusters shocked by the war effort, which we measure as the OSRD share of cluster patents in the 1940s. We take a similar logic in evaluating other outcomes at the cluster, county, and national levels.

We observe a consistent pattern across our different analyses: parallel prewar trends, a wartime spike in invention in OSRD-funded technologies, and a postwar takeoff that continues through the end of our analysis window. The magnitudes of these effects are large: for example, a doubling of the OSRD share of 1940s patents in a given cluster is associated with 20 percent higher patenting by 1960 and 30 percent by 1970, relative to prewar levels. In a subset of clusters, these magnitudes were off the charts: Middlesex, MA (the locus of World War II radar R&D; see Gross and Roche 2023) experienced a nearly *thirtyfold* increase in electronics patenting during the war, a short-lived postwar reversion, and then a sustained takeoff—with patenting in 1960 ten times prewar levels.

In addition to estimating the effects of this shock, we also examine why they were so long-lived. We first establish that the postwar takeoff in patenting is not driven by direct follow-on to OSRD invention nor by patents of firms and inventors involved in the war effort. Having ruled out these explanations, we consider two other possibilities: (i) continued government R&D investment in the same locations or (ii) self-sustaining agglomeration dynamics. Our evidence is consistent with the latter: it appears entire local research ecosystems sprang up in many locations and technology areas where OSRD activity was concentrated. In more heavily shocked clusters, we see increases in both public and private patenting and increases from a wide variety of entities, including by in-migrating firms and entrants. Beyond patents, we show that postwar firm creation and employment were higher in counties and industries that were targets of OSRD-funded research. We then document a sharp postwar divergence between US and foreign patenting in OSRD-funded technologies, suggesting its local effects rolled up to a large aggregate impact on US invention.

There is widespread recognition that World War II was a sea change event in government-science relations and in science and technology policy. Although policymakers and scholars appeal to the war effort as a paradigmatic example of the benefits of federal research funding (Bush 1945; Gruber and Johnson 2019), there has been limited empirical grounding to these claims. A sizable literature has studied the impacts of other public R&D investments on innovation (e.g., Azoulay et al. 2019b; Myers and Lanahan 2022) and other outcomes (Howell 2017).[3] Most existing evidence, however, is drawn from studies of marginal changes in funding, and often for basic science. As a result, there is limited evidence as to what effects a systemic shock to R&D funding of this scope and scale may have, over what horizons, and through what mechanisms these effects are realized. This is the main gap we address. Crucially, the passage of time allows us to evaluate long-run effects. Our results suggest that investments made in World War II may be important to understanding the postwar golden age of innovation which bridged the World War II era to the present,and to rapid postwar economic growth.

Our results also contribute to research in the geography of innovation (Feldman 1994; Audretsch and Feldman 2004), especially around agglomeration (Carlino and Kerr 2015; Kerr and Robert-Nicoud 2020). This literature frequently documents the localization of inventive activity (e.g., Jaffe, Trajtenberg, and Henderson 1993; Audretsch and Feldman 1996) and relates this to R&D productivity (e.g., Kantor and Whalley 2019; Andrews 2023; Moretti 2021; Gruber, Johnson, and Moretti 2022), identifying reasons why innovation has locally increasing returns. The literature has made less progress on the inverse question—whether discrete R&D shocks trigger agglomeration (Duranton 2007; Kerr 2010) and more generally, what catalyzes change (e.g., Chattergoon and Kerr 2022; Kim, Shaver, and Funk 2022). Because innovation is often tied to population and industrial activity, our results link to the broader literature on industrial agglomeration (see Duranton and Puga 2004 for a review), including place-based industrial policy (Chatterji, Glaeser, and Kerr 2014; Kline and Moretti 2014a, b).[4] We use this literature to frame our analysis as we explore why this transitory shock had such long-lived effects.[5]

Beyond these themes, this paper relates to a wider literature on endogenous growth (Romer 1986, 1990), where innovation features increasing returns to scale but which has few examples of discrete shocks and takeoffs. Most recently, Kantor and Whalley (2022) have examined the impacts of the Cold War expansion of aerospace R&D on local manufacturing and used this context to estimate a large fiscal multiplier on public R&D. Our paper complements this literature, highlighting the growth initiated by the World War II shock and the long-lasting changes this event brought about. As such, we bring a renewed perspective to the origins of the modern US innovation system while adding to research that studies defense R&D

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[3] Also see Santoleri et al. (2022) and Bergeaud et al. (2022), among others.

[4] A contextually related paper in this vein is Garin and Rothbaum (2022), who find that counties where government-financed manufacturing facilities were sited in World War II had higher manufacturing employment and income for decades. Empirically, these counties were quite different from those where OSRD research took place, as the latter tended to be in urban centers (located near researchers) and the former in more distant regions (to mitigate congestion and security risks, per Garin and Rothbaum 2022).

[5] In closely related research, Buenstorf and Klepper (2009) and Klepper (2010) study the emergence of high-tech US clusters, attributing their growth to spin-offs from industry pioneers. Arthur (1990) explores the effects of historical accidents on clustering via path dependence in an evolutionary framework.

(Mowery 2010; Howell et al. 2021; Moretti, Steinwender, and Van Reenen forthcoming; Belenzon and Cioaca 2021) and the impacts of war on innovation (e.g., Ruttan 2006)—including much of our own recent work (e.g., Gross and Sampat 2021, 2022a, b, 2023; Gross and Roche 2023).

We proceed as follows. In Section I we describe the World War II research effort. Section II introduces our data and empirically characterizes the World War II shock. Section III documents the effects of World War II R&D on local invention, and Section IV explores the mechanisms behind these effects. In Section V, we examine downstream impacts on industrial employment and firm creation. Section VI then evaluates impacts of World War II R&D on the direction of innovation at the national level. Section VII offers concluding remarks, including insights for open and long-running policy debates today.

I. Historical and Policy Background

A. *The World War II Research Effort*

World War II was one of the largest shocks in the history of the US innovation system. Prior to the war, there was very little federal funding of research outside of agriculture. Most academic research was funded by philanthropic foundations (Rockefeller and Carnegie, in particular) and industry. There was, if anything, an aversion among academics to public funding, reflecting concerns that it may restrict scientific freedom.

World War II changed this. Even before the attack on Pearl Harbor and the United States' official entry into the conflict, scientists, the military, and politicians anticipated that the development and application of technology would be critical for an Allied victory, that existing US military R&D was inadequate, and that coordination would be required to mobilize the scientific and technological capabilities that had developed in the interwar era.

The World War II research effort began in June 1940, when Vannevar Bush (a former vice president and dean of engineering at MIT, president of the Carnegie Institution of Washington, and chairman of the National Advisory Committee for Aeronautics) together with other members of the US scientific and technological establishment convinced President Roosevelt to establish and fund a National Research Defense Committee (NRDC) to "correlate and support scientific research on the mechanisms and devices of warfare" (Roosevelt 1940). NRDC was to supplement existing military research "by extending the research base and enlisting the co-operation of institutions and scientists" (James Conant, quoted in Stewart 1948, p. 21).

Perhaps as important as any of the technologies it helped to develop, the wartime research effort was a major innovation in the way science was supported and conducted.[6] While the First World War disrupted universities and firms by drawing scientists out of laboratories, and US government agencies themselves had previously done some research internally, the NDRC effort primarily funded research

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[6] Scholars have since described the wartime arrangement as having "portended the beginning of a new relationship between the federal government and the nation's universities" (Geiger 1993, p. 3).

"extramurally" through contracts, engaging both firms and universities, from individual investigators to larger laboratories. Impressed by its early successes, NDRC was expanded by a 1941 Executive Order to emphasize more development work (beyond just research), to solidify links with military agencies conducting research, and to take over wartime medical research and development. The new organization, the Office of Scientific Research and Development, was also eligible for regular Congressional budget appropriations. As the *New York Times* wrote, this effectively made Vannevar Bush "the czar of research" (Kaempffert 1941).

This effort helped develop a range of technologies that were crucial to the Allied victory. Radar, mass-produced penicillin, and the atomic bomb are its most memorable achievements, but OSRD also produced significant advances in rocketry, jet propulsion, radio communications, and electronic computing, plus treatments for malaria, pesticides like DDT, and more—all of which had commercial applications. Much of this R&D was concentrated in a network of new, university-based central laboratories, which conducted R&D on specific problems and connected researchers, firms, and military users.[7] These early "national labs" attracted scientists and engineers from around the country, some of whom dispersed after the war—and some of whom stayed. In parallel research, we and others have documented how these coordinated R&D programs laid foundations of new industries that emerged after the war (e.g., Klepper 2016; Gross and Roche 2023), potentially to the benefit of regions where these industries were based.

B. *Transitions to the Postwar Era*

Even before the war was over, there was broad agreement that the government should be involved in funding research at universities after the war. Perhaps ironically, the initial attempts to create a structure for postwar funding came from a critic of OSRD, Senator Harley Kilgore (D-WV). Kilgore, a New Deal Democrat, was concerned about the concentration of OSRD funding in big business and a handful of universities (Kevles 1977a). Kilgore had other concerns about the OSRD model, including that many of the contracts allowed the recipients to retain patent rights—making the intellectual output of government-supported research private property—and that there was a lack of representation from small business, independent inventors, and non-elite universities in the wartime effort. He believed each of these features of OSRD hurt the rate of technological development during the war and also led to concentration of the benefits of federal funding in a few research fields, institutions, and regions (Kevles 1977a; Kleinman 1995). In a series of bills introduced during the war, culminating in a 1944 proposal of a new "National Science Foundation," Kilgore attempted to forge a peacetime research policy that would fund basic and applied research in response to specific socioeconomic problems,

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[7] For example, radar development was centered at the MIT Radiation Laboratory (the "Rad Lab"), and radar countermeasures at the nearby Harvard Radio Research Lab (RRL). Rocket and jet propulsion research was based at the CalTech Jet Propulsion Lab (JPL), and proximity fuze development at the Johns Hopkins Applied Research Lab (APL). Early, NDRC-supported research on uranium fission took place at academic labs at the University of Chicago, UC Berkeley, and Columbia University before spinning out into the Manhattan Project, which was based in Los Alamos, New Mexico, supported by project sites around the country. These labs were the predecessors of postwar national labs in these locations, most of which are still operating today.

with a mandate for broad geographical and institutional distribution of funds, wide dissemination of research results (with public ownership of resulting patents), and political accountability of researchers.

Vannevar Bush's seminal report *Science*, *The Endless Frontier* (Bush 1945), written at the request of President Roosevelt and published near the end of the war, was, in many ways, a rejoinder to Kilgore's arguments and proposal. Like Kilgore, Bush recommended a single agency (a "National Research Foundation"), but with a focus on basic research, run by scientists, with broad scientific autonomy, and aimed at stimulating high-quality research by the best institutions and scientists. In making the case for federal funding of fundamental research at universities, the Bush Report also anticipated the market failure rationale for federal R&D funding (Arrow 1962) and the linear model of science and innovation (Mowery 1997; Nelson 1997).

