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The Hidden Costs of Securing Innovation: The Manifold Impacts of Compulsory Invention Secrecy

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Abstract. One of the most commanding powers of the U.S. Patent and Trademark Office (USPTO) is to compel inventions into secrecy, withholding patent rights and prohibiting disclosure, to prevent technology from leaking to foreign competitors. This paper studies the impacts of compulsory secrecy on firm invention and the wider innovation system. In World War II, USPTO issued secrecy orders to more than 11,000 patent applications, which it rescinded en masse at the end of the war. Compulsory secrecy caused implicated firms to shift their patenting away from treated classes, with effects persisting through at least 1960. It also restricted commercialization and impeded follow-on innovation. Yet it appears it was effective at keeping sensitive technology out of public view. The results provide insight into the effectiveness of compulsory secrecy as a regulatory strategy and into the roles, and impacts, of formal intellectual property in the innovation system.

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1. Introduction

Compulsory secrecy is one of the most imposing discretionary powers the U.S. Patent and Trademark Office (USPTO) and other patent offices have today. Since World War II, USPTO has had the legal authority to order firms and inventors to keep secret inventions in, and suspend examination of, patent applications whose disclosure it deems may pose risks to national security—not only withholding intellectual property (IP) rights, but effectively impounding new invention. The purpose of the policy is to protect domestic invention from (mis)appropriation by foreign competitors. Compulsory secrecy is ordinarily invoked with careful discretion, but in a crisis the prospects for its use grow, and increasing pressures of foreign technological competition have prompted recent considerations of expanding its use to protect economic security.

Little is known about how compulsory secrecy affects innovation. Broad invocation is not unprecedented: in World War II, USPTO ordered more than 11,000 patent applications into secrecy, covering inventions as diverse as radar, cryptography, and synthetic materials. The vast majority of these secrecy orders were rescinded when the war ended. The scope and scale of the policy, and its abrupt conclusion, present a rare opportunity to study the effects of compulsory secrecy on innovation and diffusion. Doing so can also offer insight on the value of patents and the ways in which holding up formal IP can interfere with ordinary inventive and commercial activity.

In this paper, I study how this program affected individual firms and the wider innovation system. I show that firms that received secrecy orders at high rates during the war shifted their patenting away from technology areas in which they were affected, and some temporarily stopped patenting altogether. This was particularly true for firms that were not involved in the wartime research effort. The patents of these firms that were secret for long periods were also less likely to be cited by future patents, and a deeper dive suggests this is the result of a missing generation of follow-on invention. Evidence from a case study of one firm (Du Pont) suggests that secret inventions were temporarily precluded from being commercialized. Collectively, these results point to a number of potential costs of compulsory secrecy, distorting the direction of invention and undermining firm investments in innovation. Yet the policy appears to have worked as intended: new terms in titles of secret patents saw limited mention in patent text and the wider literature until after the war ended, such that these repercussions should be evaluated against the

seeming effectiveness of the policy in keeping sensitive technological content out of public view.

To understand these results, it is useful to take a step back and consider the roles patents play in the innovation ecosystem, and how compulsory secrecy might interfere with its regular functioning. The patent system is designed to provide incentives for innovation by granting a temporary monopoly on invention, which is predicated on patents granting, in exchange for disclosure. Exclusivity with commercial opportunity allow firms to earn returns on their research investment. Information about new invention, conveyed in patent publications or otherwise, can clarify competitive positions and delineate property rights, helps inventors build on prior art, and enables others to produce and sell the invention when IP rights expire. Compulsory secrecy in the United States directly defies these goals by holding up patent rights and forbidding disclosure.

The results of this paper illustrate what can happen when these functions are suppressed. Firms caught in the crossfire might lose access to inventive inputs and opportunities to profit from their investment, and reduce or reallocate research and development (R&D) investments accordingly. Restrictions on disclosure affect follow-on innovation, which can in turn limit competition (a second, indirect channel through which incentives for innovation might be suppressed). Though World War II was an extraordinary time, unlike in Europe the domestic U.S. economy was still functioning. The evidence is thus suggestive of the impacts a similar intervention may have in other crises or even in regular times. It is not hard to imagine, for example, secrecy orders being used to protect COVID-19 vaccine development, as they once were in wartime.

The evidence points to the private value of the rights to, and commercial opportunities for, inventions that secrecy orders essentially impounded. Without exclusivity, let alone commercialization, the returns to R&D are often eradicated. In comparison with compulsory licensing, compulsory secrecy can be even more costly to firms, as it can foreclose the possibility of market entry for as long as restrictions are in place—leaving firms in the interim with only internal applications as opportunities to profit from their invention. Firms might even choose to avoid applying for patent protection to preclude the risk of being compelled into secrecy. That said, the incidence is unlikely to be uniform. Incumbent firms and firms that already rely on secrecy may stand to benefit from compulsory secrecy if it protects them from competing innovation or harms rivals. Consistent with this possibility, I show that large firms were relatively less affected.

This paper also speaks to the role of information in the functioning of the wider innovation system. A growing literature explores the role of patents in this domain, including through increasing access to patent documents (Furman et al. 2021) and policy changes that accelerated patent publication (Hegde et al. 2022), and even uses modern invention secrecy to argue for patent disclosure (de Rassenfosse et al. 2020). Although these papers detect positive effects on local patenting, patent citations, and licensing, these results are in tension with skepticism from legal scholars (e.g., Roin 2005, Fromer 2009, Devlin 2010), who point out that much of the information in patents is available through other sources, and that inventors and patent attorneys are incentivized to avoid reading prior art and draft broad patents that disclose as little as possible.[1] Relative to these examples, however, compulsory secrecy imposes significantly broader restrictions on disclosure than preventing patent publication alone. Their effects on subsequent invention are thus suggestive of the value of unrestricted information flows in supporting cumulative innovation.

More broadly, this paper fits into a wider literature on crisis innovation, especially in wartime. The two world wars have served as laboratories for many other questions about innovation, including around compulsory licensing and scientific communication (e.g., Moser and Voena 2012, Iaria et al. 2018, Biasi and Moser 2021). Recent work by Gross and Sampat (2020) suggests World War II was a fertile breeding ground for innovation, giving rise to new firms and industries, especially among those involved in the wartime research effort. Firms squelched by compulsory secrecy and lacking a government customer, however, may not have been so lucky.

The paper is organized as follows. Section 2 describes compulsory secrecy as implemented during World War II, traces its history, and discusses its relevance today. Section 3 introduces the data and provides an empirical characterization of the World War II secrecy program. Section 4 studies the effects of compulsory secrecy on firms, and Section 5 on innovation more broadly. In each case, I attack the question from multiple angles. Section 6 then presents countervailing evidence that the program was effective in its goal of protecting sensitive technology from public disclosure. Section 7 concludes with competing perspectives on the importance of these results and their implications for managers, policymakers, and innovation.

2. Historical Background

World War II began in 1939 when Germany invaded Poland; France, the United Kingdom, and other countries declared war on Germany; and Russia counter-invaded Poland from the east. By the summer of 1940, Germany occupied France, Belgium, Luxembourg, the Netherlands, Denmark, and Norway and had begun bombing England. Although the United States did not enter the war until after the attack on Pearl Harbor at the end of 1941, it recognized the brewing crisis and began preparing for its eventual entry after the fall of France in May 1940.

Among these preparations was the reintroduction of compulsory secrecy. On July 1, 1940, the U.S. Congress passed a law (Public Law 700, henceforth P.L. 700) to renew an invention secrecy program first introduced near the end of World War I that had empowered the USPTO to issue secrecy orders on patent applications. The law specifically authorized USPTO to order that inventions in patent applications be kept secret, and withhold the granting of a patent, for as long as needed if its disclosure might be "detrimental to the public safety or defense." Recipients of secrecy orders were, however, permitted to tender their inventions to the federal government and seek compensation for government use if a patent was eventually granted. Violations were initially punishable by loss of patent rights, but supplementary legislation a year later increased penalties to up to two years in prison and a $10,000 fine, while adding a prohibition on all foreign filing.[2] In 1942, the policy was further amended to remain in force for as long as the United States was at war.

To implement P.L. 700, the USPTO created a new internal office named the Patent Office Defense Committee (later the Patent Office War Division, or POWD) to handle secrecy evaluations (Donnelly 1942).[3] When patent applications arrived at the USPTO, they were first assigned to one of 65 patent examining divisions, each led by a primary examiner and specializing in a particular subject matter. The secrecy evaluation process began with these primary examiners, who forwarded to the POWD applications for inventions that in their opinion "discloses a matter related to the national defense" (U.S. Office of Scientific Research and Development 1944, p. 1).

At the POWD, technical staff from four agencies—the War Department (represented by the Army and Navy Patent Advisory Board, or ANPAB), War Production Board (WPB), Office of Scientific Research and Development (OSRD), and Petroleum Administration for War (PAW)—evaluated these applications and made recommendations on secrecy. Online Appendix A shows examples of secrecy determination forms that accompanied each application and circulated among the evaluators. As soon as one recommended secrecy, a secrecy order was issued and patent examination suspended. The applicant was sent a standardized notification letter explaining that a secrecy order had been issued, instructing not to disclose the invention without USPTO permission at risk for a fine, jail time, and forfeiture of the patent, suggesting that the applicant tender the invention to the government, and offering no means for appeal (example notification letters are shown in online Appendix B). Upon enactment of P.L. 700, the USPTO began by reviewing recently allowed patents that were ready to issue, followed by pending applications and new applications.

