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The Consequences of Invention Secrecy: Evidence from the USPTO Patent Secrecy Program in World War II

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ABSTRACT

This paper studies the effects of the USPTO's patent secrecy program in World War II, under which over 11,000 U.S. patent applications were issued secrecy orders which halted examination and prohibited inventors from disclosing their inventions or filing in foreign countries. Secrecy orders were issued most heavily in high-tech areas important to the war effort - such as radar, electronics, and synthetic materials { and nearly all rescinded at the end of the war. I find that compulsory invention secrecy reduced follow-on invention and restricted commercialization, but as part of the security policies in place during the war it appears to have been effective at keeping sensitive technology out of the public view. The results shed light on the consequences of invention secrecy, which is widely used by inventors to protect and appropriate the returns to innovation, and yield lessons for ongoing debate over potential measures to protect U.S. inventors against the growing incidence of foreign IP theft today.

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Scientific espionage, in the form of research theft and misappropriation of intellectual property by foreign adversaries, is an increasingly serious problem for U.S. firms, universities, and government agencies, and according to the FBI is "the most severe counterintelligence threat facing [the U.S.] today" (Priestap 2018).[1] As federal agencies scramble to develop a response, one of their first moves appears to be tightening information access (New York Times 2019). The policy goal is clear, as a matter of economic security. But these policies also cut against basic principles of scientific openness and communication and have prompted concerns about the effects of such restrictions on scientific progress. The increasing risk of intellectual property theft may also be increasing firms' already-strong preference for trade secrecy as a strategy for appropriating returns to innovation (Levin et al. 1987, Cohen et al. 2000). Despite the growing hunger for secrecy as a competitive and regulatory strategy, the potential consequences are poorly understood and woefully understudied, for the simple fact that secrecy is – by definition – hard to observe.

History, however, provides an opening in the form of a compulsory secrecy policy in World War II, which I study in this paper. In 1940, with war raging in Europe, the U.S. Congress authorized government agencies to issue compulsory secrecy orders to inventions in U.S. patent applications whose disclosure it deemed a potential security risk. Secrecy orders were issued widely during the war – to over 11,000 patent applications, covering inventions as diverse as radar, cryptography, and synthetic materials – prohibiting disclosure by any means and withholding the granting of any intellectual property rights. The vast majority of these secrecy orders were then abruptly rescinded at the end of the war. The scope and scale of the policy, and its abrupt conclusion, creates a rare opportunity to systematically study the effects of invention secrecy.

I show that although patents with secrecy orders were positively selected, those with longer secrecy terms were less likely to be cited by future patents, suggesting a reduction in closely-related follow-on invention – this being particularly true for patents of filers which were not government R&D contractors during the war. The effects extend to the product market, where terms from chemical patents with a secrecy order are less likely to appear in chemical company product catalogs. Yet new terms in secret patents also see limited mention in the public record until after the war ends, such that the repercussions must be evaluated against the seeming effectiveness of the policy in keeping sensitive technological content out of the public domain.

Information about new invention plays an multifaceted role in technological progress, allowing

[1]Media outlets have reported on both U.S. citizens and foreign nationals in the U.S. being prosecuted for illegally sharing proprietary research with foreign firms or governments (e.g., Wall Street Journal 2018, 2019), including by academic scientists participating in peer review of grant applications, sparking far-reaching investigations by the FBI and fanning fears that foreign governments are "exploiting the relative openness of the American scientific system to engage in wholesale economic espionage" (New York Times 2019).

inventors to build on prior art, delineating property rights, and enabling others to produce and sell the invention when intellectual property rights expire. For these reasons, invention disclosure has been a policy objective in the U.S. since the Patent Act of 1790, which required inventors filing for a patent to include a replicable specification of their invention so that "the public may have [its] full benefit." U.S. science policy agencies are likewise tasked with promoting scientific communication for similar reasons. U.S. invention secrecy policy defies these goals and has roots in a law enacted in October 1917, near the end of World War I, which authorized the USPTO to order that inventions in patent applications be kept secret, and withhold the grant of a patent, whenever its "publication or disclosure" may "endanger the successful prosecution of the war."