Though the Bush Report had a strong ideological impact on US policy, many of its specific proposals met a cool reception, including from Kilgore and other liberals, who preferred a more egalitarian peacetime approach, and from President Truman, who insisted on a politically appointed director. By the time NSF legislation was enacted in 1950—following five years of debate around Bush and Kilgore's competing visions—many of OSRD's remaining research contracts had been transferred to mission agencies (e.g., the Office of Naval Research, the Atomic Energy Commission, and the National Institutes of Health), precluding the single-agency approach Bush (and Kilgore) had envisioned. Though the NSF was in large part "a triumph for Bush" (Kevles 1977a, p. 25)—primarily focused on basic research, administered by scientists—its budget was small, and it was a "puny partner" in the overall enterprise (Kevles 1977b, p. 358).

While each of the other major postwar R&D funding agencies had their own rules and procedures, a striking feature of federal research funding in the decades that followed was its continued geographic and institutional concentration. Though a variety of legislative initiatives and programs, historical and recent, have attempted to widen the distribution of funding—channeling Kilgore's criticism of OSRD and concerns about extending the OSRD model in peacetime—opponents of these programs typically argue that funding should be directed to the best researchers and institutions, as determined by the scientific community, echoing Bush. One reason for this tension is disagreement over what the goals of R&D policy are or should be. But a key and complementary gap in this debate is evidence on the impacts of these choices: whether the geographic distribution of R&D funding matters for local economic development and the degree to which returns accrue locally versus more broadly. One goal of this paper is to speak to these questions.

II. Data

To assess the effects of the World War II shock, we have collected, transcribed, and harmonized a complete record of all 2,254 OSRD contracts (to 461 distinct contractors), all 7,910 inventions reported under them, and all 2,637 patents on these inventions.[8] Through additional sources not included in OSRD's public records

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[8] We observe detailed data on each contract, including the contractor, subject matter (OSRD division that wrote the contract), total value, security classification, patent policy, and termination date.

(e.g., the Manhattan Project), we identified a total of 3,137 OSRD-funded, patented inventions, which we use to measure the OSRD shock, preferring these to OSRD's prime contract spending because they represent outputs, merge to other sources, and bring us closest to the level where the work was performed.[9]

We link these data to the US patent record. To do so, we compile data on US patents granted between 1920 and 1979, merging a USPTO master file of patents with patent number, patent class (USPC), and issue date (Marco et al. 2015) with data on (i) serial numbers and filing dates; (ii) front-page citations; (iii) harmonized assignee names and types; and (iv) inventor locations, which we measure using data from Petralia, Balland, and Rigby (2016); Berkes (2018); and Bergeaud and Verluise (2022) (see online Appendix B.1).[10] We supplement these data with new administrative, archival data on government-funded patents since the early 1900s, which we introduce in online Appendix B.2 (also see Gross and Sampat 2023a) and which comprise a significantly larger set than can be measured from patent publications (Fleming et al. 2019). For our cross-country comparisons, we add data from the European Patent Office (EPO) PATSTAT database on granted patents in the United States, Great Britain, and France over the same period, which include similar information to that of our USPTO base layer.

In Section V, we measure county-level employment and firm creation by industry using the US Census Bureau's County Business Patterns (CBP) and Dun and Bradstreet's (D&B) historical data files. We use CBP and D&B data from 1980 (the latter lists over 4.5 million US establishments, including their four-digit SIC and founding year) to study long-run outcomes, and we apply a USPTO crosswalk to map SIC codes and patent subclasses to a common, SIC-derived (but USPTO-generated) classification, enabling us to perform analysis that links our treatment to industry outcomes.[11,12,13] We restrict the D&B sample to single-location firms and headquarters establishments and to firms that we can accurately geocode using address information (89 percent of the sample). We then aggregate up firm counts to the county × industry × founding decade level, to smooth over bunched rounding in founding years. From the CBP, we thus obtain a 1980 cross section of county-industries, and from D&B, we build a 1920–1980 panel of county-industries.

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[9] Beyond the 3,382 patent applications (2,637 issued patents) identified in OSRD records, we measure an additional 461 OSRD-funded serials (388 patents) associated with the Manhattan Project through a public records request (Streifer 2017) and 36 serials (8 patents) from records of the Army's Judge Advocate General's office (see Gross 2023). We also supplement these records with an automated, text-based search for continuations and divisions of these patent applications, which identifies another 104 OSRD-supported patents.

[10] We are grateful to all three sets of authors for sharing the data.

[11] Our choice to use 1980 data files has several motivations. Earlier CBP editions that we have experimented with (e.g., 1956, 1959, 1970) report three- and four-digit SICs with much lower frequency, undermining the patent-industry crosswalk and limiting power, whereas the CBP from the late 1970s onward provides finer disaggregation. Earlier D&B files are significantly smaller, and we believe only a partial accounting. Additionally, we prefer data produced under the same SIC edition as the USPTO crosswalk (1972). We lose relatively little by limiting the CBP-based analysis to 1980, as the CBP only exists post-1947, precluding pre-/postwar comparisons.

[12] The D&B data cover a large sample of US establishments, approximating the universe (4.531 million establishments in 1980, versus 4.543 million in the CBP and 4.533 million in the Census Bureau's Longitudinal Business Database). Note that the D&B firm counts are by construction conditioned on survival to 1980. We will use industry × founding year fixed effects to account for differential survival rates across firm birth cohorts.

[13] Data available at https://www.uspto.gov/web/offices/ac/ido/oeip/taf/data/sic_conc/.

Table 1—Top Ten Patent Classes of OSRD Patents (Denominator: OSRD Patents)

		OSRD patents		1933–1940 patents	
USPC	Description	Percent	Rank	Percent	Rank
342	Directive radio wave systems/devices (radar)	6.6	1	0.2	167
102	Ammunition and explosives	5.8	2	0.2	170
315	Electric lamp and discharge devices: Systems	4.8	3	0.6	302
250	Nuclear energy	4.0	4	0.1	117
333	Wave transmission lines and networks	3.6	5	0.2	164
343	Radio wave antennas	3.4	6	0.2	141
423	Inorganic chemistry	3.2	7	0.7	309
367	Acoustic wave systems/devices	3.1	8	0.1	79
324	Electricity: Measuring and testing	3.0	9	0.5	284
327	Misc. electrical devices, circuits, and systems	2.9	10	0.1	85

Note: The table lists the top patent classes of OSRD patents, alongside their share of OSRD patents and of post-Depression 1930s patents for comparison.

Distribution of OSRD Activity across Space and Subject Matter.—OSRD contracted for research in a wide range of subject areas and with an array of contractors. Table 1 lists the top ten OSRD patent classes and their share of OSRD patents, contrasting this with the share of patents these classes comprised in the recent prewar era. Together with Figure 1, the table brings into relief how large a shock World War II was for US innovation, both in scale and in the subject matter of the technologies OSRD was pushing.

In the online Appendix we provide additional context. Of particular note are online Appendix Tables C.1 and C.2, which report the top (i) broad technology areas and (ii) specific patent classes with OSRD patents in the 1940s, ranked by the OSRD-funded share of 1940s patents—measuring the size of the shock. Atop online Appendix Table C.1 is nuclear energy, but most other high-ranking subjects are in the domain of electronics and communications, including radar and microwave engineering, semiconductors, electrical computing, and cryptography, highlighting the role that World War II research made in advancing these fields, with potential applications beyond war fighting.

Figure 2 maps locations in the continental United States with OSRD-funded patents, although a handful of states received a large majority of its funding (online Appendix Table A.2), and particular programs were concentrated in specific locations, OSRD-funded R&D spanned the country. Table 2 weaves these threads together, listing the top five counties with the most OSRD patents in select technology areas and the OSRD-funded share of local patenting in the 1940s—i.e., the shock whose effects we examine next.

III. Postwar Takeoff of World War II Technology Clusters

To understand the impacts of World War II on the US innovation system, our starting point is to examine the growth of regional innovation hubs.

A closer look at an example can motivate our approach. Middlesex County, Massachusetts—home to the Route-128 postwar technology hub—is in many ways the canonical example. Prior to the war, the Boston area was not an electronics hub, but during the war, OSRD stood up two large, central laboratories (the MIT Radiation Laboratory and its offshoot Harvard Radio Research Laboratory) to

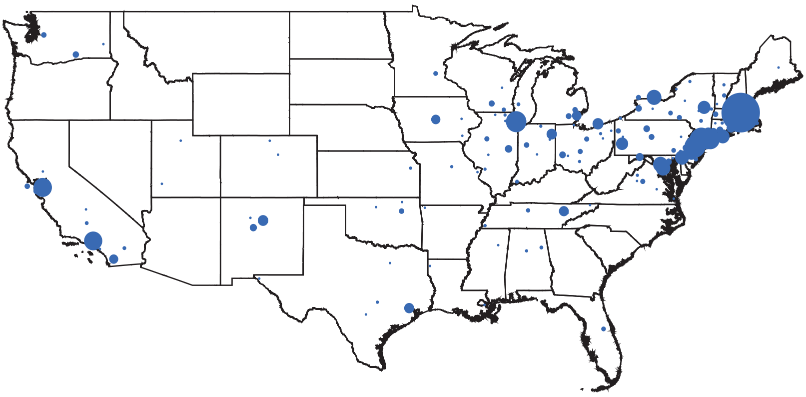

Figure 2. Geography of OSRD-Funded Invention in World War II

Notes: The figure maps counties with OSRD-funded patents. Bubble sizes proportional to each county's total number of OSRD patents.

Table 2—Top Clusters with OSRD Patents, 1941–1948 (Select Technology Areas)

Panel A. Technology area: All

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Middlesex, MA	446	12.3%
2	Essex, NJ	139	2.5%
3	Mercer, NJ	129	10.2%
4	Cook, IL	121	0.7%
5	Alameda, CA	98	3.7%

Panel B. Technology area: Communications (21)

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Middlesex, MA	216	45.5%
2	Mercer, NJ	37	14.3%
3	Suffolk, MA	35	35.7%
4	Essex, NJ	31	6.8%
5	Suffolk, NY	27	9.2%

Panel C. Technology area: Electrical lighting (41)

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Essex, NJ	39	10.1%
2	Middlesex, MA	38	14.4%
3	Mercer, NJ	25	17.5%
4	Schenectady, NY	17	8.5%
5	Allen, IN	9	22.5%

Panel D. Technology area: Electrical devices (42)

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Middlesex, MA	61	21.7%
2	Nassau, NY	25	10.4%
3	Washington, DC	13	7.4%
4	Suffolk, NY	12	5.7%
5	Suffolk, MA	11	15.1%

Panel E. Technology area: Measuring, testing (43)

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Monroe, NY	22	20.0%
2	Middlesex, MA	20	16.9%
3	Nassau, NY	18	13.0%
4	Harris, TX	9	7.1%
5	Los Angeles, CA	9	3.5%

Panel F. Technology area: Nuclear, X-rays (44)

Rank	County	OSRD patents, 1941–1948 Number	 Share of cluster
1	Alameda, CA	56	68.3%
2	Cook, IL	41	28.9%
3	Santa Fe, NM	14	66.7%
4	Anderson, TN	8	17.0%
5	Mercer, NJ	7	24.1%

Notes: The table lists the top clusters in select technology areas by number of OSRD patents and the share of local patents that were OSRD funded. Displayed technology areas are shown alongside their NBER technology subcategory (Hall, Jaffe, and Trajtenberg 2001) and selected due to their prominence or importance to OSRD's agenda.