Although the issuance of secrecy orders may have been noisier in the earliest stages of the program (as review procedures were being developed), contemporary evidence suggests administrators were generally careful to avoid issuing secrecy orders without compelling reasons (Moore 1945). Once issued, secrecy orders could be reviewed and rescinded if it was determined that the enemy had access to comparable technology or an invention was no longer of strategic value. When one of the reviewing agencies sought to have a secrecy order rescinded, a copy of the application in question would be recirculated to reviewers from the other three agencies, who then had to concur in the rescission for the secrecy order to be lifted—a process that could take two to six months—but the "natural tendency [was] to 'play it safe' and leave the secrecy order in effect" (Stoutenburgh 1945). Records of OSRD correspondence suggest that these case-by-case rescissions were relatively rare, and that most were issued in 1945, near the end of the war.[4]

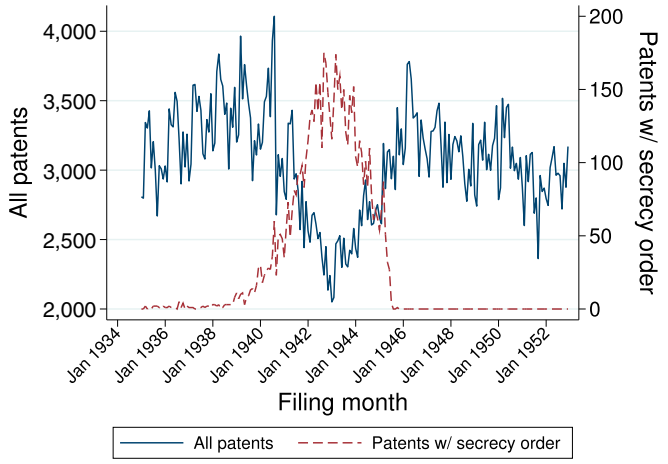
The war in Europe ended on May 7, 1945; in the Pacific, on September 2. On August 30, a newly appointed patent commissioner (Casper Ooms) organized an interagency meeting to discuss the "expedited removal" of outstanding secrecy orders (Moore 1945). When representatives from the War Department raised concerns about inventions they believed should stay secret, the participants agreed to a 90-day grace period in which these advisory agencies could compile a list of those patents that they wished to be excepted from a mass rescindment. The meeting ended in the issuance of a general rescinding order (henceforth GRO) under which all outstanding secrecy orders were rescinded effective November 30, 1945, except those that the recommending agencies requested be exempt—and OSRD made sure that patents from the atomic fission project would remain under seal (Bush 1945). By the end of the year, there were fewer than 800 secrecy orders outstanding, with most on nuclear energy patents (U.S. Army Office of the Judge Advocate General (JAG) 1945, U.S. House Committee on Government Operations 1980).

Contemporary records from the U.S. Army's Judge Advocate General's office (JAG 1945) indicate that 11,182 secrecy orders were issued through June 14, 1945. Given that the program wound down that summer, the true total is likely on the order of 11,200. Its records show that secrecy orders accelerated in the early years of the war, peaking in 1943–1944. Figure 1 confirms these patterns in the data, which will be introduced and discussed in Section 3.

2.1. Postwar Invention Secrecy Policy

Although the war ended in 1945, the need to protect recent and ongoing developments in sensitive technology such as atomic energy persisted into the 1950s and beyond. The USPTO's wartime authority to issue

Figure 1. (Color online) Monthly Patent Applications, 1935–1952



Note. Figure shows monthly counts of (i) patent filings from 1935 to 1952 (solid line/left axis), and (ii) filings observed in the data as having been issued secrecy orders under P.L. 700 (dashed line/right axis).

secrecy orders remained in place through 1952, when the World War II national emergency was officially terminated. Prior to doing so, Congress enacted a peacetime invention secrecy policy to continue these wartime sequestrations under the Invention Secrecy Act of 1951. Although the restrictions and penalties remained the same, the new law made a few key departures from P.L. 700, the most important being (i) fixed, one-year terms, subject to renewal by the requesting agency, which nominally subjected outstanding secrecy orders to annual review (whereas secrecy orders during the war had no expiration); and (ii) a means of appeal.

Secrecy orders have issued under the Invention Secrecy Act ever since, although the available data suggest at lower frequency than during World War II: between 2005 and 2015, the USPTO issued 1,171 secrecy orders among 5.8 million applications (FAS 2018), whereas during World War II it did so on roughly one of every 25 patents filed. Thus, although compulsory, secrecy is ordinarily invoked with discretion, in a crisis the prospects for its use grow.

Increasing global technological competition has prompted a re-examination and proposed expansion of compulsory secrecy to protect U.S. economic security, defined as ensuring that U.S. firms realize the full benefit of their R&D investment. When the U.S. House of Representatives raised the possibility and USPTO solicited public comments (United States Patent and Trademark Office (USPTO) 2012), the request for comments posed several of the questions asked in this paper, including:

1. What would be the effect of establishing a new regulatory scheme based on economic security on United States businesses, industries, and the economy?

2. How would it affect the public notice function that underlies the policy of publication, including the ability of U.S. inventors and innovators to timely access the newest technical information upon which to build and stay ahead?

3. How would it affect firms with operations or sales in foreign countries?

Various firms and lobbying groups responded with concerns that such a policy would deprive inventors of technical information (e.g., Intellectual Property Owners Association (IPOA) 2012); preclude commercialization of innovations that are easily observed or reverse-engineered (American Intellectual Property Law Association 2012); and discourage R&D or drive it away from the U.S. patent system (American Bar Association 2012, IPOA 2012).

These objections are consistent with views in the 1940s. OSRD's director (Vannevar Bush) noted that its contractors were uneasy about the possibility that "foreign companies would be able to enter the world commercial market [ahead] of the U.S. manufacturers," due to compulsory secrecy (Stoutenburgh 1945). Even those in charge of administering the compulsory secrecy program had hesitations: in discussing the possibility of a peace-time policy at the August 30, 1945, meeting, representatives from various agencies were concerned that it would drive invention underground, delay diffusion, and slow technological progress (Moore 1945).[5]

3. Data

To study the effects of compulsory secrecy, I combine several sources of data, beginning with the complete record of the nearly 2.5 million patents granted between 1920 and 1979 from the USPTO historical master file (Marco et al. 2015), which includes grant dates, patent class (USPC), and two-digit National Bureau of Economic Research (NBER) technology

category (Hall et al. 2001). I supplement these data with patent serial numbers (i.e., application numbers) and filing dates collected from FreePatentsOnline.com, from which I also collect the complete network of forward and backward front-page citations, and with standardized assignee names from Clarivate's Derwent Innovation.

Using the assignee names, I classify assignees into four categories: firms, universities and hospitals, government agencies, and individuals. At certain points in the paper, I will also distinguish between patents assigned to OSRD contractors (performing R&D for the war effort) and noncontractors, which were identified from OSRD archival records (see Gross and Sampat 2020). Concurrent with these efforts, I also identify all patents associated with the Manhattan Project research program from Streifer (2017) and exclude them from the following analysis, as both the narrative history and the data indicate that these patents were not only (very) secret, but also exempted from the 1945 rescinding order. Online Appendix A describes in detail how these data were prepared, as well as steps taken to improve the quality of the data on serials, filing dates, and assignee names. Together with online Appendix C, it also shows that Manhattan Project patents were fundamentally different from other secret patents, with later filing dates and much longer grant delays, and clearly not subject to the rescinding order—motivating my dropping them from the sample.

I use the records of three agencies—OSRD, the Office of Production Research and Development (OPRD), and the U.S. Army Judge Advocate General (JAG)—to identify patent applications with secrecy orders. Collectively, these records identified 8,475 patent applications that were ordered secret during the war (roughly 75% of the likely true total of approximately11,200, which rises to 9,518, or 85%, if the nonintersecting Manhattan Project serials from Streifer (2017) are added). Of these, 6,353 (75%) were granted by 1979, with the remainder either abandoned or still secret (for example, two such applications on cryptographic inventions remained secret until they were granted in 2000).[6] The OSRD and OPRD records also identify roughly 19,000 patent applications that were formally evaluated for secrecy but disapproved, and the 13,131 of these which were granted will be used later as a comparison group for patents that were ordered secret.

In addition to numeric data on patents and citations, this paper also uses information from patents' textual content. I obtain from Google the title and full text of each patent in the 1920–1979 sample, and I identify words (more precisely, word stems) first used in the title of a patent filed between 1940 and 1945. New words are used in this paper as a measure of new ideas that entered the patent record during World War II (Iaria et al. 2018), whose diffusion can be traced both within the patent record and beyond it, using other data sources such as books and product catalogs. Measuring words in patent titles presents two advantages over the full text: not only are titular words the most meaningful in describing the invention, but they are also available with minimal transcription error. Full text optical character recognition (OCR) errors are pervasive in historical patents, leading to severe bias when measuring words' earliest usage, though not their overall frequency.[7]

3.1. Completeness of Secrecy Order Records

There are two ways in which these data might be mismeasured. The first is truncation: there may be patent applications from the 1940s that we know were ordered secret (because they appear in the archival lists of secret serials) but remain secret, and have thus not yet granted. The second is measurement error: there may be granted patents that were secret but we do not measure as secret, because these records are incomplete. In other words, there may be inventions that we know were secret but we cannot measure in the grant data, and vice versa.

Given how much time has elapsed, it is unlikely that many World War II era patents remain secret today, though inevitably it is difficult to know for sure. Of the known-secret serials that have since granted, 93% granted by 1950, 99% by 1960, and 99.9% by 1970. Unmeasured secrecy orders might be a more binding concern, but here we may be assured by three considerations: (i) if Manhattan Project patent applications are included, we have identified around 85% of all applications with secrecy orders; (ii) insofar as secrecy orders are undermeasured, this is likely to bias comparisons in a conservative direction, as the control group will have some (unmeasured) secret patents in it; and (iii) this bias will tend to be small in magnitude, because secret applications were only a fraction of total applications (albeit higher in some technology areas).

3.2. Patent Citations as a Measure of Follow-on Invention

The analysis will open in Section 4 by studying the effects of compulsory secrecy on directly treated firms, before widening our aperture to study its effects on innovation broadly in Section 5. Forward patent citations will be used throughout this section to measure follow-on invention, supplemented later by content-based measures. To interpret these results, it is useful to first understand how citations were historically generated, and what they represent.

At its most literal, the patent citations measured in this paper are references to relevant prior art. As online

Appendix A shows, prior art references have been a part of patent examination since before USPTO began requiring that published patents list these references on the last (now, front) page. In the course of patent examination, examiners make reference to prior art that they have used to evaluate the novelty of the applicant's claims, and in 1947, USPTO began requiring that these references be printed on the published patent itself. Until the USPTO established applicants' duty to disclose related prior art in 1992, it appears these references were made primarily by patent examiners. As such, patent citations identify closely related invention, not information flows per se, but this is enough to measure de facto follow-on invention.