In 1940, in anticipation of entry into the war, the U.S. Congress renewed this legislation, and from July 1940 to August 1945, the USPTO ordered thousands of patent applications into secrecy. I combine several sources of data to study the effects of this program, beginning with the universe of patents granted between 1920 and 1979 and the network of patent citations among them. Using the archival records of government agencies which reviewed patent applications and advised the USPTO on the issuance of secrecy orders, I identify the serial numbers of roughly 8,500 patent applications issued secrecy orders during World War II, and an additional 20,000 which were formally evaluated for secrecy but disapproved, which in turn link to 6,352 granted patents with secrecy orders, and 13,151 more which were reviewed but not ordered secret. The technology areas in which secrecy orders were heavily issued reflected the priorities of the war effort, and at the height of the war, more than half of all new patents in these classes were "going dark".

The first question this paper tackles is whether secrecy impeded follow-on. However, because secrecy is a selected condition, a simple comparison between secret and non-secret patents is problematic. I instead estimate the effects of secrecy off of the intensive margin (duration), comparing forward citations of secret and non-secret patents filed earlier versus later in the war, which experienced longer or shorter secrecy terms (respectively) as a result of the mass rescindment in late 1945. I show that patents with shorter secrecy are subsequently more likely to be cited than patents with longer secrecy, particularly patents filed by firms and individuals who were not contracting with the government to provide R&D for the war effort. In robustness checks, I show that these patterns are (i) a result of secrecy itself, as there are no differences for patents which were evaluated for secrecy but not ordered secret; (ii) unlikely to be a result of differential selection into secrecy over time; and (iii) driven by non-self citations, with no effects for self-citations – collectively suggesting causality. The point estimates indicate that a secret patent filed in 1945 on average has a 15% higher probability of being cited than a secret patent filed in 1940.

Although patent citations are the traditional measure of follow-on invention used with patent data (e.g., Jaffe et al. 1993) – most literally, inventions closely-related enough to be compared during patent examination – they also have important limitations (e.g., Alcacer et al. 2009, Bryan et al. 2018). The most important limitation (for this paper) is that the public citation record only begins in 1947, which is when the USPTO began requiring that the patent document include references to prior art. As an alternative, I develop a content-based measure of follow-on proposed by Iaria et al. (2018): I identify word stems which first appeared in the title of patents filed between 1940 and 1945, as a proxy for new ideas which entered the patent record in this period, and treat the use of these words in future patents as an alternate measure of "citations" not subject to the 1947 constraint, comprising a smaller sample but yielding similar results.

Compulsory secrecy may have also impeded commercialization by forcing firms to keep inventions out of the product market when the product risks disclosure. This constraint would be particularly binding in industries where an invention often *is* the product, such as the chemical industry. To evaluate this question, I identify new words and stems in chemical patents filed 1940-1945 and look for these words in DuPont chemical product catalogs before, during, and after the war. The evidence suggests that secrecy indeed interfered with commercialization: words which first appeared in secret patents were significantly less likely to be included in the product catalog during and immediately after the war (most were not), but the effects vanish by 1949.

The final test of the paper is whether secrecy orders were ultimately effective at keeping invention secret. I return to word stems from titles of war-era patents and look for the use of these words in the Google Books corpus around the time of the war, using Google's N-grams data, which provide an approximate measure of the public discourse. Words which first entered the patent record in secret versus non-secret patents were not used at differential rates prior to 1945, but after the war, use of words from secret patents discretely, permanently jumps.