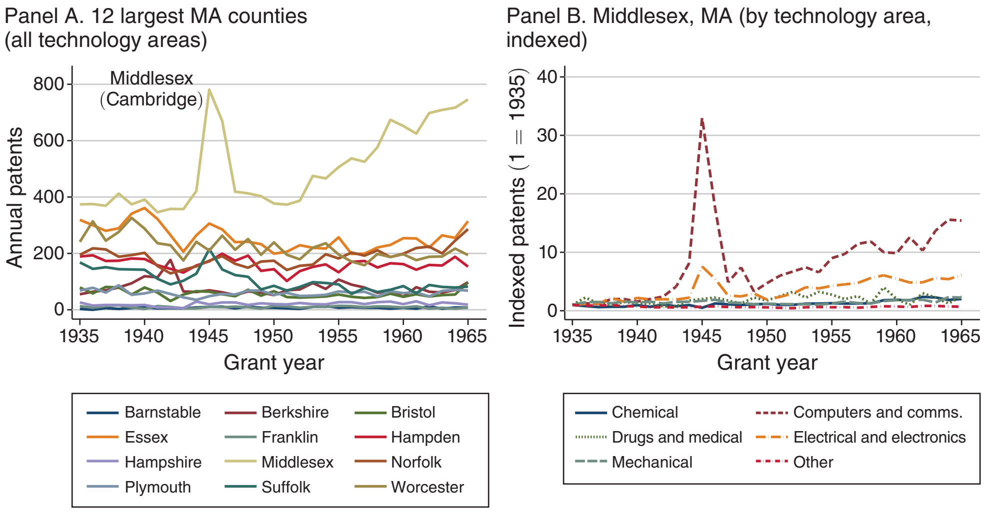

Figure 3. Patenting Trends in Massachusetts Counties, 1935 to 1965

Notes: Figure shows total annual patents filed in the top 12 Massachusetts counties. The figure illustrates, for Middlesex County (location of Cambridge, home to Harvard and MIT): (i) relatively constant, pre-1940 level differences in patenting; (ii) a mid-1940s spike (doubling) of patenting, driven by war-related research; (iii) a return to approximately prewar levels; and (iv) a takeoff in the early 1950s. The raw data illustrate the general pattern that we find throughout the paper.

perform and manage wartime radar research. These programs drew in researchers from around the country—and not only did many of them stay, but the advances in electronics and microwave engineering that this effort produced were then parlayed into a wide range of postwar technological developments (Buderi 1996; Mindell 2002). The Rad Lab has been widely credited as jump-starting the Route-128 technology hub (Saxenian 1996) by helping to establish an ecosystem of universities, government laboratories, large firms, and postwar start-ups and spin-offs.[14]

To put numbers to this example, Figure 3, panel A shows the time series of filed patents in the 12 largest Massachusetts counties from 1935 to 1965. Prior to the war, Middlesex produced more annual patents in levels but was not on a noticeably different time trend than other counties. During the war, invention spiked, driven by OSRD-funded R&D (see Table 2), and after the war returned to prewar levels, before taking off in the 1950s. By the mid-1960s, Middlesex was producing twice its number of prewar patents, as this modern cluster was taking shape.

What technologies were behind this postwar takeoff? In panel B we look within county, comparing Middlesex County patenting in high-level technology areas (one-digit NBER categories) around the war. We plot time series for six technology categories (chemical, communications, pharmaceutical, electrical and electronic, mechanical, other), indexed to 1935 levels, and find similar patterns of even larger magnitude. Communications patenting—which microwave radar technologies

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[14] Other examples of clusters we observe as having OSRD-funded R&D and postwar growth (through 1970) include communications and electronics in central New Jersey and greater New York City (e.g., Mercer, New Jersey or Long Island) and to some degree Santa Clara, California—although the growth of Silicon Valley is, in our view, more attributable to postwar developments. An important corollary question is why some of these clusters later diverged—including the classic question of why Silicon Valley took off but central New Jersey did not.

group into—grew nearly thirtyfold in the war, returned to prewar levels, and was by 1965 over ten times higher. Electronics patenting followed a similar, if attenuated, pattern. The evidence is consistent with the area's well-documented postwar technological and economic development, which others have qualitatively traced to OSRD-led R&D activity (e.g., Saxenian 1996).

This evidence motivates the empirical comparisons we make in the rest of this section, where we systematically compare patenting over time in clusters (counties × technology areas) with higher versus lower levels of OSRD investment. We will henceforth measure technology areas at the slightly more disaggregated level of two-digit NBER patent categories (which group up USPTO patent classes; see Hall, Jaffe, and Trajtenberg 2001). Our baseline specification comparing treated and untreated clusters is motivated by certain classes of endogenous growth models (e.g., Romer 1990). This specification—which we derive in Appendix D from first principles—will effectively provide a test of whether Romerian endogenous growth took hold in treated clusters as a result of OSRD-driven increases in the stock of innovation or inventive capabilities. The specification is as follows:

$$(1) \qquad \ln(\mathit{Patents})_{ict} = \sum_{t=1931}^{1970} \beta_t \cdot \ln(\mathit{OSRD\ rate})_{ic} \cdot \mathit{Year}_t + \alpha_{ic} + \delta_t + \varepsilon_{ict},$$

where i indexes counties, c indexes patent categories, and t indexes years, and the sample runs from 1930 to 1970, with standard errors clustered at the county level. Our principal treatment measure is what we henceforth call the "OSRD rate": the fraction of patents filed in a given cluster between 1941 and 1948 that were OSRD funded. Our primary specification uses a continuous measure of the logged OSRD rate, which mechanically restricts the sample to clusters with at least one OSRD patent.[15] We at times present results from specifications with treatment quartiles, which allows us to compare segments of the treatment distribution in a more flexible way, against clusters with no OSRD patents (the reference group):

$$(2) \qquad \ln(\mathit{Patents})_{ict} = \sum_{q=1}^{4} \sum_{t=1931}^{1970} \beta_{qt} \cdot \mathbf{1}\{\mathit{Treatment\ quartile\ q}\}_{ict} \cdot \mathit{Year}_t + \alpha_{ic} + \delta_t + \varepsilon_{ict}.$$

It is important to note that these specifications will not necessarily identify the effects of the OSRD shock on local invention in isolation because in equilibrium our units may be interdependent: each cluster's outcomes are codetermined with others' (e.g., a migration response would implicate both treated and untreated clusters). What we do identify is the effects of the shock on agglomeration and on widening gaps between clusters that by implication follow.

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[15] The analytical approach we take is designed to evaluate how intensely local innovation systems were engaged in the OSRD effort and relate this intensity to their future growth. An alternative is to measure the treatment as OSRD patents (rather than the OSRD rate) and estimate the elasticity of postwar patents and OSRD patents—though even then, we would want to control for total war-era patenting, to not confound OSRD clusters with generally inventive clusters. This alternative is mechanically nearly equivalent, since $\ln(\mathit{OSRD\ Rate}) = \ln(\mathit{OSRD\ patents}) - \ln(1941\text{–}1948\ \mathit{patents})$, but relaxes the implicit parameter restriction. We evaluate this alternative in online Appendix D, where we find similar results to those we estimate under equation (1).

A. *Identification*

A potential concern is the endogeneity of the locations and subjects of OSRD research and the possibility that funding choices may correlate with other determinants of innovation. This concern can take multiple forms. For example, OSRD investment may have been directed to technologies that were ripe for exploiting—and places that were ripe for exploiting them. Or concurrent war-driven shocks, like the (massive) surge in military production, may correlate with OSRD investment in technology and geographic space and concurrently affect the outcomes we study. Each of these possibilities would result in upwardly biased empirical estimates.

Formally, the identifying assumption is that the OSRD shock is not correlated with unobserved determinants of pre- or postwar cluster patenting. This requires that these clusters were not otherwise likely to change around World War II (due to latent, location-specific technological potential or contemporaneous shocks). Sufficient conditions, in turn, are that either the places or technologies OSRD supported were independent of unobserved factors.

Our understanding of how OSRD worked provides support for this assumption. Though OSRD's R&D priorities were not randomly chosen, they were mainly products of short-run military need rather than long-run commercial promise. These priorities were set in collaboration with the military, through which it identified needs that could potentially be met by new technology. In some cases, it engaged in new problems (e.g., engineering controlled nuclear reactions). In other cases, it took existing problems that were stuck and pushed them forward (e.g., microwave radar). Its portfolio included projects with high uncertainty, some unsuccessful despite early enthusiasm (e.g., synthetic penicillin), and others with long odds that succeeded. Technical feasibility was a criterion in deciding how to allocate scarce inputs (especially research talent, more than funding), but postwar civilian demand was not a major consideration, given the existential crisis facing the nation. OSRD's first condition for any project was thus that it would help win the war—which, for example, led to the atomic bomb being prioritized over advanced rocketry, which was viewed as a weapon of future wars (Zachary 1997). Table 1 illustrates how different OSRD's priorities were from the status quo ante. In a postwar retrospective, OSRD Secretary Irvin Stewart reinforces this point, commenting on the independent nature of the shock: "The shift in emphasis and even in direction was enormous … subjects of minor importance in peacetime become of controlling importance in war. Some subjects are born of war" (Stewart 1948, p. 102).

The argument that short-run military need and the potential for immediate payoff drove OSRD funding choices—and hence, that resource allocations were not structurally endogenous to the outcomes we study—does not preclude a possible confounding effect if these were correlated with long-run demand or technological promise. Our reading of history, however, is that OSRD discontinuously pushed out the frontier for most technologies it funded.[16] Many of the technologies that existed at the end of the war were barely conceived or were considered impossible before

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[16] The radar project, for example, was described as "five years of furious technology [development] … [that] advanced knowledge in its field by 25 years" (Massachusetts Institute of Technology 1946, p. 7).

it, and others were conceived or known but not commercially pursued until OSRD research developed them.

With respect to OSRD's geography, research performers were explicitly chosen on their ability to deliver high-quality results, as fast as possible (Stewart 1948). Often, however, these were new and nonobvious: many World War II R&D problems were novel, and the United States lacked a deep bench of researchers with direct experience (it is telling that academic physicists led most of the major OSRD programs rather than firms or engineers; see Kevles 1977b). Features of each R&D problem also shaped OSRD's choices over who would do the work and whether and how it was divided: for example, complex systems engineering problems like radar were not easily divisible, and their R&D was thus geographically concentrated—often in university-hosted, government-funded central laboratories. These not only presented a new, "big science" approach to applied R&D but also a new set of performers and a new geographic distribution.