Given the historical data-generating process, many of the concerns about what citations measure in the modern period (e.g., Alcácer et al. 2009, Sampat 2010, Cotropia et al. 2013, Roach and Cohen 2013) are less relevant than they would otherwise be. That most (if not nearly all) of the citations in these data will be examiner-added is also potentially important, and discussed at more length in online Appendix A. However, as Moser et al. (2017) have shown with more recent data, examiners tend to use the characteristics of an invention (rather than performance) to identify prior art. Presuming this generalizes to the historical period, the citations in this paper are best described as a measure of intellectual proximity and content-driven connections.

3.3. Characteristics of Secrecy Orders

It is useful to begin with a descriptive account of patenting and secrecy orders in the World War II period. Figure 1 shows monthly patent filings at USPTO from 1935 to 1952 (solid line, measured by left axis), and monthly applications ordered into secrecy (dashed line, measured by right axis). Aggregate patenting declined by nearly 50% by the height of the war in 1943, as resources were diverted away from invention and into war and military production. Naturally, however, this is also when secrecy orders were issued most intensively, trailing off by mid-1945.

Figure 2 shows the distribution of patenting and secrecy orders across one-digit NBER patent categories. Although aggregate patenting declined during the war, its distribution across technology areas was relatively stable (panel (a)). The fraction of patents ordered secret, on the other hand, varied significantly over the course of the war and across technologies, with the most affected of these broad classes (Computers & Communications, which included radar) having nearly one of every three to four patents sequestered between 1942 and 1944.

The technological priorities of the war effort can be seen more precisely in the set of patent classes in which secrecy orders were issued at particularly high frequency. Table 1 lists the top 10 classes by the fraction of applications between 1939 and 1945 ordered secret, where for the purposes of this table, I include Manhattan Project patents and measure them as secret. On this list are nuclear reactions, cryptography, radar, synthetic rubber, and catalytic cracking (fuel production)—most of which are technologies with both military and commercial value. At the height of the war, more than half of filings in these classes were ushered into secrecy.

Secrecy orders were inevitably not randomly issued: the narrative evidence suggests that patent applications were evaluated carefully and in good faith, with more sensitive and important inventions being the primary focus. As a test for selection, Table 2 estimates mean differences in patents' forward citations as a function of whether a given patent was issued a secrecy order and/or evaluated for a secrecy order. The regressions in this table condition on fixed effects for each patent's (i) primary class and filing year (for within-cohort comparisons) and (ii) grant year (because patents only become citable after grant). The estimated equation is:

$$Y_i = \beta_1 \cdot \mathbb{1}(Secret)_i + \beta_2 \cdot \mathbb{1}(Evaluated)_i + \alpha_{ct} + \gamma_g + \varepsilon_i, \tag{1}$$

where i indexes patents (the unit of observation), c, t, and g represent the patent's class, filing year, and grant year (fixed for each patent i), $\mathbb{1}(Secret)_i$ indicates that patent i was ordered secret, $\mathbb{1}(Evaluated)_i$ indicates that patent i was formally evaluated for secrecy (irrespective of whether it was then ordered secret), α_{ct} and γ_g are fixed effects, and standard errors are clustered by patent class. Table 2 shows that patents evaluated for secrecy were cited more, by more parties, and by patents in more classes than those that were not. Patents with a secrecy order were cited even more, on average receiving more than 1.5 times as many citations as the typical patent from the same class and year (up 2.6 citations on an average of 4.6).

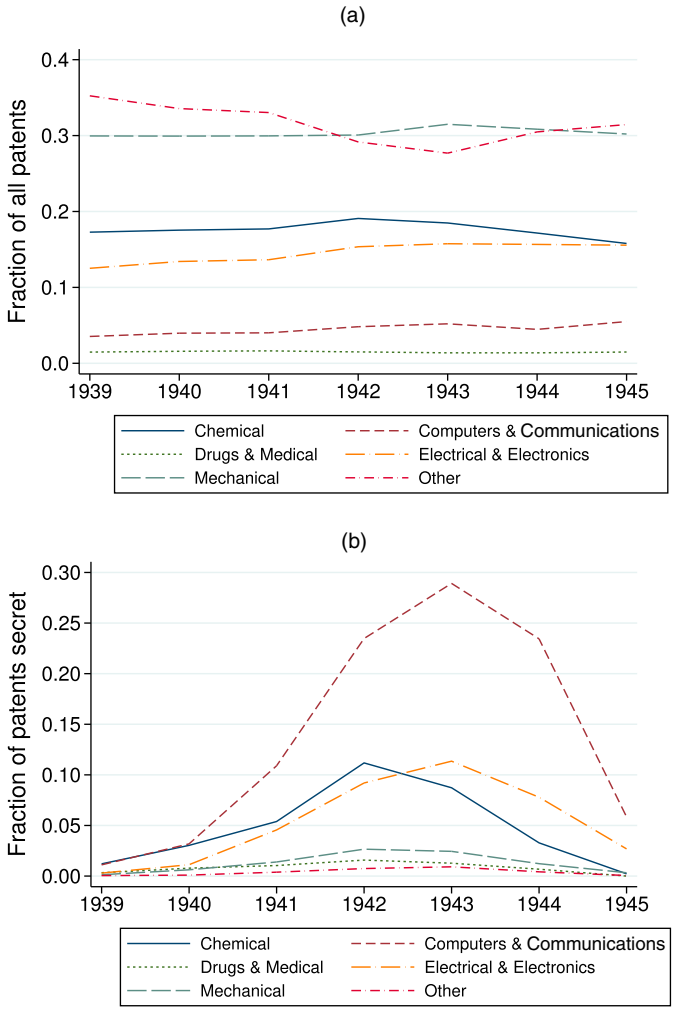
Among the many narrative records describing the secrecy program and internal agency memoranda, including by the two OSRD employees who were assigned to review patent applications for secrecy and whose names are on most of the secrecy determination forms in the OSRD records (e.g., Beckler 1944), there is no indication that the standard for secrecy varied over time. Although this standard was not explicit, one reviewer from the War Production Board noted that he "used… two criteria in deciding whether secrecy should be imposed" (Moore 1945):

1. Does the invention in question have direct bearing on the war effort?

2. Could the information in the application be useful to our enemies?

Additional evidence in online Appendix D shores up this interpretation. Empirically, characteristics of

Figure 2. (Color online) Patterns in Distribution of Patent Applications Across NBER Patent Categories



Notes. Panel (a) shows the distribution of patent filings across one-digit technology categories in each year from 1939–1945. Panel (b) shows the rate at which filings in each category were issued secrecy orders over time.

Table 1. Top 10 Patent Classes with Applications Placed in Secrecy, 1939–1945

USPC	Description	Percent of applications with secrecy order, 1939–1945	Max percent secret in any year, 1939–1945
376	Induced nuclear reactions	74.8%	90.9%
380	Cryptography	45.2%	71.4%
342	Directive radio wave systems/ devices (radar)	37.8%	61.4%
367	Acoustic wave systems/devices	29.6%	55.9%
526	Synthetic resins or natural rubbers	28.6%	62.4%
333	Wave transmission lines and networks	28.1%	51.8%
585	Chemistry of hydrocarbon compounds	25.9%	51.9%
315	Electric lamp and discharge device systems	25.6%	42.4%
327	Electrical devices, circuits, and systems	22.0%	52.0%
343	Radio wave antennas	21.1%	56.0%

Notes. The sample includes Manhattan Project patents, which I also measure as secret (see text and online Appendix A), though these will later be excluded from my analysis. Data for eventually granted patents only.

Table 2. Forward Citations of Secret vs. Nonsecret Patents, 1939–1945

	Outcomes				
Variable	Cites	Citers	Citing classes	Nonself	Self
Secrecy ordered	1.578***	1.232***	0.364***	1.422***	0.134***
	(0.349)	(0.275)	(0.080)	(0.321)	(0.039)
Secrecy evaluated	0.926***	0.615***	0.293***	0.743***	0.170***
	(0.111)	(0.077)	(0.036)	(0.100)	(0.018)
N	242,614	242,614	242,614	242,614	242,614
R^2	0.09	0.09	0.12	0.09	0.06
Grant year fixed effects	Y	Y	Y	Y	Y
Class-year fixed effects	Y	Y	Y	Y	Y
Mean of dependent variable	4.63	4.23	2.06	4.27	0.27

Notes. Table estimates the probability that a patent filed between July 1940 and June 1945 generates any forward citations, as a function of whether the patent was evaluated for secrecy and/or ordered secret, with estimates by filing year, and with 1940 being the omitted reference year. Column (1) includes all such patents. Columns (2) and (3) restricts the sample to patents by non-OSRD and OSRD contractors, respectively. Columns (4) and (5) repeat this comparison in a pooled, triple-differenced sample. All columns control for (i) patent class x filing year and (ii) grant year fixed effects. Specifications estimated via OLS. Standard errors clustered by patent class in parentheses.
***$p < 0.01$.

patents that correlate strongly with future citations, such as patent length, were stable for secret and nonsecret patents throughout the war (e.g., Figure D.1 in the online appendix). Among patents formally evaluated for secrecy, the fraction ordered secret increased slightly over the period, from around 25% in 1941 to 40% in 1945, which could be a result of either (i) patent examiners applying higher standards in deciding which patents to submit to secrecy evaluation, such that fewer were evaluated and a larger fraction of this set was ordered secret; or (ii) the evaluated pool remaining fixed, and secrecy evaluators lowering the threshold for a secrecy order.

3.4. Immediate Effect: Delayed Grant and Publication

Although secrecy orders were sometimes rescinded early, the majority were in place until the GRO took effect in late 1945. Table 3 illustrates the effect that this had on total pendency, estimating the incremental grant lag of patents filed each year from 1939 to 1945 with a secrecy order, relative to others in the same class and filing year.[8] The effect of secrecy on grant lags is on average about 2.5 extra years for 1940 and 1941 applications, doubling the mean—and not significantly different from zero by 1945. Note that the table includes 1939 filings for completeness, as many were ordered secret, but patents filed in 1939 that received a secrecy order were necessarily still pending as of the enactment of P.L. 700 in July 1940, and their grant lags are thus in part mechanical. For this reason, later tables will focus on the July 1940 to June 1945 period.

Figure 3 shows the full distribution of grant lags for secret patents shifting down monotonically over time to match that of their nonsecret counterparts in the same class and filing year by 1945. No comparable differences emerge when comparing patents evaluated for secrecy but not ordered secret against those not evaluated for secrecy at all (Figure C.1 in the online appendix), suggesting that it was secrecy, not evaluation, which generated these delays.