Collectively, these results yield lessons on the consequences of invention secrecy. Previous research in this area has focused primarily on inventors' choice between patenting and trade secrecy, with a mix of theoretical papers, surveys, and empirical analysis studying the characteristics of – and conditions under which – inventors opt for patents versus trade secrecy to protect IP.[2] With the exception of recent work on the effects of changes in the strength of trade secrecy laws on publicly-listed firms' R&D (Png 2017a) and the intensity of patenting in process versus product innovation (Ganglmair and Reimers 2019), there is little research on the impacts of invention secrecy beyond

[2]See Hall et al. (2014) for a review. The theoretical literature includes Anton and Yao (2004), Kultti et al. (2007); surveys: Levin et al. (1987), Cohen et al. (2000), Arundel and Kabla (1998), Arundel (2001); empirical analysis: Moser (2005, 2012), Fontana et al. (2013), Png (2017b), Ganglmair and Reimers (2019).

the private returns to the inventor choosing its IP strategy.

This paper also connects to a growing literature on patents' disclosure function, which has examined the effects of increasing access to patent publications through the USPTO's Patent and Trademark Depository Library network (Furman et al. 2018) and of recent policy changes which accelerated the publication of U.S. patent applications (e.g., Hegde et al. 2018, Hegde and Luo 2017). 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 applicants are incentivized not only to obscure the specification of inventions in the patent, but also to avoid reading patents at all. Contemporary evidence from the 1940s is thin, but two later reports from the National Science Foundation and National Academy of Sciences (NSF 1958, NAS 1969) suggest that patent documents were not in and of themselves a major source of technical information at that time.[3] Moreover, because the invention secrecy policy studied in this paper is broader than the suppression of patent publication alone, extending to all channels of communication, these concerns are less relevant to this paper.

The two World Wars have served as laboratories for many other questions about innovation (e.g., Moser and Voena 2012, Biasi and Moser 2018). Iaria et al. (2018) is perhaps the most closely related work, as they study the effect of a disruption in scientific communication in the form of a boycott of Central powers' scientists during and after World War I, and show that this boycott led to a reduction in citations of foreign publications, the similarity of paper titles, and the production of basic science. This paper adds a new dimension to this literature, focusing on the consequences of a sweeping patent secrecy program affecting firms in inventive sector.

The historical setting bears implications for the present. Secrecy orders continue to be issued today under the Invention Secrecy Act of 1951, albeit at lower frequency than in the 1940s, and Freedom of Information Act (FOIA) requests by the Federation of American Scientists (FAS) have revealed 5,792 secrecy orders in effect as of 2018 (FAS 2018). Although rare, the impact of a secrecy order on filers can be severe (AUECO 2019). Moreover, with U.S. firms, policymakers, and law enforcement agencies increasingly alarmed at intellectual property (IP) theft by foreign competitors and governments, interest in both regulatory action and *voluntary* trade secrecy is only intensifying.[4]

[3] These sources do document that many R&D-intensive firms had technical libraries with books, journals, conference proceedings, and patents and weekly editions of USPTO Official Gazette, so in many cases, patents were available to be read (or ordered) as needed. However, according to NAS (1969), "of the communication that is used by each researcher as an inspiration and as a data flow that makes his own work possible, some 80 percent [comes] from other researchers at a stage before formal communication, through informal channels of the grapevine, the conference, the seminar, the preprint, and the other tentacles of... the Invisible College."

[4] Anecdotally, R&D-intensive firms such as SpaceX have publicly discussed their avoidance of patenting because

Thus far, the effort to combat industrial espionage has mostly been limited to law enforcement (criminal prosecution), and the question remains of how regulators are going to get ahead of the problem. Further restrictions on information access, and even an expansion of compulsory secrecy, are options that have entered policy debates (USPTO 2012, NIH 2019).