Insofar as OSRD contract placement was nonrandom, empirical evidence (e.g., Figure 3) suggests this was more so the case on levels than trends. We show later in this paper that this pattern is quite general: prewar invention in more and less intensively treated clusters followed precisely estimated parallel trends until 1940 and only diverged after the OSRD shock took place. Despite these parallel trends, a remaining threat to identification could be other war-driven shocks coinciding with OSRD investment. A specific example is the possibility that large, wartime military equipment demand may have spilled in private R&D by war equipment suppliers, in the same locations and technologies OSRD funded. We systematically examine this alternative in online Appendix E but find that a range of evidence suggests against demand-based interpretations.

B. *Baseline Effects*

Figure 4, panel A presents our main result, displaying β_t estimates from equation (1) with 95 percent confidence intervals. Clusters with a larger OSRD shock (i) did not grow statistically differently than clusters with a smaller shock prior to 1940, (ii) experienced a relative surge during the war, (iii) briefly contracted from their midwar peak when the war ended, and then (iv) experienced a sustained takeoff. The magnitudes indicate that a doubling of a cluster's OSRD rate was associated with 20 percent greater patenting by 1960, and 30 percent by 1970.

In panels B and C, we reestimate equation (1) for non-OSRD and nongovernment interest patents, where we see similar long-run patterns but a smoothing out of the 1940s, indicating that the mid-1940s "bump" in panel A was the OSRD shock itself.

Online Appendix C provides several supporting results. Online Appendix Figure C.2 shows similar effects for citation-weighted patents and per capita patenting, which rules out that the results are driven by population changes—and thus indicates economically meaningful impacts on local inventive productivity. Online Appendix Figure C.4 reestimates equation (1), omitting individual states—and establishing that the result is not driven by any one state, county, or cluster. Online Appendix Figure C.5 reproduces Figure 4 but with estimates from equation (2), plotting the β_t parameters for clusters in the top quartile of the OSRD shock. Patenting in these clusters is 60 percent higher by 1970.

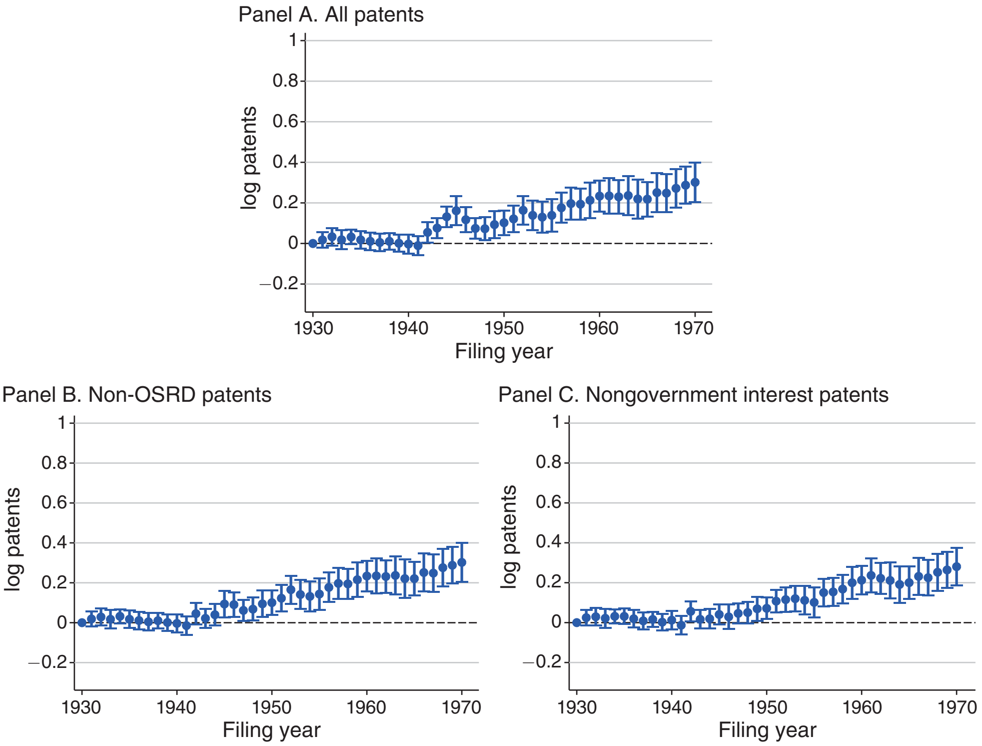

FIGURE 4. EFFECTS OF OSRD ON CLUSTER PATENTING, 1930–1970

Notes: The figure shows annual estimates of the effects of the OSRD shock on county-category patenting. The independent variable measures the log fraction of US patents in each county-category between 1941 and 1948 that were OSRD-funded. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the county level.

In online Appendix F, we show that our results are similar—if anything, more precise—when estimated for inverse hyperbolic sine (IHS) patents, which approximates the log transformation but is defined at zero and thus includes cluster-years with no patents. In online Appendix G we show that our results are the same for more aggregated geographic units such as CBSAs (core-based statistical areas). Given that our analysis window spans the prewar to postwar era, which saw a dispersion of population and economic activity from urban centers, it is ambiguous whether a more appropriate geographic unit of analysis would be counties (for the earlier era) versus CBSAs (for the later era), but it is reassuring that results are not sensitive to this choice.

C. *Heterogeneity*

The most striking implication of the results thus far is that World War II was a formative event setting in motion increasing agglomeration of inventive activity around the country and ostensibly the takeoff of technology clusters persisting to this day. A corollary question is whether it was an equalizing force or merely deepened existing geographic differences.

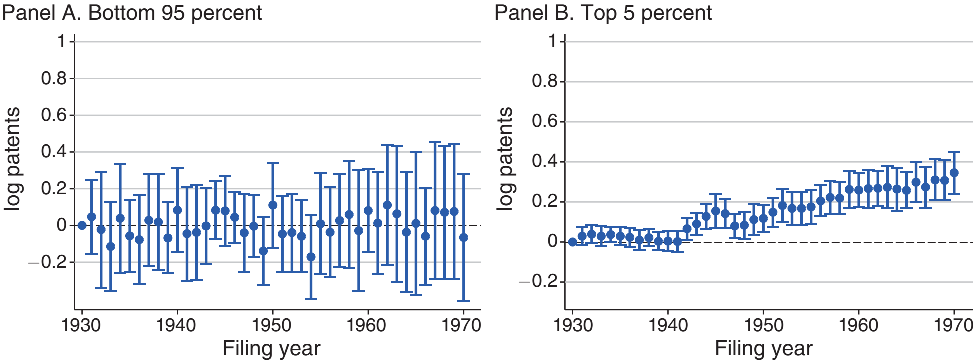

Figure 5. Effects of OSRD on Cluster Patenting, for Clusters in Counties in the Bottom 95 Percent versus Top 5 Percent of 1930s Patenting

Notes: The figure shows annual estimates of the effects of the OSRD shock on county-category patenting, for counties in the bottom 95 percent and top 5 percent of 1930s patenting. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the county level.

To further explore this question, we partition counties into the top 5 percent versus bottom 95 percent of 1930s patenting (by patent count). When equation (1) is estimated for each group, it becomes apparent that the effects are entirely driven by counties that were already among the most inventive before World War II (Figure 5). Yet even in these clusters, the OSRD treatment does not coincide with any differential growth leading up to the war: the entirety of the OSRD effect takes place with the wartime surge in patenting and the postwar takeoff. The evidence thus supports an interpretation of both continuity and change, like that seen in our Massachusetts example (in Figure 3): prewar differences persisted, but the war caused a trend shift. In simpler terms, the OSRD's effect was to catalyze long-run growth in existing geographic centers of invention.

A second question is whether the OSRD effect was general across all technologies whose development it funded or stronger for some fields over others. We evaluate this question by partitioning the sample by one-digit NBER categories (Chemicals, Computers and Communications, Drugs and Medical, Electrical and Electronics, Mechanical, and Other). Online Appendix Figure C.3 reestimates equation (1) for each of these categories. Our main result is primarily (although not exclusively) driven by the electrical and electronics field, where the long-run impact of OSRD was a 40 percent increase in cluster patenting by 1970.

D. *Spillovers*

Thus far, our analysis presumes and estimates localized impacts of the OSRD shock in the counties and technology areas where R&D investments were made. Yet investments in specific technologies may filter down to others, including via direct linkages or shared inputs and customers. Given that spillovers may be a means through which the effects of the OSRD shock compounded for specific cities and regions, we seek to more closely examine their magnitude.

Our focus will be on within-county spillovers across technology areas. We estimate an augmented version of equation (2), where we include measures not only of a given cluster's treatment quartile but also measures of (i) whether a "nearby"

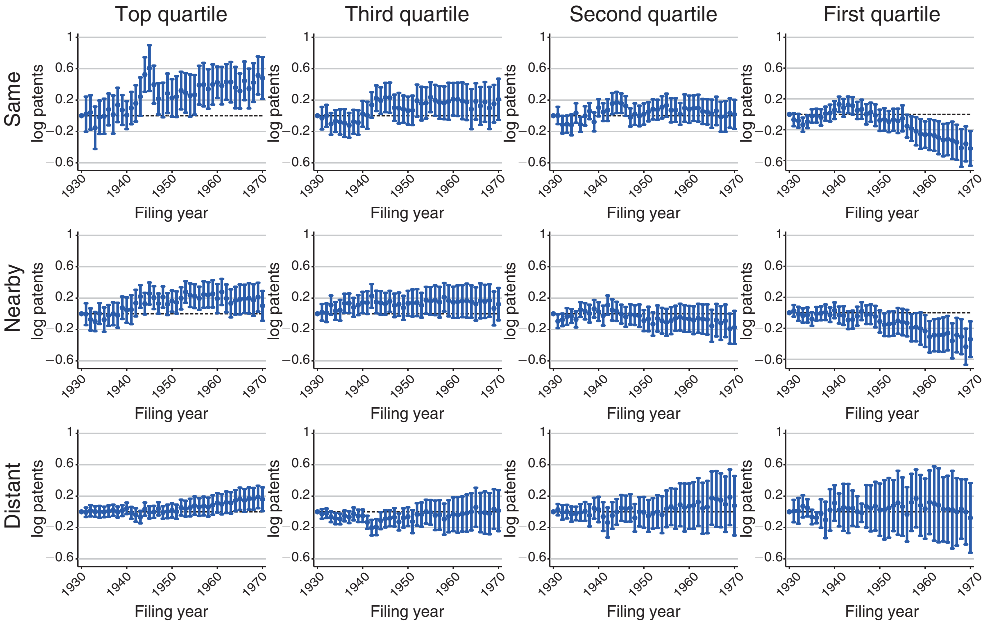

Figure 6. Effects of OSRD on Cluster Patenting, 1930–1970, Cross-Technology Area Spillovers Horse Race Regression of Treatment in (i) Same Technology Area, (ii) Nearby Technology Areas, (iii) More Distant Technology Areas

Notes: The figure shows annual estimates of the effects of the OSRD shock on county-category patenting. The independent variable measures the quartile of treatment intensity, conditional on treatment (the fraction of US patents in each county-category between 1941 and 1948 that were OSRD funded, conditional on any), of three types: (i) in the given county-category (top row), (ii) in the same county and proximate technology categories (same one-digit NBER category, per Hall et al. 2001; middle row), and (iii) in the same county and more distant technology categories (other one-digit NBER categories; bottom row). Parameters across all panels are estimated jointly (in one regression) relative to a reference group of county-categories without any OSRD patents. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the county level.

technology area was in each treatment quartile and (ii) whether a more distant technology area was in each treatment quartile, where proximity is measured vis-à-vis one-digit NBER categories: two technologies under the same patent category are considered proximate. We effectively estimate a horse race regression, pitting localized shocks against nearby and more distant shocks (in technology space).