4. Effects of Compulsory Secrecy on Firms

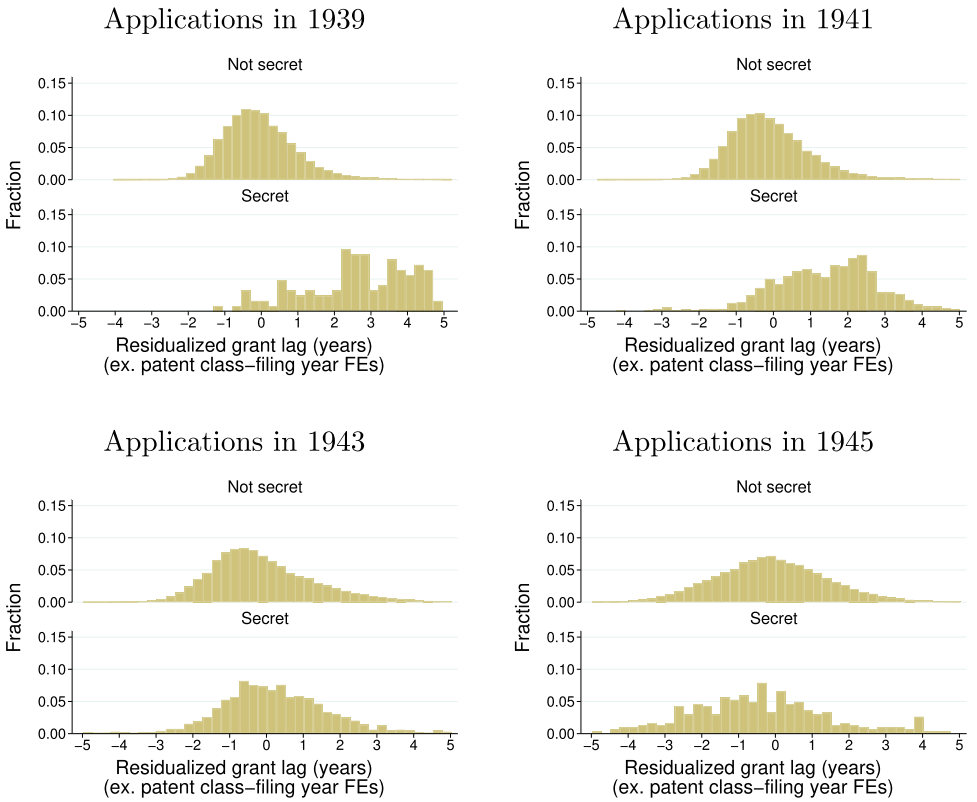
We begin by examining how compulsory secrecy affected firm invention. A useful thought experiment

Table 3. Effects of Secrecy Orders on Application-Grant Lags, 1939–1945

	Grant lag, for patents filed in						
Variable	1939	1940	1941	1942	1943	1944	1945
Secrecy ordered	3.272***	2.527***	2.303***	1.299***	0.826***	0.401	0.233
	(0.259)	(0.154)	(0.163)	(0.118)	(0.127)	(0.268)	(0.286)
N	40,739	40,361	35,206	29,524	28,459	31,962	36,363
R^2	0.17	0.20	0.23	0.22	0.20	0.20	0.19
Class fixed effects	Y	Y	Y	Y	Y	Y	Y
Mean lag	2.25	2.31	2.42	2.70	2.97	3.44	4.00

Notes. Table estimates differences in patents' grant lags for secret versus nonsecret patents, by filing year. All columns include patent class fixed effects, such that comparisons are between patents in the same class in the given year. Standard errors clustered by patent class in parentheses.
***$p < 0.01$.

Figure 3. (Color online) Application-Grant Lags of Patents Placed Under Secrecy vs. Others, 1939–1945



Notes. Figure shows the distribution of residual grant lags of patent applications with versus without secrecy orders, after controlling for patent class-year fixed effects. Patent applications filed prior to July 1940 were only evaluated for secrecy if still under examination (such that pre-1940 differences in total pendency are in part selected).

to have in mind as we build to the analysis is to imagine the strategic challenge facing patent filers after they receive their first secrecy order, or after receiving many secrecy orders. Some filers may not even know that USPTO has the authority to order inventions into secrecy, with all the repercussions that brings, until they receive the notice that informs them that examination is indefinitely on hold, the invention cannot be disclosed, and there is no process for appeal, though they can tender their inventions for government use with a soft promise of eventual remuneration. Should filers continue inventing, or patenting, in the technology area that they have now discovered is at risk? Should they continue inventing or filing at all?

A natural instinct might be to exploit an assignee's first secrecy order as a shock and compare its patenting before and after. This approach, however, is intrinsically problematic because patenting is serially correlated, and a secrecy order by definition implies that a patent application was filed, increasing the likelihood of others arriving before and after—which leads to spurious pretrends and positive effects. The approach I take instead is to compare assignees' pre- and postwar patenting as a function of their wartime exposure to compulsory secrecy.

Concretely, I estimate assignees' propensity to patent in a given two-digit technology category, as well as in any category, before and after the war, as a function of the rate at which they received secrecy orders during the war itself. The analysis will initially be performed at the assignee-category level before aggregating up to the assignee level. The focal outcome variables will measure whether the assignee filed at least one patent in a given category, or at all, in five-year intervals around World War II: 1930–1934 and 1935–1939 (prewar), and 1946–1950, 1951–1955, and 1956–1960 (postwar). The treatment variable, denoted $SecrecyRate_i$, measures the fraction of an assignee's filings between 1940 and 1945 (in a given category, or overall, as the case may be) that were ordered into secrecy. I thus estimate the following specification:

$$Y_{it} = \sum_t \beta_t \cdot SecrecyRate_i \cdot Period_t + \alpha_i + \delta_t + \varepsilon_{it}, \qquad (2)$$

where i indexes assignees/assignee-categories (the units), t indexes periods, α_i and δ_t are unit and time fixed effects, and standard errors are clustered by unit.

In implementing this analysis, I further condition the sample in two ways. The first is to restrict to incumbent filers: I require that assignees in the sample

have at least one patent pre-1940. Because firms inventing in areas at risk for secrecy orders may be different from those that are not, I also require that assignees have at least one secrecy order in the war, ensuring that the estimated effects are estimated off of the intensive margin of secrecy.

The results for assignee-category patenting are shown in Table 4. This table examines whether a given assignee patents in a given technology area in each of the periods shown, as a function of the intensity with which it received secrecy orders in that area during the war. All estimates are relative to 1930–1934 (the omitted category). The first column provides results for all assignees in this sample, and the latter columns for different assignee subsamples. The last two columns examine entrants, rather than incumbents, defined locally (no pre-1940 patents in the given technology area, column (6)) and globally (no patents at all pre-1940, column (7)). The results indicate that assignees more heavily affected by compulsory secrecy were more likely to stop patenting in technology areas where they were affected, with these effects persistent through 1960. A closer look at the results by subsample provides further clues: these effects are primarily driven by non-OSRD contractors (column (2))—that is, firms without a government customer—and by small assignees (column (4)), defined here as those with fewer than 20 patents pre-1940.

Table 5 performs similar analysis at the assignee level, asking whether a given assignee patents at all, as a function of the intensity with which it received secrecy orders during the war. The table bears a similar format to Table 4, adding two columns subsampling assignees that I label as technologically focused or diversified, measured with an indicator for whether all of their pre-1940 patents were concentrated in one technology area. Here I find similar but somewhat attenuated results, with stronger effects for non-OSRD, small, and technologically focused assignees. In other words, those who had their patents sequestered at high rates, without a government customer or much technological flexibility, were less likely to patent thereafter.

Tables D.2.1 and D.2.2 in the online appendix re-estimate Equation (2) with a binned (rather than continuous) treatment measure. For the assignee-category regressions, these bins are secrecy rates in (0,0.25], (0.25,0.75], and (0.75,1]; for assignees, they are (0,0.1], (0.1,0.25], and (0.25,1]. The precise intervals are chosen to be easy to interpret yet each have enough mass to support estimation. The results in these tables indicate that the results are driven by those assignees whose World War II era patents were ordered into secrecy at the highest rates.

Given the reliance on patent data, it is hard to be certain whether the results reflect reduced invention or simply reduced patenting, with a concomitant shift to informal IP such as trade secrets. Either result may be concerning to both managers and regulators. The latter would reflect a weakening of formal IP, and by driving invention underground—away from the patent system—it might undermine other functions it is designed to achieve, such as disclosure. That the effects are more pronounced for smaller firms, however, suggests firm responses are on the R&D margin, because if they were on the IP strategy margin, large firms would be more sensitive (Png 2017). The persistence of these effects might be

Table 4. Effects of Secrecy Orders on Pr(Assignee Patents in Given Class)

Variable	(1) All	(2) Non-OSRD	(3) OSRD	(4) Small	(5) Large	(6) Entrant	(7) Entrant
Wartime secrecy rate × (1935–1939)	0.173	0.086	0.184	−0.269	0.134		
	(0.108)	(0.133)	(0.193)	(0.182)	(0.150)		
Wartime secrecy rate × (1946–1950)	−0.270***	−0.396***	0.119	−0.670***	−0.217	−0.601***	−0.600***
	(0.090)	(0.109)	(0.170)	(0.151)	(0.136)	(0.055)	(0.070)
Wartime secrecy rate × (1951–1955)	−0.304***	−0.382***	0.088	−0.646***	−0.181	−0.596***	−0.561***
	(0.087)	(0.104)	(0.187)	(0.145)	(0.142)	(0.058)	(0.076)
Wartime secrecy rate × (1956–1960)	−0.245***	−0.255**	0.026	−0.401**	−0.179	−0.459***	−0.336***
	(0.085)	(0.106)	(0.180)	(0.155)	(0.134)	(0.060)	(0.076)
N	3,635	1,960	1,675	905	2,730	1,809	1,071
R^2	0.51	0.51	0.39	0.46	0.45	0.20	0.20
Assignee × NBER category fixed effects	Y	Y	Y	Y	Y		
NBER category fixed effects						Y	Y

Notes. Table estimates the effect of the secrecy order program on affected assignees' postwar patenting, relative to prewar patenting, in a given technology category where it received secrecy orders. Observations are assignees x NBER categories x years, in all cases organized into a balanced panel from 1930 to 1960, and aggregated to the periods 1930–1934, 1935–1939, 1940–1945, 1946–1950, 1951–1955, and 1956–1960. The dependent variable measures whether the assignee filed any patent in the given NBER category and period. "Wartime secrecy rate" measures the fraction of the given assignee's filings from 1940 to 1945 in the given NBER category that received a secrecy order, which is then interacted with indicators for later periods to estimate effects over time. Samples are restricted to assignee-categories with ≥1 prewar patent and ≥1 secrecy order, and omits the 1940–1945 period, such that the table shows a pre- versus postwar comparison. All regressions include dummies for each of the interacted postperiods (not shown). Standard errors clustered by assignee in parentheses.