The paper proceeds as follows. Section 1 describes the wartime patent secrecy policy, the context in which it arose, and its legacy today. Section 2 introduces the data, and Section 3 summarizes the empirical characteristics of the secrecy order program. Section 4 estimates the effects of secrecy orders on follow-on invention, using both citation- and content-based measures, and discusses two channels that might explain these results. Section 5 studies the effects of secrecy orders on commercialization of invention. Section 6 then asks whether the program was ultimately effective. Section 7 concludes by discussing alternative views on the importance of these findings and remaining questions for research on modern invention secrecy strategies.

1 Historical Background

Although the U.S. did not enter World War II until December 1941, preparations for war began in 1940. Among them was legislation enacted by the U.S. Congress to renew an invention secrecy policy established near the end of World War I, which had empowered the USPTO to issue secrecy orders on patent applications with content deemed sensitive for national security, but which had lapsed with cessation of hostilities. The decision to revive this policy was shrewd, if not clairvoyant, as the outcome of World War II later hinged on relative advantages in technology, powered by a massive, domestic applied research effort (Gross and Sampat 2019), and keeping U.S. technology out of enemy hands was crucial to the success of the U.S. war effort.

Public Law 700 of the 76th Congress (henceforth P.L. 700), enacted July 1, 1940, authorized the 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 U.S. government for its use, and later sue for compensation after the patent is granted if the invention was used.[5] Violations were initially punishable by abandonment of the application

"Chinese competitors would just use [SpaceX patents] as a recipe book" (Business Insider 2012).

[5]The importance of the statute's provision for the tender of inventions lay in the fact that patent applications at the USPTO were treated as private property and could not be disclosed to other parties, including government agencies, without the consent of the filer. Even technical experts evaluating patent applications for secrecy on behalf of the War Department and other agencies were sworn to not divulge any information they may acquire in doing so. As a result, without tender, "it was possible that an invention of importance would rest in the Patent Office unexploited

(i.e., loss of patent rights), but follow-up legislation on August 21, 1941 (77th Congress, P.L. 239) threatened up to two years in prison and a fine of up to $10,000.[6] In 1942, the policy was further amended to remain in force for as long as the U.S. was at war.

To implement P.L. 700, the USPTO immediately created a new internal office named the Patent Office Defense Committee (which later evolved into the Patent Office War Division, or POWD) on July 9, 1940 to handle secrecy evaluations (Donnelly 1942).[7] 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 applications for inventions which in their opinion "discloses a matter related to the national defense" to the POWD (OSRD Administrative Circular 10: Patents, April 27, 1944). At the POWD, representatives of 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) – reviewed these applications and made recommendations for the issuance of secrecy orders. Appendix A shows examples of secrecy determination forms that would accompany each application and which circulated among the evaluators with a possible interest in the invention. As soon as any of these reviewers recommended secrecy, a secrecy order would be issued and patent examination indefinitely suspended for as long as the secrecy order was in place. The applicant would then be sent a standardized notification letter explaining that a secrecy order has been issued, instructing the inventor not to disclose the invention without the permission of the USPTO at risk of a fine, jail time, and forfeiture of the patent, suggesting that the inventor tender his or her invention to the government, and offering no means for appeal, as there was none at the time (example notification letters are shown in Appendix B). Upon enactment of P.L. 700, the USPTO commenced the secrecy order program by reviewing recently-allowed patents which 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

by the inventor and unavailable to interested agencies" (JAG 1945). Although many inventions were so tendered, there are only a handful of examples of claims for ex-post compensation by inventors who did so, and only a fraction of these concluded in a favorable outcome for the inventor (U.S. Congress 1980).

[6] 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 U.K., which had an invention secrecy program of its own.

[7] Information on the administration of secrecy orders described here compiled from Fenning (1940), Donnelly (1942), OSRD (1944), JAG (1945), U.S. Government Manual (1945).