Figure 6 plots estimates (and 95 percent confidence intervals) for all treatment quartiles (columns) across all three types of shocks: local, nearby, and distant (rows). Standard errors increase somewhat, as we are estimating more than ten times as many parameters as in equation (1) (because the specification includes annual parameters for four treatment quartiles, crossed by three levels of technological distance). Several patterns are nevertheless apparent.

First, our baseline effects are largest for the top treatment quartile and attenuate at lower quartiles (matching online Appendix Figure C.6, which shows the full set of parameters from equation (2)). Second, these effects are largest for localized shocks (in the same technology area). Third, we find evidence of spillovers that attenuate with technological distance. Fourth, low-treatment clusters experience *declining* invention post–World War II, suggesting that the widening regional differences we observe may have been accelerated by (or even driven by) invention migrating to heavily treated clusters. Although the evidence thus far suggests this migration was not a result of population movements per se (online Appendix Figure C.2), a postwar relocation of R&D activity may have one means through which agglomeration took place. More fully understanding how these agglomerative clusters took shape after World War II is the task we take on next.[17]

IV. Emergent Local Innovation Systems

Despite the fact that World War II was, on its own, an inherently temporary shock to the innovation system, the evidence thus far indicates that its effects not only persisted but compounded for several decades. Our question for this section is why. To understand the mechanisms of persistence, we first consider OSRD's direct impacts in the form of growing postwar invention building directly on OSRD-funded research, which our evidence rules out as a driving force behind the divergence we found in Section III. We are left with two possibilities. One is postwar government R&D investment in the same regions and technology areas that OSRD funded—i.e., a sustained push—driven by continuity in defense R&D funding structures and military need in the Cold War era. The other is an organic growth takeoff, powered by Marshallian increasing returns to scale.

A. *Direct Follow-On to OSRD Invention*

We begin by exploring the more direct channels through which OSRD-funded R&D might affect local invention, such as direct follow-on invention or invention by firms or inventors who participated in the OSRD effort and developed capabilities and expertise that it could harness after the war ended. We measure follow-on invention in the form of patents that cite OSRD patents, and OSRD firms as firm assignees that produced an OSRD patent.[18]

In Figure 7, we estimate equation (1) over these categories. Panels A1 and A2 estimate the effects of the OSRD shock on patents that do and do not cite OSRD patents (respectively), where it is apparent that the effect is entirely driven by the latter. In panels B1 and B2, we estimate the effect on patents of OSRD firms and other assignees, again finding that the effect is primarily driven by the latter. For brevity, we do not show the inventor results, though the patterns are the same—which is consistent with our priors, given the magnitudes of our effects and that many of these individuals' careers had waned by the end of our sample. Collectively, the evidence suggests against an interpretation of long-lasting direct impacts.

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[17] This evidence is consistent with recent perspectives on technology spillovers attenuating with technological distance (e.g., Myers and Lanahan 2022). While in principle, the evidence of spillovers could challenge identification of our core results if technologically proximate clusters tended to be jointly treated, we are (paradoxically) reassured on this matter by the same evidence that raises it because Figure 6 controls for nearby technology area shocks and still finds effects in the focal cluster. Moreover, as we are aiming to evaluate the effect of the OSRD program, we consider the bundled direct and spillover effects to be the object of interest.

[18] Given the challenges of longitudinal inventor linking and disambiguation, and our own hesitations in the resulting links, we do not attempt to link all OSRD inventors to their pre- and postwar patents but rather focus on researchers at two of the largest OSRD-funded research labs (the MIT Radiation Laboratory and Harvard Radio Research Lab), which we have hand-matched to patents in concurrent research (Gross and Roche 2023).

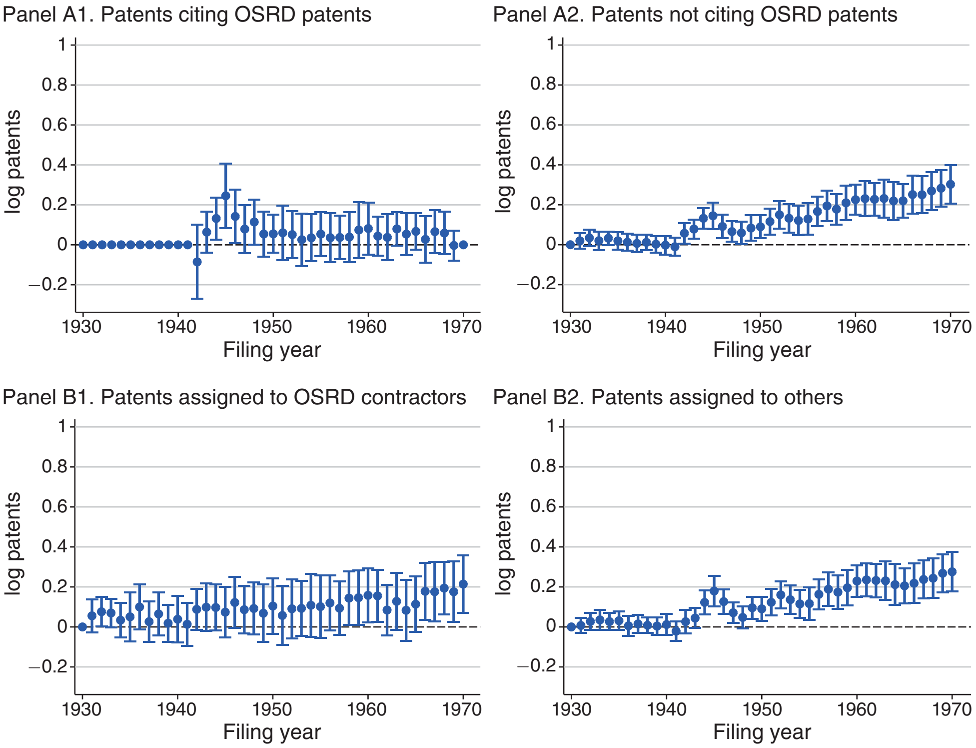

Figure 7. Effects Not Explained by OSRD's Direct Impacts on Local Invention

Notes: The figure shows annual estimates of the effects of the OSRD shock on county-category (i) patents citing versus not citing OSRD patents and (ii) patents assigned to OSRD contractors versus others, as an exploration of the direct impacts of OSRD on postwar invention in the treated clusters. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the county level.

B. *Postwar Government R&D Investment*

Our second hypothesis is that the postwar takeoffs we find were powered by continued government R&D investment in the same subjects and regions. In the context of the Cold War expansion of federal R&D, and the continuity in many military R&D priorities (e.g., aerospace, missiles, radar, nuclear arms), this is a natural conjecture.[19] To evaluate this question, we take two approaches. First, we reestimate equation (1), controlling for clusters' government-funded share of postwar patents (henceforth, the "USG rate"), crossed by year—in effect, accounting for the fact that many of these clusters remained "defense R&D places" (in the language of Kantor and Whalley 2022), which may have grown differentially in the postwar era. The results are unchanged (and thus, for brevity, not reported here). Second, we partition the sample into clusters with zero, below-median (conditional on nonzero), and above-median postwar USG rates and reestimate equation (1) for each group.

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[19] Indeed, our data indicate substantial path dependence in the location and subject matter of Cold War government R&D (online Appendix Table C.3).

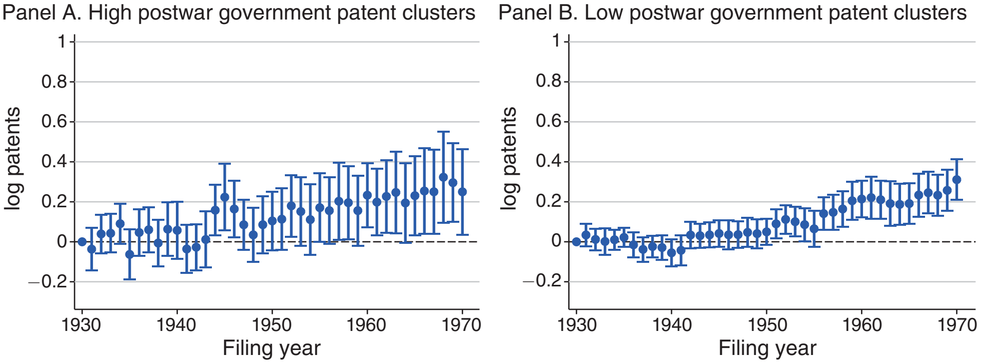

Figure 8. Effects Not Explained by Sustained Government Investment in Local Invention

Notes: The figure shows annual estimates of the effects of the OSRD shock on county-category patents in county-categories with above- and below-median postwar (1950–1969) government-funded patent rates, as an exploration of the role of sustained public R&D investment as an explanation for persistence. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the county level.

Figure 8, panels A and B show that the OSRD shock had similar effects in clusters with higher and lower postwar government-funded invention.

A related question is whether the results in Section III could be attributable to local universities, many of which expanded their research mission in the Cold War era (Geiger 1993; Lowen 1997). In additional analysis (online Appendix Figure C.7), we examine whether our main results vary in counties with or without a top university. We identify top universities in two ways. First, we use a National Academy of Sciences report on PhD production at US universities from 1920 to 1962 (Harmon and Soldz 1963), and the NSF Survey of Earned Doctorates (its successor), to measure PhD graduates in the physical and biological sciences between 1950 and 1969 and identify the top 20 and 50 universities in terms of PhDs granted in these fields. Second, we borrow a measure of "top 40" universities from the Harmon and Soldz (1963) report. When we control for these measures, our results are unchanged. However, across all three measures, we find that the effects of OSRD are roughly twice as large in clusters with a leading university—and still substantial in those without one. The results suggest that although educational institutions were not the direct drivers of the OSRD effect, they reinforced its effect by supporting the growth of local ecosystems in the postwar era.