**$p < 0.05$; ***$p < 0.01$.

Table 5. Effects of Secrecy Orders on Pr(Assignee Patents in any Class)

Variable	(1) All	(2) Non-OSRD	(3) OSRD	(4) Small	(5) Large	(6) Focused	(7) Diversified	(8) Entrant
Wartime secrecy rate × (1935–1939)	0.118	0.059	0.101	−0.226	0.157	−0.519	0.137	
	(0.153)	(0.165)	(0.214)	(0.186)	(0.177)	(0.314)	(0.174)	
Wartime secrecy rate × (1946–1950)	−0.272**	−0.294**	−0.043	−0.470***	−0.311	−0.614**	−0.324**	−0.600***
	(0.134)	(0.145)	(0.288)	(0.167)	(0.314)	(0.282)	(0.156)	(0.062)
Wartime secrecy rate × (1951–1955)	−0.358***	−0.353***	−0.185	−0.509***	−0.451	−0.850***	−0.367***	−0.522***
	(0.108)	(0.116)	(0.395)	(0.139)	(0.296)	(0.227)	(0.135)	(0.061)
Wartime secrecy rate × (1956–1960)	−0.211*	−0.186	0.085	−0.319**	−0.200	−0.672***	−0.217	−0.352***
	(0.108)	(0.118)	(0.368)	(0.139)	(0.309)	(0.228)	(0.133)	(0.058)
N	2,380	1,885	495	1,290	1,090	435	1,945	969
R^2	0.52	0.51	0.34	0.47	0.46	0.43	0.51	0.22
Assignee fixed effects	Y	Y	Y	Y	Y	Y	Y	

Notes. Table estimates the effect of the secrecy order program on affected assignees' postwar patenting, relative to prewar patenting, in any technology category. Observations are assignees x years, in all cases organized into a balanced panel from 1930 to 1960, and aggregated to the periods 1930–1934, 1935–1939, 1940–1945, 1946–1950, 1951–1955, and 1956–1960. The dependent variable measures whether the assignee filed any patent in the period. "Wartime secrecy rate" measures the fraction of the given assignee's filings from 1940 to 1945 that received a secrecy order, which is then interacted with indicators for later periods to estimate effects over time. Samples are restricted to assignees with ≥1 prewar patent and ≥1 secrecy order, and omits the 1940–1945 period, such that the table shows a pre- versus postwar comparison. All regressions include dummies for each of the interacted postperiods (not shown). Standard errors clustered by assignee in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

due to fixed costs of changing R&D direction (e.g., of reverting to pre- or midwar projects) after compulsory secrecy ended in 1945, or the extension of compulsory secrecy policy to peace-time in the early 1950s.

Of these two interpretations, the former could have broad implications, especially had compulsory secrecy been sustained at the levels applied in the war—or should it be expanded again. Rigidities and switching costs in R&D portfolios can spring from many sources, including specific R&D assets that are slow or costly to build—such as human capital and know-how, commercialization infrastructure, or established routines and organizational structures—or managerial inertia due to incentives or ambiguity aversion. For some firms, compulsory secrecy might have eliminated opportunity costs to shifting direction, and once these changes were made, reverting was costly. Others may have pulled out of R&D entirely, especially without a government customer. That the effects in Table 5 are larger for smaller and more technologically focused assignees, with fewer existing alternatives to reallocate to, hints that some rigidities may be at play.

4.1. Restricted Commercialization

In the case of inventions that might be disclosed through licensing or sales to customers, compulsory secrecy could have conceivably impeded firms from commercialization. Finding inventions that fit these criteria and whose commercial sale can be measured is difficult, but a natural place to start is with inventions that are themselves final goods.

The most accessible setting that I could find for testing this question is the specialty chemicals industry. Much as they do now, large chemical manufacturers in the 1940s circulated product catalogs listing their commercial products, where we can search for chemical terms from contemporary patents. I specifically focus on the Du Pont chemical company, whose catalogs are available from the Du Pont collection at the Hagley Museum. Du Pont was the largest U.S. chemical manufacturer at this time, with the most patents and the most secrecy orders. For this exercise, I extracted the text of five editions: 1938, 1944, 1946, 1949, and 1955–1956.

To build a sample of words to search for in these catalogs, I began with the set of words whose stems first appeared in the title of a patent which was filed between 1940 and 1945 and classified in a chemical patent class. I then reviewed these stems to identify 572 stems that relate to chemical compounds or processes, and programmatically searched for words with these stems in each edition of the catalog. The test is then whether the stems from secret versus nonsecret patent titles were differentially likely to appear in each edition of the catalog.

Table E.1 in the online appendix shows the results: stems that first appeared in a secret patent are less likely to be included in the catalog in 1944 and 1946, with no significant differences in the other years, nor for stems from patents evaluated for secrecy but not ordered secret. When compared against the baseline rate of ≈10% of nonevaluated stems appearing in the catalog, the effect size indicates that almost none of the stems from secret patents show up in 1944 and 1946—which, as the table shows, is in fact true by the raw counts in each volume. These differences could be due to Du Pont inventions being withheld from the product market, or a reduction in licensing and sale of external inventions—either would be consistent with the restrictions of secrecy orders. If the former, it is worth noting that the welfare implications are

ambiguous, since we cannot rule out that products serving similar functions were developed and commercialized by others, but this can be true at the same time as private costs were incurred by treated firms.

5. Effects on Follow-on Invention

Compulsory secrecy may also interfere with the broader functioning of the patent system, beyond the directly treated firms alone. Patents are potentially important not only to incentives for innovation, but also to expanding access to frontier technical information (e.g., Furman et al. 2021). Suppressing disclosure more broadly could undermine innovation and innovation strategy, since one firm's inventive output is another's input.[9] The World War II episode provides an opportunity to explore whether compulsory secrecy may thwart this function.

In this section, I examine the effects of secrecy on follow-on invention. Simple comparisons between secret and nonsecret patents' citations can be problematic because secrecy orders (and evaluations) were selected (Table 2). I instead focus on the intensive margin: variation in filing dates, combined with en masse rescindment, generates variation in secrecy duration.[10] Exploiting the mass rescindment event, I am able to compare patents that were secret for more versus less time, differencing against contemporaries in the same patent class and filing year. The sample for this analysis will be all patents filed between July 1, 1940, when P.L. 700 was enacted, and June 30, 1945. Restricting the sample to patents filed after July 1, 1940, drops some earlier filings that were still pending as of that date and were subsequently ordered secret, but because these are already selected on longer examination, I focus on patents filed after P.L. 700 was active.

Throughout this section, I estimate variants of the following specification via ordinary least squares (OLS):

$$Y_i = \sum_{t=1941}^{1945} \beta_{1t} \cdot \mathbb{1}(Secret)_i + \sum_{t=1941}^{1945} \beta_{2t} \cdot \mathbb{1}(Evaluated)_i + \gamma_1 \cdot \mathbb{1}(Secret)_i + \gamma_2 \cdot \mathbb{1}(Evaluated)_i + \alpha_{ct} + \gamma_g + \varepsilon_i, \quad (3)$$

where β_{1t} and β_{2t} are estimated by filing year and other variables are defined as before. The variable Y_i will alternately be (i) whether the patent was ever cited, (ii) whether it reached particular citation thresholds, or (iii) citation counts, estimated with a count model—each measured through 1979, by which point these patents will have realized most of their eventual citations (Hall et al. 2001). I estimate separate effects by filing year to enable comparisons between secret and nonsecret patents filed earlier or later in the war, with 1940 being the omitted category. With this specification, we will be able to make statements about the difference between secret patents and their nonsecret contemporaries in the same class filed in 1945, and compare it to same such difference for those filed in 1940, for which a secrecy order was far more imposing.

Although secrecy orders were restrictive, contemporary sources suggest secret inventions could in select cases be shared. Moreland (1943) and Stewart (1943) both indicate that OSRD contractors could request permission to disclose inventions, especially to military suppliers. Griffiths (1942) states as much explicitly: "If for the purpose of development or manufacture it appears necessary to communicate to one or more reliable and responsible persons…an application held in secrecy, a petition for modification of the order [can be] made, stating the purpose of the proposed disclosure, vouching for the reliability and integrity of these persons." I will thus distinguish between patents of OSRD contractors and other assignees in the following analysis.

Contemporaneous trends in U.S. invention (e.g., the growth of immigrant inventors in Moser et al. 2014) will be accounted for by class-year fixed effects. But a remaining threat to this approach is the possibility of time-varying selection into secrecy: if evaluators applied more stringent standards later in the war, then what appears to be an effect of a shorter secrecy term may just be positive selection. The evidence from Section 3 suggests this is unlikely to be the case, with little evidence that evaluation standards, or characteristics of patents that predict future citations, varied systematically over time—and if anything, it raises the possibility of loosening evaluation standards, which would bias the estimates toward zero. To further explore this possibility, I run robustness checks controlling for a series of patent- and assignee-level characteristics. I also discuss the degree of selection on unobservables that would be required to explain the results (Oster 2019). As a placebo test, I also separately estimate Equation (3) for nonself-citations and self-citations, as secrecy should only affect the former, whereas selection will be reflected in both.

The main limitation of historical citation-based analysis is the fact that the citation record only begins in February 1947, which is when the USPTO first required granted patents to include formal references to prior art. As a result, any citations observed in these data are necessarily from patents granted after 1947, which will undercount follow-on invention granted prior to this date (although modern evidence suggests that the bulk of forward citations are accumulated over longer horizons, e.g., Hall et al. 2001). This truncation of the citation record will affect earlier applications more than later ones, which have fewer years of missing citations—but it should affect secret and nonsecret patents of the same class and vintage in a similar way. The class-year fixed effects will account for any truncation in citation counts flexibly by technology area.