(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 re-circulated to reviewers from the other three agencies, who then had to concur in the rescission for the secrecy order to be lifted – a process which 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.[8]

On August 30, 1945 – after the end of hostilities in Europe, and shortly before the end in the Pacific theatre – a recently-appointed new Patent Commissioner (Ooms) organized an inter-agency meeting to discuss the "expedited removal" of outstanding secrecy orders (Moore 1945). When representatives from the War Department raised concerns about a subset of cases which they wished to remain secret, the participants agreed to a 90-day grace period in which these advisory agencies could compile a list of those patents which 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, excepting applications which the recommending agencies requested be kept secret.

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.

Secrecy orders issued by year, July 1940 to June 1945

	Secrecy orders issued	Inventions tendered
Jul-40 to Dec-41	918	95
1942	2,611	555
1943	3,508	1,966
1944	3,165	2,143
Jan-45 to Mar-45	613	319
Apr-45 to Jun-45	367	unknown
Total	11,182	5,078

[8]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 which it had recommended for secrecy, and that by September 1945, nearly all had been rescinded (Moore 1945). Of the 6,352 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.

Post-war invention secrecy policy

By December 31, 1945, there were less than 800 outstanding secrecy orders, with most being on inventions related to atomic energy research (JAG 1945, U.S. Congress 1980). Although the war had ended, the wartime secrecy order program remained in effect, as the national emergency declared by Congress was not terminated until 1952. In the intervening years, the number of outstanding secrecy orders grew to nearly 2,400 (Lee 1997), as secrecy orders continued to be issued on inventions considered a security risk – especially those related to nuclear energy.

In 1951, Congress converted the wartime invention secrecy policy to a peacetime policy with the enactment of the Invention Secrecy Act of 1951. Although the restrictions and penalties remained the same, the Invention Secrecy Act made a few key departures from P.L. 700 and its subsequent amendments, the most notable being fixed, one-year terms subject to renewal by the requesting agency, which at least nominally subjected outstanding secrecy orders to annual review, and a provision granting inventors the right to appeal a secrecy determination. Secrecy orders continue to be issued under the authority of this legislation today, albeit at much lower frequency than during World War II: between 2005 and 2015, the USPTO issued just 1,171 secrecy orders, out of a total of nearly 5.8 million applications filed (FAS 2018).

Concerns about adverse effects of an invention secrecy policy

Though the benefits of secrecy orders were undisputed in a time of war, contemporaries also raised concerns about adverse consequences. Fenning (1940), for example, writes in the *Journal of the Patent Office Society* about the potential for secrecy orders to "prevent disclosure of applications to interfering parties and [thus] decision of interferences." Vannevar Bush noted that OSRD contractors were uneasy about the possibility that "foreign companies would be able to enter the world commercial market... in the lead of the U.S. manufacturers" when U.S. firms' patent applications were held up by secrecy orders (Stoutenburgh 1945). Even those in charge of administering the program had hesitations: in a discussion about the possibility of a peace-time invention secrecy policy at the August 30, 1945 meeting, participants raised several objections, including that it would delay the utilization of invention, drive invention underground and slow technological progress, and preclude civilian users from being able to access and work out the "bugs" in inventions with both civilian and military value "so that when the military forces need them [they] can quickly be added to war uses" – with radio and radar being given as examples (Moore 1945).

The full range of concerns was recently on display after a USPTO request for comments in 2012 on

the feasibility of placing "economically significant" patents under secrecy order (Federal Register 2012), issued at the behest of Congress. Respondents included several organizations with an interest in such a policy, such as the American Bar Association (ABA), American Intellectual Property Law Association (AIPLA), and the Intellectual Property Owners Association (IPOA). Their concerns included (i) undermining the public notice function of patents and depriving inventors of technical information, at the risk of "stifling innovation" (IPOA 2012); (ii) precluding commercialization of inventions which are readily ascertained by observation or reverse-engineering (AIPLA 2012); (iii) driving R&D underground or overseas, away from the U.S. patent system (IPOA 2012); or even (iv) discouraging invention altogether (IPOA 2012, ABA 2012). These concerns would have applied in the 1940s as well – (i) and (ii) are both a focus of this paper – though it appears they were treated by policymakers as second-order issues against the backdrop of war.