C. *Increasing Returns to Scale*

The remaining possibility we see is a Marshallian takeoff, springing from wartime R&D investments that established a collection of firms, inventors, and institutions with experience in new, frontier technologies around which clusters could grow.

In this case, we would expect a wide range of changes to take place. With our data, we are able to examine if—and show evidence that—the OSRD shock led to an expanding set of local, R&D-performing firms and institutions; increasing private and public invention; growth of incumbent firms, in-migration, and de novo entry; deepening linkages between local invention; and, ultimately, deconcentration of invention as local innovation systems grew.

Table 3—Firm Patents: All, Incumbents, and Entrants (Incumbents by Geographic and Technological Proximity)

		Same county		Diff. county		
	All (1)	Same field (2)	Diff. field (3)	Same field (4)	Diff. field (5)	Entrants (6)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1935\text{–}1939\}$	−0.008	−0.006	0.016	0.013	−0.013	0.023
	(0.015)	(0.021)	(0.015)	(0.021)	(0.026)	(0.020)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1940\text{–}1944\}$	0.032	0.019	0.062	0.058	0.024	0.066
	(0.024)	(0.030)	(0.016)	(0.019)	(0.027)	(0.022)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1945\text{–}1949\}$	0.049	0.041	0.077	0.076	0.017	0.060
	(0.034)	(0.044)	(0.016)	(0.017)	(0.021)	(0.019)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1950\text{–}1954\}$	0.080	0.063	0.078	0.069	0.023	0.092
	(0.040)	(0.049)	(0.024)	(0.023)	(0.016)	(0.027)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1955\text{–}1959\}$	0.125	0.127	0.053	0.046	0.037	0.100
	(0.045)	(0.055)	(0.030)	(0.026)	(0.017)	(0.028)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1960\text{–}1964\}$	0.158	0.135	0.107	0.095	0.015	0.088
	(0.049)	(0.059)	(0.033)	(0.029)	(0.025)	(0.039)
$\ln(\textit{OSRD rate}) \times \mathbf{1}\{1965\text{–}1970\}$	0.188	0.182	0.101	0.041	0.002	0.088
	(0.054)	(0.062)	(0.033)	(0.034)	(0.016)	(0.040)
Observations	20,376	17,691	10,823	10,474	3,197	9,123
R^2	0.75	0.71	0.47	0.37	0.19	0.59
Y mean	1.89	1.79	0.67	0.61	0.21	0.66
County-cat FEs	X	X	X	X	X	X
Year FEs	X	X	X	X	X	X

Notes: The table estimates the effect of the OSRD shock on firm patenting. Observations are at the county-category-year level. Outcome variables measured in logs. Column 1 measures all firm patents; column 2, those by firms with prior patents in the same county and technology area; columns 3 to 5, those by firms with prior patents only in a different county and/or technology area; and column 6, those by firms with no prior patents. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county-category and year fixed effects, and the omitted (reference) category for each county-category is the 1930–1934 period. Each row thus indicates the percentage increase in cluster patenting in a given period associated with a doubling of the cluster's OSRD rate. Log transformations restrict the sample in each column to observations with patents of the given type and clusters with ≥1 OSRD patent. SEs clustered by county in parentheses.

We begin by examining the growth in patenting across a range of actors. To do so, we transition from a specification with annual parameters to estimating quinquennial parameters, to simplify the presentation. Table 3 estimates the effect of the OSRD shock on firm patenting, which column 1 shows grew significantly over the postwar period. To understand the source of these patterns, we divide our sample into patents by incumbent firms (i.e., those with prior patents) and new firms (without prior patents) and further subdivide incumbent firms into those with prior patents in the given cluster versus those whose prior patents were in other counties or technology areas. This will allow us to look for evidence of R&D-performing firms crowding into treated clusters.

We find growing firm patenting from multiple directions, including by cluster incumbents (column 2) but also by local firms migrating into the cluster from other technology areas (column 3) and more geographically distant firms in the same technology area reallocating R&D activity to treated clusters (column 4), as well as by new patenting firms (column 6). We do not find a comparable effect for patenting by geographically and technologically distant firms (column 5), suggesting that the agglomerative impacts of OSRD shock had some limits in scope.

We find similar results when outcomes are measured as the number of unique firms filing patents in the given cluster and year rather than the number of firm

Table 4—Nongovernment- versus Government-Funded Patents (Total and by Agency)

	Non govt (1)	Govt (2)	DOD (3)	DOE (4)	NASA (5)	USDA (6)
$\ln(OSRD\ rate) \times \mathbf{1}\{1935–1939\}$	−0.006	0.007	0.003			0.127
	(0.012)	(0.031)	(0.036)			(0.098)
$\ln(OSRD\ rate) \times \mathbf{1}\{1940–1944\}$	−0.003	0.089	0.060	−0.052		0.288
	(0.018)	(0.058)	(0.056)	(0.062)		(0.234)
$\ln(OSRD\ rate) \times \mathbf{1}\{1945–1949\}$	0.026	0.145	0.144	0.009		0.208
	(0.026)	(0.072)	(0.073)	(0.056)		(0.227)
$\ln(OSRD\ rate) \times \mathbf{1}\{1950–1954\}$	0.084	0.131	0.145	−0.064		0.270
	(0.030)	(0.073)	(0.071)	(0.043)		(0.232)
$\ln(OSRD\ rate) \times \mathbf{1}\{1955–1959\}$	0.133	0.153	0.173	−0.029		0.220
	(0.036)	(0.081)	(0.079)	(0.057)		(0.221)
$\ln(OSRD\ rate) \times \mathbf{1}\{1960–1964\}$	0.193	0.181	0.197	0.017	0.022	0.353
	(0.042)	(0.075)	(0.072)	(0.046)	(0.074)	(0.222)
$\ln(OSRD\ rate) \times \mathbf{1}\{1965–1970\}$	0.221	0.212	0.219	−0.004	0.087	0.334
	(0.046)	(0.072)	(0.066)	(0.036)	(0.080)	(0.222)
Observations	22,251	9,571	8,057	1,344	254	279
R^2	0.79	0.44	0.44	0.44	0.44	0.48
Y mean	2.01	0.73	0.68	0.44	0.42	0.51
County-cat FEs	X	X	X	X	X	X
Year FEs	X	X	X	X	X	X

Notes: The table estimates the effect of the OSRD shock on government-funded patenting. Observations are at the county-category-year level. Outcome variables measured in logs. Column 1 measures nongovernment-funded patents; column 2, government-funded patents; and columns 3 to 6, patents by agency: Department of Defense (DOD), Department of Energy (DOE), National Aeronautics and Space Administration (NASA), and Department of Agriculture (USDA). Columns are labeled with modern agencies, but the DOD and DOE categories include predecessor agencies before they were established in 1947 and 1977, respectively. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county-category and year fixed effects, and the omitted (reference) category for each county-category is the 1930–1934 period. Each row thus indicates the percentage increase in cluster patenting in a given period associated with a doubling of the cluster's OSRD rate. Log transformations restrict the sample in each column to observations with patents of the given type and clusters with $\geq$1 OSRD patent. SEs clustered by county in parentheses.

patents—reflecting the broadening inventive base. Complementing, and in some cases even feeding, this firm growth was government-funded invention. The well-known history of the Silicon Valley and Boston-area clusters, for example, is rich in stories of both industry- and military-led research in this era. Though government invention does not explain the effects of the OSRD shock, in Table 4 we examine to what degree it followed. Column 2 shows that government-funded invention grew rapidly after the war in clusters that OSRD itself funded—but as column 1 conveys, nongovernment-funded R&D grew at a similar rate. The growth in government-funded invention was entirely driven by defense R&D (columns 3 to 6), which dominated the federal R&D budget in the postwar era.

In Table 5 we examine patent citation flows, which has traditionally been applied as a proxy for knowledge spillovers—a tradition we continue, despite known limitations. We estimate, in parallel, the share of backward (forward) citations made by (accruing to) patents in a given cluster and year that are to prior (from future) patents in the same county and/or technology area, as a function of the OSRD shock. Because citations were only included in patent publications beginning in 1947, our analysis of backward citations applies to post-1947 patents. Since these citations point to earlier patents, forward citations can be measured for the full sample.

Table 5—Share of Forward and Backward Citations to Local Patents

	Backward citations			Forward citations		
	Same county and field (1)	Same county, diff. field (2)	Diff. county, same field (3)	Same county and field (4)	Same county, diff. field (5)	Diff. county, same field (6)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1935\text{–}1939\}$				−0.001	−0.000	0.005
				(0.001)	(0.000)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1940\text{–}1944\}$				−0.001	−0.001	0.011
				(0.001)	(0.000)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1945\text{–}1949\}$				−0.000	0.001	0.015
				(0.001)	(0.001)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1950\text{–}1954\}$	0.002	−0.000	0.003	0.001	0.001	0.017
	(0.002)	(0.001)	(0.005)	(0.001)	(0.001)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1955\text{–}1959\}$	0.002	0.001	0.001	0.002	0.001	0.013
	(0.001)	(0.001)	(0.005)	(0.001)	(0.000)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1960\text{–}1964\}$	0.005	−0.000	0.012	0.003	0.002	0.011
	(0.002)	(0.001)	(0.005)	(0.001)	(0.000)	(0.004)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1965\text{–}1970\}$	0.006	0.002	0.009	0.005	0.002	0.007
	(0.002)	(0.001)	(0.005)	(0.001)	(0.000)	(0.004)
Observations	13,803	13,803	13,803	22,613	22,613	22,613
R^2	0.29	0.17	0.17	0.23	0.13	0.29
Y mean	0.04	0.02	0.46	0.02	0.01	0.28
County-cat FEs	X	X	X	X	X	X
Year FEs	X	X	X	X	X	X

Notes: The table estimates the effect of the OSRD shock on local versus distant citation flows. Observations are at the county-category-year level. Outcome variable in columns 1 to 3 is the share of backward citations made by patents filed in a given cell that are to prior patents in the same county and technology category (column 1), the same county but different technology category (column 2), and a different county but same technology category (column 3). Outcome variable in columns 4 to 6 is the analog for forward citations accruing to patents in the given cell from future patents of each column type. The front-page patent citation record begins in February 1947. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county-category and year fixed effects, and the omitted (reference) category for each county-category is the 1930–1934 period. Each row thus indicates the percentage increase in cluster citation shares in a given period associated with a doubling of the cluster's OSRD rate. Log transformations restrict the sample in each column to observations with citations of the given type and clusters with ≥ 1 OSRD patent. SEs clustered by county in parentheses.

Broadly, Table 5 provides evidence of growing local citation flows following the OSRD shock. As a benchmark, the share of backward and forward citations that occur in the immediate neighborhood of a given patent (same county and technology area) is low, at roughly 2 percent and 4 percent, respectively—reflecting the literal definition of citations as references to prior art against which the novelty of a patent's claims are evaluated by examiners, which exists widely. However, we note a few patterns. By the late 1960s, patents in more heavily shocked clusters have a higher fraction of backward citations to others in the same cluster (an increase of roughly 15 percent of the mean), as well as a higher fraction to patents in the same county but a different area (up 10 percent of the mean) or the same area but a different county (up 2 percent of the mean). These patents are likewise accruing a higher fraction of their forward citations within cluster (up 25 percent of the mean).