5.1. Forward Citations

In Table 6, I estimate the probability that a patent is ever cited. Column (1) does so for the full sample, and finds no statistical differences in the likelihood that earlier or later secret patents are subsequently cited. When we split the sample into non-OSRD contractors and OSRD contractors (columns (2) and (3)), we see heterogeneity. Noncontractor patents filed early in the war are significantly less likely to be cited than contemporaries, but this effect reverses for later filings, with the effect approximately monotonic in the filing year, consistent with longer secrecy terms reducing the likelihood of future citation. The point estimates suggest that secret patents filed in 1945 are nearly 15% more likely to later be cited than those filed in 1940. There are no such patterns for patents evaluated for secrecy but not ordered secret—with these estimates being relatively precise zeros—suggesting that the effects are driven by secrecy specifically.[11] In contrast, there is no detectable effect of compulsory secrecy on citations of inventions by OSRD contractors. The final two columns of the table show results from a triple-differences specification, where the focal variables are included alone and interacted with an indicator for OSRD contractors, but where fixed effects can be estimated off of the pooled sample. The results are consistent.

Table 7 explores the robustness of these results to a variety of controls. Column (1) reproduces the result from Table 6 for non-OSRD contractors. Column (2) then controls for other observable patent characteristics, with fixed effects for the number of inventors and patent length (measured as number of pages and drawings), which correlate with citations (online Appendix C). Column (3) controls for other assignee characteristics, with fixed effects for firms and individuals, and fixed effects for the assignee's prewar patenting in the 1930s, as a measure of assignees' prior experience in and intensity of invention. Column (4) includes both the patent and assignee controls, and column (5) replaces the latter with assignee fixed effects. Across all five specifications, the empirical patterns are unchanged—although standard errors increase in column (5), due to the

Table 6. Effects of Secrecy on Probability of Any Forward Citations

				Triple difference	
Variable	All (1)	Non-OSRD (2)	OSRD (3)	All (4)	OSRD (rel. to all) (5)
Secrecy ordered	−0.000	−0.065*	0.048	−0.065**	0.115***
	(0.021)	(0.033)	(0.030)	(0.031)	(0.040)
× filed in 1941	−0.024	0.026	−0.050	0.023	−0.083
	(0.024)	(0.041)	(0.035)	(0.040)	(0.051)
× filed in 1942	0.011	0.048	−0.016	0.049	−0.075
	(0.022)	(0.038)	(0.031)	(0.036)	(0.046)
× filed in 1943	0.018	0.086**	−0.040	0.081**	−0.115**
	(0.023)	(0.042)	(0.030)	(0.040)	(0.047)
× filed in 1944	0.020	0.069	−0.024	0.072*	−0.101**
	(0.026)	(0.044)	(0.034)	(0.042)	(0.049)
× filed in 1945	0.030	0.129***	−0.016	0.140***	−0.178***
	(0.027)	(0.044)	(0.040)	(0.041)	(0.051)
Secrecy evaluated	0.018	0.036**	−0.011	0.039**	−0.049**
	(0.013)	(0.017)	(0.022)	(0.016)	(0.024)
× filed in 1941	0.011	−0.001	0.027	−0.004	0.030
	(0.015)	(0.019)	(0.024)	(0.018)	(0.027)
× filed in 1942	−0.004	−0.020	0.016	−0.022	0.037
	(0.014)	(0.020)	(0.023)	(0.018)	(0.024)
× filed in 1943	0.010	−0.008	0.031	−0.013	0.044*
	(0.015)	(0.019)	(0.023)	(0.018)	(0.026)
× filed in 1944	0.007	−0.014	0.028	−0.016	0.046*
	(0.017)	(0.022)	(0.025)	(0.021)	(0.028)
× filed in 1945	0.011	−0.010	0.026	−0.021	0.059*
	(0.019)	(0.026)	(0.025)	(0.025)	(0.031)
Secret + Eval = 0	0.39	0.45	0.05		
Delta 1941	−0.1997	0.5551	−0.3460		
Delta 1942	0.0552	0.9936	−0.0577		
Delta 1943	0.0951	1.4300	−0.1762		
Delta 1944	0.1309	1.9356	−0.1215		
Delta 1945	0.4041	3.4941	−0.2052		

Notes. Table estimates differences in patents' forward citations, unique citing assignees, unique citing classes, nonself-citations, and self-citations for patents that were evaluated for secrecy and/or ordered secret. All columns control for (i) patent class by filing year and (ii) grant year fixed effects. Standard errors clustered by patent class in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 7. Effects of Secrecy on Probability of Any Forward Citations: Robustness to Alternative Specifications (Non-OSRD Only)

Variable	(1)	(2)	(3)	(4)	(5)
Secrecy ordered	−0.065*	−0.065**	−0.068**	−0.067**	−0.079
	(0.033)	(0.033)	(0.034)	(0.033)	(0.050)
× filed in 1941	0.026	0.024	0.028	0.023	0.036
	(0.041)	(0.040)	(0.042)	(0.041)	(0.062)
× filed in 1942	0.048	0.045	0.050	0.047	0.050
	(0.038)	(0.037)	(0.038)	(0.037)	(0.056)
× filed in 1943	0.086**	0.084**	0.086**	0.084**	0.096
	(0.042)	(0.041)	(0.042)	(0.042)	(0.061)
× filed in 1944	0.069	0.062	0.070*	0.065	0.058
	(0.044)	(0.043)	(0.042)	(0.042)	(0.061)
× filed in 1945	0.129***	0.123***	0.129***	0.122***	0.153***
	(0.044)	(0.044)	(0.044)	(0.044)	(0.058)
Secrecy evaluated	0.036**	0.027	0.032*	0.024	0.027
	(0.017)	(0.017)	(0.017)	(0.017)	(0.027)
× filed in 1941	−0.001	0.002	−0.002	0.001	0.003
	(0.019)	(0.020)	(0.019)	(0.019)	(0.029)
× filed in 1942	−0.020	−0.015	−0.021	−0.017	−0.028
	(0.020)	(0.020)	(0.019)	(0.019)	(0.029)
× filed in 1943	−0.008	−0.006	−0.010	−0.008	−0.023
	(0.019)	(0.020)	(0.019)	(0.019)	(0.031)
× filed in 1944	−0.014	−0.009	−0.015	−0.011	−0.021
	(0.022)	(0.022)	(0.022)	(0.022)	(0.031)
× filed in 1945	−0.010	−0.009	−0.015	−0.014	−0.039
	(0.026)	(0.027)	(0.026)	(0.027)	(0.039)
N	125,130	124,962	125,130	124,962	124,962
R^2	0.05	0.06	0.05	0.06	0.54
Secret + Eval = 0	0.45	0.32	0.34	0.25	0.30
Delta 1941	0.5551	0.4844	0.5954	0.4719	0.6127
Delta 1942	0.9936	0.9496	1.0524	0.9751	0.8006
Delta 1943	1.4300	1.4304	1.4241	1.4119	1.2344
Delta 1944	1.9356	1.7289	1.9737	1.8158	1.1407
Delta 1945	3.4941	3.1574	3.4667	3.0952	2.9524
Grant year fixed effects	Y	Y	Y	Y	Y
Class-year fixed effects	Y	Y	Y	Y	Y
Patent controls		Y		Y	Y
Assignee controls			Y	Y	
Assignee fixed effects					Y
Mean of dependent variable	0.86	0.86	0.86	0.86	0.86

Notes. Table estimates the probability that a patent filed between July 1940 and June 1945 generates any forward citations, as a function of whether the patent was evaluated for secrecy and/or ordered secret, with estimates by filing year, and with 1940 being the omitted reference year. Sample restricted to patents by non-OSRD contractors only. Column (1) presents the baseline result from Table 6. Columns (2), (4), and (5) control for various patent characteristics (fixed effects for the number of inventors, number of pages in the patent publication, number of drawings). Columns (3) and (4) control for characteristics of assignees (indicators for whether the assignee is a firm or individual, and fixed effects for the assignee's number of patents in the 1930s). Specifications estimated via OLS. SEs clustered by patent class in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

more limited within variation available for estimating the effects of secrecy.

In both tables I calculate and present the Oster δ-statistic for each of the focal parameters, which informs us how large the selection on unobservables has to be, relative to the selection on observables, for the true parameters to be zero, given estimated values (Oster 2019). When δ is low, it takes little selection on unobservables to reverse the controlled effect; that is, the estimated effect is accurate only if there is approximately zero selection on unobservables. When δ is high (e.g., > 1), the effect is relatively robust to selection on unobservables.[12] I find that this statistic is consistently above one for the statistically significant, later-year parameters.

Online Appendix D presents additional results. Tables D.3.2 and D.3.3 reproduce the regressions in Table 6, first excluding secret patents granted prior to August 30, 1945 (indicating that they were rescinded early), and then excluding patents in weapons-related classes, which were of high military priority but had only limited commercial potential, such as firearms, ammunition, ordnance, and explosives. The results are not sensitive to either restriction. Table D.3.4 separately estimates the

effects for nonself- and self-citations, and citations from firms versus individuals, where we see that the results are driven by nonself citations, with no such effects for self-citations, and by citations from firms, rather than individuals. The latter result, in particular, suggests that secrecy impeded the flow of information feeding an ecosystem of firm invention.

Table D.3.5 in the online appendix studies effects on forward citation in levels, first using indicators for different citation thresholds (columns (1) to (6)), which can be estimated via OLS with multilevel fixed effects without an incidental parameters problem and is thus the preferred approach, and then for citation counts (column (7)), estimated as a conditional fixed-effects Poisson with filing and grant year fixed effects, reported as incidence rate ratios. The table shows that the effects of secrecy are strongest at lower citation thresholds, particularly for the probability of receiving at least one or two citations, but not detectable for higher thresholds. The Poisson estimates suggest that secret patents filed in 1945 receive roughly 1.65 times the citations of those filed in 1940.

5.2. Alternative Measure: Diffusion of New Words

Although researchers from Jaffe et al. (1993) to Galasso and Schankerman (2015) have used patent citations to measure follow-on invention, and many of the idiosyncracies of modern citation data do not apply in the period studied in this paper, the previous analysis still faces two limitations. The first is that patents only become citable when published—which motivated the inclusion of grant year fixed effects. An additional limitation that is particularly germane to this paper is that the patent citation record only begins in 1947, as the USPTO did not require inventors to list references to prior art on published patents until February 4, 1947.[13]

I thus develop a workaround content-based measure of follow-on invention that can be constructed for patents throughout this period. I identify new word stems in patent titles as ideas that entered the patent record during the war (see Section 3), and measure later patents' use of stems that first appeared in secret versus nonsecret patents. The approach is similar to that of Iaria et al. (2018), who study the introduction of new words in the title of scientific publications as a proxy for new scientific concepts, and the use of those words in patents.[14]

In preparing the data, I take the 1,143 stems first appearing in the title of a patent filed between July 1, 1940, and June 30, 1945, and for each stem I identify all subsequent patents with that stem in its title. This approach yields a panel of usage for every stem, and it allows us to compare the nearly 100 stems that originated in secret patents against the remainder that did not. Comparisons in levels remain difficult, due to positive selection: new stems from secret patents are subsequently used more than their nonsecret counterparts, much like the patterns in Table 2. However, we can estimate variants of Equation (3) for word usage in place of patent citations.

The results are shown Table 8 for the 561 word stems that originated in patents of non-OSRD contractors filed between July 1940 and December 1944 (because there were no stems originating in secret patents from 1945, the 1945 year is omitted). Due to the small sample, these regressions reduce the class-year fixed effects to filing year fixed effects only, as class-year fixed effects would leave too little residual variation to identify the focal parameters.

The results are similar to those in Tables 6 and 7. Column (1) estimates the effects on log stem usage (through 1979) and finds that new stems from secret patents filed in 1940 on average have lower subsequent usage, but these effects more than reverse for new stems from later filings in 1943 and 1944. We see similar patterns for the probability of achieving 10, 20, 30, and 50 uses (columns (2) to (5)), though the effects are statistically weaker at higher thresholds. As before, there are no statistically significant effects for stems first appearing in patents evaluated for secrecy but not ordered secret, though in this case the estimates are somewhat noisy.

5.3. Mechanisms: Temporarily Veiled or Permanently Forgotten?

The results invite the question of why a temporary secrecy policy would affect long-run citations. One possibility is a missing generation of follow-on invention. An alternative with perhaps more serious implications is that sequestered inventions were permanently forgotten, with entire threads of innovation left behind. To explore which of these two mechanisms is driving the results, Table D.3.6 in the online appendix estimates analogous regressions for the probability of being cited in subsequent cohorts of inventions, focusing on patents filed between two and 25 years later, to see whether the differences between patents with shorter and longer secrecy terms arise in the short run or long run. The results suggest a lost generation interpretation: patents with shorter secrecy are more likely to be cited by patents filed three to four years later than are those with longer secrecy, but these differences fade when comparing the likelihood of citation by later patents.

6. Were Secrecy Orders Effective at Preventing Disclosure?

Whether the consequences of compulsory secrecy were understood at the time, the intent of the policy was to safeguard invention whose disclosure might be detrimental to the public safety or defense. Other security measures were also in place during the war, including traditional security classification of government activities. As part of these broader measures,

Table 8. Effects of Secrecy on Diffusion of New Word Stems in Patent Titles

Variable	(1) Ln(Uses)	(2) Uses ≥ 10	(3) Uses ≥ 20	(4) Uses ≥ 30	(5) Uses ≥ 50
Secrecy ordered	−0.987***	−0.667***	−0.333*	−0.333*	−0.167
	(0.356)	(0.195)	(0.195)	(0.195)	(0.154)
× filed in 1941	0.699	0.708*	0.333	0.333	−0.000
	(0.829)	(0.383)	(0.344)	(0.344)	(0.280)
× filed in 1942	0.784	0.702*	0.262	0.262	0.095
	(1.094)	(0.358)	(0.318)	(0.318)	(0.345)
× filed in 1943	1.398**	0.817***	0.308	0.375	0.408
	(0.681)	(0.248)	(0.298)	(0.285)	(0.251)
× filed in 1944	1.876***	0.967***	0.533	0.633*	0.367
	(0.709)	(0.258)	(0.333)	(0.334)	(0.339)
Secrecy evaluated	0.208	0.207	0.050	0.158	0.018
	(0.405)	(0.201)	(0.208)	(0.206)	(0.164)
× filed in 1941	0.616	−0.052	0.126	0.069	0.302
	(0.566)	(0.265)	(0.245)	(0.243)	(0.218)
× filed in 1942	0.820	−0.066	0.105	0.091	0.335
	(0.912)	(0.287)	(0.299)	(0.296)	(0.262)
× filed in 1943	−0.021	−0.182	0.031	−0.037	−0.044
	(0.503)	(0.237)	(0.259)	(0.233)	(0.188)
× filed in 1944	−0.101	−0.044	−0.004	−0.130	0.009
	(0.533)	(0.259)	(0.252)	(0.248)	(0.206)
N	561	561	561	561	561
R^2	0.03	0.03	0.02	0.03	0.04
Filing year fixed effects	Y	Y	Y	Y	Y
Mean of dependent variable	2.82	0.54	0.35	0.28	0.19

Notes. Table estimates the subsequent usage of word stems that first appeared in the title of a patent filed in 1940 to 1944, as a function of whether the first patent with the stem was evaluated for secrecy and/or ordered secret, with estimates by filing year, and with 1940 being the omitted reference year. Sample restricted to new stems from non-OSRD contractors only; 1945 is omitted because there were no such stems originating in secret patents that year. Column (1) estimates effects on the number of subsequent patents with that stem in the invention title (through 1979). Columns (2) to (5) estimate effects on the probability of a stem generating 10, 20, 30, and 50 such uses. The latter four specifications are estimated via OLS. Standard errors clustered by patent class in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

was compulsory secrecy effective at keeping sensitive new technology out of public view?

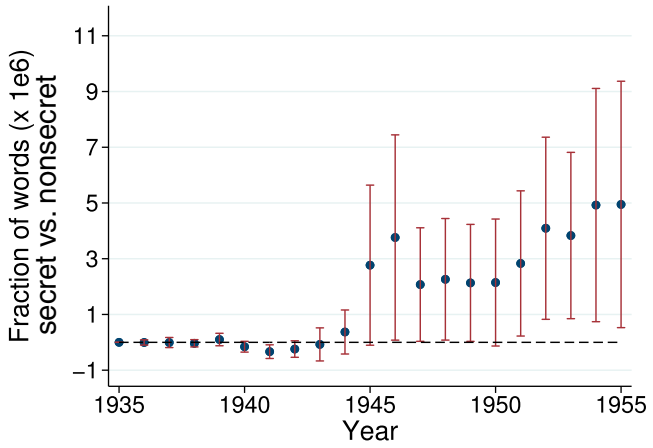
I take two approaches to answering this question. Both examine the wider use of new terms from secret patents, not limiting ourselves to patent titles alone. I first turn to patent full text. For each stem that first appeared in the title of a patent filed in 1940 to 1945, I measure the fraction of nonsecret patents using that stem in their full text, by year. I then compare the annual frequency of stems first appearing in secret patents versus nonsecret patents, by year, truncating to stems below the 90th percentile of pretitular usage so as to eliminate already common language—although the results are similar for 75th, 90th, or 95th percentile truncation.[15] Specifically, I run the following regression on a sample of 1,143 unique stems from 1935 to 1955, where i indexes stems and t indexes years, and standard errors are clustered by stem:

$$\text{Pct. of corpus}_{it} = \sum_{t=1936}^{1955} \beta_{1t} \cdot \mathbb{1}(Secret)_i + \sum_{t=1936}^{1955} \beta_{2t} \cdot \mathbb{1}(Evaluated)_i + \alpha_i + \delta_t + \varepsilon_{it}. \quad (4)$$

Figure 4 plots the annual differences (the β_{1t} parameters), along with the associated 95% confidence intervals. The results indicate that prior to 1945, there was not differential usage of words whose stem first entered the patent record in secret or nonsecret patents, but that beginning in 1945, the use of words from secret patents' titles in the full text discretely jumps, with the difference persistent through at least 1955. Incremental effects are found for stems originating in the title of patents evaluated but not made secret (Figure D.4.1 in the online appendix).

I next turn to the Google Books corpus, as a data source that can measure broader use beyond patents alone, and perform a similar exercise. Google makes publicly available data on the annual usage of individual words and phrases (N-grams) in the books it had scanned into its Google Books service as of 2012, which provides insight into a wide corpus. Prior work has argued that this corpus can be treated as a library and used to characterize lexica (Pechenick et al. 2015). Because this corpus is increasingly populated by scientific texts across the 20th century, it is also well-suited to measuring the diffusion of technical or scientific concepts.

Figure 4. (Color online) Annual Use of New Word Stems from Secret vs. Nonsecret Patent Titles, Measuring Use in Patents' Full Text



Notes. Figure shows estimated differences over time in the patent full text frequency of word stems that first appeared in the title of a secret versus nonsecret patent filed in the 1940–1945 period. Specification includes stem fixed effects, such that comparisons are within stems, over with 1935 the omitted category. Sample censors stems at the 90th percentile of prepatent usage in patents' full text, to eliminate already common language. Error bars represent 95% confidence intervals, computed from standard errors clustered at the stem level.

For this exercise, I retrieved the annual usage of words with stems that entered the patent record in the title of a patent filed from 1940 to 1945 (as before), as well as the total number of words in the corpus by year, to calculate focal stems' frequency as a fraction of the corpus in a given year. I match 1,089 stems (95% of the original 1,143) from patent titles to the Google Books data in this way. I then compare the annual frequency of stems first appearing in secret patents versus nonsecret patents, by year, again truncating to stems below the 90th percentile of prepatent usage in the Google Books corpus, though the results are likewise similar for 75th, 90th, or 95th percentile truncation. I re-estimate Equation (4) on this sample.

Figure 5 presents the results. There is again no differential usage prior to 1945 of words whose stem first entered the patent record in secret or nonsecret patents, but beginning in 1945, the use of words from secret patents in this corpus discretely jumps, with a persistent difference thereafter. Moreover, no such effects are present for stems originating in patents evaluated for secrecy but not made secret (Figure D.4.2 in the online appendix). That the sharp jump in the use of technical words from secret patents occurs only after secrecy orders were rescinded in 1945 suggests the policy was indeed relatively effective at achieving its intended security objective.