The final result we present is a summary statistic for the collective evidence. Table 6 estimates the concentration of cluster patenting across filers as a function of the OSRD shock. In column 1 we measure a Herfindahl index, and in columns 2 to 5 we measure concentration ratios for the top 1, 5, 10, and 20 filers (respectively). The results suggest that the shocked clusters experienced a significant broadening of

Table 6—Concentration of Cluster Patenting (Assignee HHI and Patent Shares)

		Share held by top X assignees			
	HHI (1)	Top 1 (2)	Top 5 (3)	Top 10 (4)	Top 20 (5)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1935\text{–}1939\}$	−0.003	−0.005	−0.006	−0.001	−0.005
	(0.004)	(0.006)	(0.005)	(0.004)	(0.005)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1940\text{–}1944\}$	−0.009	−0.011	−0.008	−0.003	−0.002
	(0.006)	(0.008)	(0.006)	(0.005)	(0.005)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1945\text{–}1949\}$	−0.028	−0.010	−0.004	0.002	0.003
	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1950\text{–}1954\}$	−0.029	−0.017	−0.011	−0.007	−0.001
	(0.008)	(0.009)	(0.011)	(0.008)	(0.007)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1955\text{–}1959\}$	−0.039	−0.028	−0.008	−0.004	−0.001
	(0.008)	(0.012)	(0.012)	(0.008)	(0.007)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1960\text{–}1964\}$	−0.058	−0.040	−0.006	−0.002	0.006
	(0.009)	(0.013)	(0.013)	(0.009)	(0.007)
$\ln(\mathit{OSRD\ rate}) \times \mathbf{1}\{1965\text{–}1970\}$	−0.055	−0.064	−0.030	−0.024	−0.017
	(0.008)	(0.013)	(0.015)	(0.008)	(0.006)
Observations	22,938	22,938	22,,938	22,938	22,938
R^2	0.63	0.51	0.46	0.33	0.20
Y mean	0.38	0.65	0.98	1.03	1.05
County-cat FEs	X	X	X	X	X
Year FEs	X	X	X	X	X

Notes: The table estimates the effect of the OSRD shock on the concentration of local patenting. Observations are at the county-category-year level. Column 1 measures an assignee Herfindahl index, and columns 2 to 5 measure concentration ratios. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county-category and year fixed effects, and the omitted (reference) category for each county-category is the 1930–1934 period. Each row thus indicates the percentage increase in cluster concentration in a given period associated with a doubling of the cluster's OSRD rate. Log transformations restrict the sample in each column to observations with patents and clusters with $\geq$1 OSRD patent. SEs clustered by county in parentheses.

their inventive base over the postwar era, with much of this effect driven by deconcentration away from the single dominant filer. In effect, what used to be company towns became significantly more diverse in their R&D performers.

The evidence is broadly consistent with prior research on industrial agglomeration. The economic geography literature has consolidated around three sources of agglomeration economies, which Duranton and Puga (2004) have characterized as "sharing" (of indivisible local assets, like universities or infrastructure), "matching" (of buyers and sellers of goods and labor), and "learning" (knowledge spillovers). Though these mechanisms are typically observationally equivalent, they provide useful structure for interpreting our results. The growth of local R&D-performing firms and institutions (insofar as we can measure them), including (i) firms migrating into the treated clusters from other locations and technology areas and (ii) government agencies locating labs and contracting with firms in these clusters, is consistent with the local advantages borne out of assets like large talent pools, financial capital, and research facilities. This density also supports more efficient matching, particularly through labor mobility.[20] Insofar as patent citations may reflect intellectual linkages, we explicitly find evidence of growing knowledge spillovers.

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[20] We do not document labor mobility directly, due to data limitations: linked employee panels are difficult to construct for this period. We forgo building a linked inventor panel across the universe of inventors due to

V. Downstream: Entrepreneurship and Employment

Did the growth of these postwar innovation clusters have broader impacts on local economies? The downstream effects of local and regional R&D investments is an important question not only for research on agglomeration but also for policy to improve local economic performance through place-based public R&D investments (Glaeser and Hausman 2020). What are the downstream effects of big, applied push R&D investments on local economic outcomes?

Research has increasingly begun to speak to these questions, especially in the context of Cold War–era R&D shocks. Schweiger, Stepanov, and Zacchia (2022), for example, show that Soviet "Science Cities"—R&D centers created by the Soviet government in the mid-twentieth century to support R&D in key technologies—today have higher education, skilled employment, patenting activity, and incomes. Kantor and Whalley (2022) show that in US counties that were target locations for Space Race R&D, manufacturing employment, output, and productivity grew more quickly in and after the Space Race era. We complement this literature by examining the impacts of public investments in specific technologies on the industries that produce them, and with a shock that provides variation both within and across counties, technologies, and industries.

We use CBP data to measure local employment in select industries in 1980 and D&B data to measure local business creation in these industries from 1920 to 1980. We link industries to the patent data (where we observe the OSRD shock) using a USPTO-produced crosswalk, which concords both SIC industries and patent subclasses to a common set of 41 unique industry codes. Several of these codes group up into an "Electrical and Electronic Equipment and Supplies" category—including the industry code with the most associated OSRD patents ("Electronic components and accessories and communications equipment"). This, together with prior evidence that the electrical and electronics area is where the OSRD shock had bite (online Appendix Figure C.3) and the broader growth of the electronics industry in the postwar period, motivates our focus on this category, and the analysis below will be performed across counties and industries in the electrical field. Online Appendix B lists the complete set of industries included in this sample.

We first explore OSRD's long-run, downstream employment effects. For this analysis, we estimate the effects of both extensive and intensive treatment measures on industry employment. Where employment counts are suppressed by the CBP (e.g., for small county-industry cells that pose a risk of disclosure), we impute employment from the establishment size distribution (in the spirit of Duranton, Morrow, and Turner 2014). To accommodate sparse samples, we replace log transformations with inverse hyperbolic sine transformations, which retains zeros in the explanatory and outcome variables but otherwise resembles the shape of our standard approach, and in successive specifications we control for counties' manufacturing employment

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hesitations with the quality of the links we can make, including selection into linking, disambiguation challenges, and the sensitivity of mobility measurement to the standardization of assignee names, firm reorganization, and name changes—as well as limited power, given that patenting is a rare event for most individuals and the median inventor has one patent. We instead note that improved matching is a corollary of thick labor markets.

Table 7—Effects on 1980 County Employment in High-Tech Manufacturing Industries

	Extensive			Intensive		
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbf{1}\{$*Any OSRD patents*$\}$	0.898 (0.226)	0.914 (0.166)	0.922 (0.166)			
IHS(*OSRD rate*)				1.712 (0.868)	1.137 (0.614)	1.175 (0.614)
Observations	3,770	3,770	3,770	2,022	2,022	2,022
R^2	0.54	0.77	0.77	0.62	0.86	0.86
Y mean	4.37	4.37	4.37	4.08	4.08	4.08
County FEs	X	X	X	X	X	X
Industry FEs	X	X	X	X	X	X
IHS mfg. empl.		X	X		X	X
IHS all empl.			X			X

Notes: The table estimates the relationship between counties' postwar employment in select industries and OSRD patenting in classes that crosswalk to these industries. Observations are at the county-industry level, with the sample restricted to industries in the broader domain of "Electrical and Electronic Equipment and Supplies" (see text). Industrial employment measured from the 1980 US County Business Patterns (CBP). The outcome in all columns is the inverse hyperbolic sine (IHS) of industry employment. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county and industry fixed effects. Successive columns add controls for IHS manufacturing employment and IHS total employment. SEs clustered by county in parentheses.

(across all manufacturing SICs) and total employment (across all SICs). Formally, we estimate the regression below:

$$(3)\quad \text{IHS}(\mathit{Employment})_{id} = \beta \cdot \mathit{OSRDTreatment}_{id} + \alpha_i + \gamma_d + \mathbf{X}_{id}\phi + \varepsilon_{id},$$

where i and d index counties and industries, α_i and γ_d are fixed effects, $\mathbf{X}_{id}$ are controls, and standard errors are clustered at the county level. Because employment in a given county and industry is determined in equilibrium with others, the results we obtain under this approach should not be interpreted as a multiplier on R&D (as in Kantor and Whalley 2022) but rather as divergence: without more structure, we are unable to distinguish net job growth from share-stealing, either of which could increase differences between counties. As with the rest of this paper, however, our goal is to evaluate the degree to which the OSRD shock led economic activity to agglomerate in the treated clusters and widened gaps in economic performance.

Table 7 presents the results. Columns 1 to 3 show that county-industries that engaged in OSRD R&D have roughly 90 percent greater employment in associated manufacturing industries in 1980 than those that did not, while columns 4 to 6 suggest that a doubling of the OSRD rate is associated with a more than doubling of manufacturing employment. These results should be interpreted with caution since we do not observe the prewar period and the relationship could potentially be endogenous. However, it is reassuring that many of these industries (e.g., electronic components) did not take much shape until after World War II.