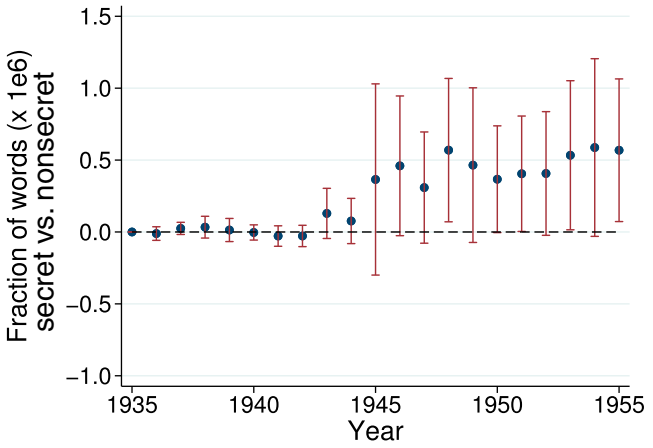
In Tables D.4.1 and D.4.2 in the online appendix, I estimate a difference-in-differences version of Equation (4), comparing stem usage in the pre- and post-1945 eras. In both tables, the dependent variable in the first three columns is annual stem frequency, and in the last three columns is the annual fraction of works in the corpus that include the stem; each individual column denotes sample truncations at assorted percentiles of prewar usage. These tables confirm the difference-in-difference estimates are statistically significant at traditional levels, and there is no such difference for stems from patents evaluated for secrecy but not ordered secret.

7. Discussion and Concluding Remarks

Bringing the collective evidence into full view, this paper shows that compulsory secrecy has myriad effects on firms and the wider innovation system, discouraging firms from inventing or filing patents in affected technology technology areas, impeding commercialization, and obstructing follow-on innovation—in the interest of protecting domestic technology from leaking to foreign competitors. Perhaps reassuringly, it appears that the intervention worked as intended with respect to security goals, though readers might also wish to consider at what cost.

Although the setting is historical, the intervention has direct modern relevance at a time when firms and governments in the United States and other Western countries are battling foreign misappropriation of intellectual property, and especially in a crisis such as a global war or pandemic. This paper highlights the tradeoffs that managers and regulators might wish to consider when compulsory secrecy is a policy option. With respect to foreign competitive threats, domestic firms and regulators may have (relatively) aligned interests and be able to work collaboratively in evaluating these tradeoffs. More broadly, managers may wish to consider mitigating measures and prepare contingencies for compulsory secrecy, including strengthening informal IP protection.

Figure 5. (Color online) Annual Use of New Word Stems from Secret vs. Nonsecret Patent Titles, Measuring Use in the Google Books Corpus



Notes. Figure shows estimated differences over time in the Google Books frequency of word stems that first appeared in the title of a secret versus nonsecret patent filed in the 1940–1945 period. Specification includes stem fixed effects, such that comparisons are within stems, over time with 1935 the omitted category. Sample censors stems at the 90th percentile of prepatent usage in the Google Books corpus, to eliminate already common language. Error bars represent 95% confidence intervals, computed from standard errors clustered at the stem level.

That said, not all firms are likely to be equally affected by compulsory secrecy. Some may even stand to benefit. Restricting information flows creates a dynamic tradeoff for an R&D-investing firm: it loses access to information about rivals that might advance its investments in innovation today, but its rivals do as well, averting competing innovation tomorrow. These restrictions might be advantageous for incumbents, who can keep earning rents from past R&D investments when innovation and entry are stymied. Similarly, the abrogation of formal IP rights may be advantageous for firms that do not rely heavily on them, and have built systems and structures to protect IP by other means—because they may not be affected by compulsory secrecy, but their rivals may be. The tensions that policies like this one present, and the incidence they have on different types of firms, are undoubtedly interesting and deserving of more attention.

The broader lesson from this historical episode pertains to the roles, and impacts, of intellectual property in the innovation system. Basic principles of both intellectual property rights and scientific openness have been enshrined in U.S. law and policy since the Patent Act of 1790 required inventors to disclose their inventions in exchange for property rights. The results of this paper illustrate what can happen when these rights and requirements are forbidden, even temporarily: patenting may decline or shift toward protected subjects, and commercial impacts and follow-on invention may be stymied. They also provide a rare window into the effects of secrecy—one of the main tools that firms use to protect innovation (Levin et al. 1987, Cohen et al. 2000). Though the example in this paper is compulsory rather than voluntary, it provides a reference point for understanding how secrecy can affect the functioning of the innovation system.

The evidence nevertheless leaves us with unresolved questions. For example, the effects of compulsory secrecy could potentially have been very different had it been in place for a longer time, or had the policy been applied throughout the war as intensively as it was at its height in 1943 (Figure 1). Understanding how the effects of patent policies vary with their duration or provisional status is an important question for future work, and is beyond the scope of this paper. The aggregate effects are also not fully known. In this case, patent classes in which secrecy orders were issued at the highest rates during the war were growing quickly both before and after the war, relative to others (see online Appendix F), suggesting the impact on aggregate invention may have been limited—but pretrends and the absence of a clean control group make conclusive inference on this front impossible, and in future applications, the aggregate impacts could be more severe.

These and other questions around compulsory and voluntary secrecy are left to future research. As it is, perhaps the biggest open question is what firms or regulators can do to combat foreign threats to intellectual property and preserve competitive positions with less collateral damage than the World War II intervention. It is not an easy question, but it is one where more research and experimentation is acutely needed, as this article brings into focus the heretofore hidden costs of existing policies and programs for securing innovation.

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Endnotes

[1] Even the legal literature is mixed, as Ouellette (2012) shows that inventors in some fields, such as nanotechnology, use patents as a source of background knowledge, even as other legal scholars find otherwise (see Ouellette 2012 for a review). Graham and Hegde (2015, p. 237) nevertheless argue that patent publication can serve to publicize an invention's "existence, quality, and scope" to competitors, investors, and potential licensees.

[2] The initial legislation prohibited the disclosure of inventions ordered secret, including via foreign filing, except with approval from the USPTO. This statute left a loophole for inventions filed in foreign countries prior to being filed at the USPTO, which were as such previously disclosed. The 1941 amendment closed this loophole by prohibiting individuals from filing any patent on U.S. inventions in foreign countries without prior consent of the USPTO, irrespective of the issuance of a secrecy order, punishable by dispossession of existing patents and permanent disbarment from filing or assisting in the filing of patents thereafter. When permits for foreign filing were granted, they were typically to file in the United Kingdom, which had an invention secrecy program of its own.

[3] Information on the administration of secrecy orders described here was compiled from Fenning (1940), Donnelly (1942), and the Office of War Information (1945).

[4] For example, of the 4,837 secrecy orders identified in OSRD records, only 311 were noted in these records as having been rescinded. Contemporary documents do indicate, however, that the WPB conducted a review in 1944 of the 1,700 applications it had recommended for secrecy, and that by September 1945, nearly all had been rescinded (Moore 1945). Of the 6,353 patents with secrecy orders observed in the data, 1,134 (17.9%) were granted before the General Rescinding Order took effect on November 30, 1945, implying that their secrecy orders were rescinded early—though it appears that the vast majority of these were rescinded that year.

[5] This was more than a theoretical possibility: Stoutenburgh (1945), for example, describes one firm (National Cash Register) that was threatened with the loss of patent rights in the United Kingdom if it did not prosecute a patent application that USPTO had ordered secret—and that the U.S. secrecy order prohibited.

[6] Although I observe only a subset (albeit a considerable majority) of secrecy orders, this undercounting only presents a risk of bias in a conservative direction due to attenuation: if the control group includes unobserved secret patents, then treatment-control differences will simply be understated.

[7] To confirm this intuition, I experimented with measuring new words in patents' full text. OCR errors cause many words that were in fact new in the 1940s to be dropped as an existing word because it appears in the full text of earlier patents due to OCR error. For example, "radar" first appears in the title of patent 3015096, "Radar counter-measure radio repeater," filed on March 30, 1942, and in the OCR full text of several patents from the 1800s, including patents on washing machines, cigar bundlers, and burglar alarms.

[8] Table C.1 in the online appendix shows unconditional average grant lags by filing year for (i) patents not evaluated for secrecy, (ii) those evaluated for secrecy but not secret, and (iii) those ordered secret. It further divides these lags into years from filing to secrecy evaluation and from secrecy evaluation to grant, where known. The increase in total pendency for secret patents is shown here to be driven by the secrecy, specifically.

[9] Reflecting the importance of information to firm innovation, many firms historically kept on-site technical libraries with books, journals, conference proceedings, and patents for their research staff to reference (NSF 1958)—resources that have since been supplanted by electronic indexing and digital libraries.

[10] Variation in filing dates combined with mass rescindment generates intent-to-treat variation in secrecy duration. Noncompliance (in the econometric sense) exists in the form of early rescindments, but as Section 2 explains, these were relatively uncommon, and most were issued in 1945, shortly before the mass rescindment, such that the effects of noncompliance are limited—as confirmed by Figure 3 and Table 3.

[11] This evidence mirrors that in Figure 3 and Figure C.1 in the online appendix, which show that secrecy delayed grant significantly for patents filed in the early 1940s, but secrecy evaluation had no such effects.

[12] The intuition behind the Oster method is to see how much the focal parameter changes between a short regression and a regression with the other right-hand side variables, and how much this increases the regression R^2, and use this information to bound any potential remaining bias that could result from selection on unobservables. This exercise requires specifying a (hypothetical) maximum R^2 that could be achieved if the specification included all observed and unobserved controls. I follow Oster's suggestion and set this to be $\min\{1.3\tilde{R}, 1\}$, where $\tilde{R}$ is the R^2 from the estimated regression (see Oster 2019, p. 189, for details).

[13] A third, more subtle limitation is that secret patents might not have been accessible or salient to patent examiners in prior art searches, through which citations are generated. However, a subset of examiners necessarily had knowledge of the prior art, since secrecy review began with the examining divisions. That secret applications were considered in interferences also suggests that this was not limiting. See online Appendix A.

[14] Williams (2013) and Sampat and Williams (2019) have also made successful inroads in studying follow-on innovation in the form of scientific research and commercial products that build on and can be directly linked back to the IP-protected innovation, especially human gene sequences.

[15] That is to say, I eliminate stems whose total number of in-text uses before their first use in a title was above the 90th percentile of all stems on this measure, treating these cases as stems already in common use.

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