In Table 8 we repeat this analysis for firm creation. Here, we replace county and industry fixed effects with county-industry fixed effects, exploiting the longer panel, and estimate differences relative to 1920 (the omitted category). Year fixed effects also serve an important role in this context, given that the sample of firms is conditioned on survival to 1980, and earlier decades have fewer firms in 1980 due to intervening exits. Columns 1 to 3 indicate that counties that produced OSRD pat-

Table 8—Effects on Firm Creation in High-Tech Manufacturing Industries

	Extensive			Intensive		
	(1)	(2)	(3)	(4)	(5)	(6)
1{*Any OSRD patents*} × *1930s*	0.067 (0.033)	0.066 (0.033)	0.067 (0.033)			
1{*Any OSRD patents*} × *1940s*	0.413 (0.077)	0.412 (0.077)	0.415 (0.077)			
1{*Any OSRD patents*} × *1950s*	0.642 (0.094)	0.640 (0.093)	0.642 (0.093)			
1{*Any OSRD patents*} × *1960s*	1.125 (0.111)	1.127 (0.110)	1.128 (0.110)			
1{*Any OSRD patents*} × *1970s*	1.425 (0.137)	1.419 (0.135)	1.421 (0.135)			
IHS(*OSRD rate*) × *1930s*				−0.021 (0.039)	−0.050 (0.039)	−0.072 (0.048)
IHS(*OSRD rate*) × *1940s*				0.180 (0.098)	0.165 (0.102)	0.178 (0.108)
IHS(*OSRD rate*) × *1950s*				0.251 (0.147)	0.228 (0.143)	0.240 (0.148)
IHS(*OSRD rate*) × *1960s*				0.763 (0.273)	0.749 (0.276)	0.741 (0.279)
IHS(*OSRD rate*) × *1970s*				1.057 (0.378)	1.025 (0.363)	1.018 (0.360)
Observations	127,584	127,584	127,584	14,616	14,616	14,616
R^2	0.56	0.57	0.57	0.57	0.58	0.58
Y mean	0.05	0.05	0.05	0.29	0.29	0.29
County-Ind FEs	X	X	X	X	X	X
Year FEs	X	X	X	X	X	X
IHS mfg. firms		X	X		X	X
IHS all firms			X			X

Notes: The table estimates the relationship between counties' firm creation in select industries and OSRD patenting in classes that crosswalk to these industries. Observations are at the county-industry-decade level, with the sample restricted to industries in the broader domain of "Electrical and Electronic Equipment and Supplies" (see text). Firm creation measured from the 1980 issue of the Dun and Bradstreet establishment listings, which reports founding year for all firms in its data. Sample is restricted to headquarters and single-branch establishments and by construction conditioned on survival to 1980. The outcome in all columns is the inverse hyperbolic sine (IHS) of industry firm creation. The OSRD rate measures the OSRD-funded share of county-category patents between 1941 and 1948. All columns include county-industry fixed effects, and the omitted (reference) category for each county-industry is the 1920s decade. Successive columns add controls for IHS manufacturing firms and IHS total firms in the given year. SEs clustered by county in parentheses.

ents were increasingly likely to produce firms in associated industries, particularly during and after the 1940s, though we see a (quantitatively modest) pre-trend in the 1930s. Columns 4 to 6 indicate that a doubling of the OSRD rate is associated with a steady increase in new manufacturing businesses over the postwar era, from 15 percent to 25 percent in the 1940s and 1950s to a more than doubling by the 1970s, with no visible pre-trend on the intensive margin.

VI. Aggregate US Invention

A corollary question to the results in Section III is whether the OSRD shock affected aggregate US invention. To answer this question, we estimate a cross-country triple-difference specification, comparing patenting at the USPTO and patent offices in two other Allied countries: the United Kingdom and France. In effect, the triple-difference design will estimate country-specific changes in patenting over time in patent classes (measured here as two-digit International Patent Classes, or IPCs) that were more versus less intensively OSRD treated (the difference-in-difference) and compare these changes across countries (the third difference). This approach will thus identify differential growth in patenting in OSRD-funded technologies in the United States relative to other countries.

Similar to our prior analyses, our treatment measure is the fraction of US patents in a given patent class between 1941 and 1948 that were OSRD funded. We bin this treatment into quartiles (conditional on ≥ 1 OSRD patent), with the reference category being classes with no OSRD patents. Our principal specification compares United States and foreign log patenting, in patent classes at different treatment quartiles, before and after war. We estimate this specification over a sample of country-class-years from 1930 to 1970, omitting 1940 to 1945, as follows:

$$\ln(Patents)_{ict} = \sum_{q=1}^{4} \beta_q \cdot \mathbf{1}\{Country\ i = US\} \cdot \mathbf{1}\{Class\ c \in quartile\ q\} \cdot \mathbf{1}\{t > 1945\} + Country_i \times Class_c + Country_i \times Post_t + Class_c \times Post_t + \varepsilon_{ict}, \tag{4}$$

where i, c, and t index countries (grouped up to US versus foreign), technology classes, and years, and standard errors are clustered at the country-class level.[21] Figure 9, panel A plots the results (with 95 percent confidence intervals). We find that US patenting in the most heavily treated classes increases over 50 percent more after the war than in other countries, and this effect attenuates in both magnitude and significance as treatment intensity declines.

We also make an analogous comparison within USPTO patent records only, where we compare patenting by US versus all foreign inventors. Here, we use US patent classes (USPCs) and index time by filing dates. Panel B illustrates that the differences here are even larger than across patent offices. In the most heavily treated patent classes, postwar patenting by US inventors increases nearly 80 percent more than patenting by foreign inventors.

In online Appendix C we estimate a variant of equation (4) with annual parameters. Paralleling Figure 9, online Appendix Figure C.8 presents the estimates for patenting at USPTO versus foreign patent offices, and online Appendix Figure C.9 for USPTO patents with US versus foreign inventors. We find similar patterns to those throughout the paper: patenting in the most heavily treated classes is on a parallel prewar trend at USPTO (versus foreign patent offices) or among US inventors at USPTO (versus foreign inventors) but differentially grows in the postwar era.

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[21] Because historical PATSTAT data only provide grant (not filing) dates, t indexes grant years for the US versus foreign patent office comparisons, where we also restrict to patents with a family size of one (to ensure we are measuring the primary location), although the results are generally not sensitive to this restriction. For domestic versus foreign USPTO patents, we measure filing dates, and t indexes filing years.

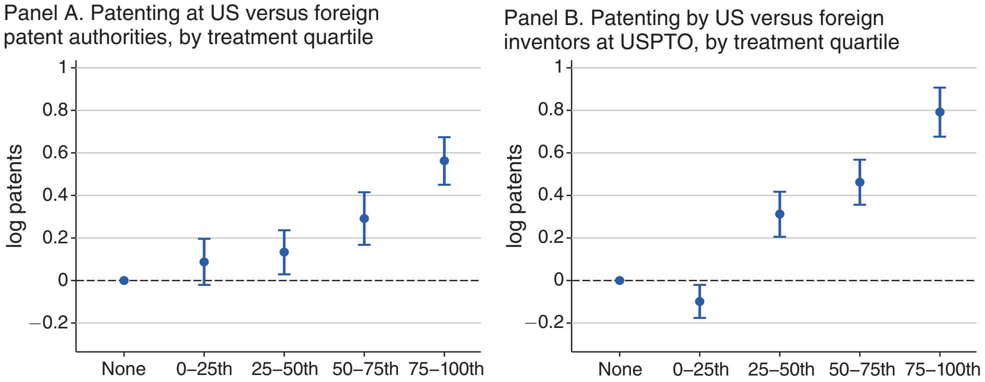

Figure 9. US versus Foreign Patenting in Each Quartile of Treated Patent Classes (Difference-in-differences, Pre-1940 versus Post-1945)

Notes: The figure shows difference-in-difference estimates of the effects of the OSRD shock on US versus foreign patenting, in patent classes (two-digit IPC in panel A, USPC in panel B) at different quartiles of OSRD treatment, as measured by the fraction of US patents in those classes between 1941 and 1948 that were OSRD funded. Error bars represent 95 percent confidence intervals, computed from SEs clustered at the country-class level.

VII. Concluding Remarks

> Although its part in the winning of the war was its greatest contribution … the full impact of its work must await the judgment of the future…
>
> —Irvin Stewart, Secretary of the OSRD (Stewart 1948, p. 298)

Despite a large historical and science policy literature on the effects of OSRD on the institutions of postwar science policy, we believe this paper to be the first quantitative empirical assessment of the long-run effects of what President Roosevelt called a "unique experiment" in research policy (Roosevelt 1944) on innovation and other economic outcomes.

With newly digitized archival data on OSRD contracts, linked to data on postwar patenting, firm creation, and employment, we found persistent effects of the World War II R&D shock on technology clusters. Treated clusters were producing another 40 percent to 50 percent more patents annually than untreated clusters by 1970, despite parallel trends in patenting before the war. In exploring mechanisms, we rule out that this was due to patenting by OSRD contractors themselves or to patents citing OSRD patents. We also used newly digitized data on the history of government patenting to show that the effects are not driven by follow-on government research investment in the same technology clusters. Instead, our evidence suggests that the effects are due to Marshallian agglomeration: with growing patenting by new and older firms, public and private, in-migrant firms and established firms, and with innovation becoming increasingly dispersed over time. Beyond patents, we also find evidence that postwar firm creation and employment were higher in OSRD-treated counties, decades out. Finally, there was also an aggregate shift in the trajectory of US innovation toward the most heavily treated technology areas.

The results provide new evidence on the persistent impacts of a large, broad, applied R&D shock on innovation, complementing a growing body of evidence on the returns to publicly funded research. The nature of the shock and its impacts evokes parallels to modern place-based industrial policies, including those introduced in the CHIPS and Science Act (recently enacted, at the time of writing). Whether these results generalize to other R&D investments, in a very different innovation system, is difficult to say. On the one hand, our results offer support for place-based R&D policy and large, public applied R&D investments. On the other, OSRD's effects may be specific to its time: today's innovation system is bigger, better developed, and global, and knowledge may be more mobile. We are also acutely aware that past public policies directed at cultivating new regional technology hubs have often fallen short of their aims (e.g., see Lerner 2009). These factors make it difficult to make direct or specific claims on the generalizability of this example to modern problems.

The results nevertheless point to several insights. In this paper we show that a large R&D shock drove long-lasting changes in economic performance, and evidence on the mechanisms—something that, to our knowledge, has not previously been shown. The evidence establishes that place-based R&D investments can have long-lasting local effects while at the same time pointing to how, in this case, they did so. Our interpretation of the evidence is that it was not any single activity or institution but rather an integrated set of institutions and actors that provided a foundation for OSRD-funded clusters to continue to grow. OSRD's approach to crisis R&D policy may have played a key role in creating this foundation: its programs integrated researchers, manufacturers, and end users, not only funding the research but also coordinating efforts and ensuring R&D was connected to production and the battlefield (Gross and Sampat 2023). Key institutional partners included universities, firms, and government-funded laboratories. Here again, Middlesex (Massachusetts) is our canonical example: the Rad Lab hosted a close-knit collaboration between academic researchers, industrial scientists, manufacturing firms, and the military—relationships that carried over into the postwar era while also spilling over to commercial innovation. If this interpretation is correct, it suggests that the cultivation of innovation ecosystems requires complementary policies and investments rather than any one intervention alone.

There are also wider implications for research, policy, and practice. At a high level, these results support Vannevar Bush's argument that federally funded research can fuel innovation and improve economic performance. But whereas Bush argued for funding "basic" research in *Science, The Endless Frontier*, OSRD's funding was primarily for applied R&D. Our results suggest that large-scale federal investments in applied research can also have large returns, or at least did in this case, potentially important given resurgent interest in "mission-oriented" R&D.

Our results also suggest that on concentration and inequality, Bush's nemesis Harley Kilgore was right to be concerned. Much of the OSRD support was directed to researchers at elite institutions and research labs (online Appendix Table A.3). Lacking a counterfactual, it is difficult to know whether the elite funding model of OSRD was the most efficient one for wartime—Were there, literally, any lost Einsteins?—but it is also hard to argue with the results. Nevertheless, Kilgore's concerns about persistent concentration of innovative activity and economic power generated by such an approach seem prescient, given the results of this paper suggesting they fueled agglomeration. Gruber and Johnson (2019) have argued that broader funding, even if it reduces efficiency, could promote not only equity but also geographically diffuse public and political buy-in for increasing federal research spending, a question we hope to explore in future research.

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