2 Data

To study the effects of the secrecy order program, I combine several sources of data, beginning with a 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 lists the universe of granted patents and their grant dates, patent class (USPC), and 2-digit 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 the Clarivate Derwent Innovation (previously Thomson Innovation) patent research database.

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 (i.e., assignees which were performing R&D for the war effort) and non-contractors, which were identified from the archival records of the OSRD. Concurrent with these efforts, I also identify all patents associated with the Manhattan Project research program and exclude them from the analysis below, as both the narrative history and the data suggest that these patents were not only secret, but also exempted from the 1945 rescinding order.[9] Appendix A

[9]The list of Manhattan Project patents was retrieved from from the Wilson Center's Digital Archive, and originally collected through a Department of Energy FOIA (see Appendix A). Interestingly, almost none of these patents appear in other archival data sources for secrecy orders, but the sensitive (top-secret) nature of the research, as well as the exceptionally long grant lags observed in the data, imply that these patent applications were secret both during and after the war. The decision to exclude these patents from the analysis is further motivated by the fact that nuclear energy patenting at this time was fundamentally different than other patenting, with primarily military or government-sanctioned civilian activity on top of the security restrictions.

describes in more detail how these data were prepared, as well as additional steps taken to improve the quality of the data on serials, filing dates, and assignee names.

I use archival records from three agencies – the OSRD, the Office of Production Research and Development (OPRD), and the U.S. Army Judge Advocate General (JAG) – to identify patent applications issued secrecy orders. Collectively, these records identified 8,475 serials which were ordered secret during the war (roughly 75% of the likely true total of ≈11,200), of which 6,352 (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).[10] The OSRD and OPRD records also identify nearly 20,000 patent applications which 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 which were ordered secret.

In addition to numeric data on patents and citations, this paper also uses information from patents' textual content.[11] I obtain from Google the title 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 invoked in this paper as a measure of "new concepts" which entered the patent record during World War II (an approach pioneered by Iaria et al. 2018), whose diffusion can be traced both within the patent record and beyond it, using other sources of data such as books and product catalogs (which I describe in Section 5). 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 throughout the period studied in this paper with minimal transcription error (whereas full text OCR errors are pervasive, and the cost of manual transcription is prohibitive). The main tradeoff visà-vis improved measurement using patent titles is sample size (a smaller number of words), and in turn statistical power.[12]

[10] Although we only observe 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).

[11] Appendix A discusses the inner workings of these data and methods in detail.

[12] In unreported analysis, I have also identified and measured the usage of new words in patents' full text. The high error rate in the OCR full text, however, results in both over- and undercounting of word usage, and a long tail of non-word "words" that only appear once or twice in the corpus. It also causes many words which were in fact new in the 1940s to be dropped as an "existing" word because it appeared in the full text of earlier patents due to OCR error. For example, the string "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 bundling machines, and burglar alarms.

Patent citations as a measure of follow-on invention

Forward patent citations will be used throughout Section 4 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 just references to the relevant prior art. As Appendix A shows, prior art references have been a part of the patent examination process since before the USPTO began requiring that published patents list these references on the final (now, front) page. In the course of patent examination, examiners make reference to prior art which they have used to evaluate the novelty of the applicant's claims, and in 1947, the 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 (if not entirely) by patent examiners. As such, citations identify *closely-related* invention, not information flows or direct inputs per se – but this is enough to measure *de facto* follow-on invention and serves the purpose of this paper.

Given the historical data-generating process, many of the concerns about what citations measure in the modern period (e.g., Alcacer 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 all) of the citations in these data will be examiner-added is also potentially important, and discussed at more length in 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 Characteristics of Secrecy Orders

To better understand the potential impacts of the secrecy order program and contextualize results throughout the paper, it is useful to begin with a descriptive overview of patenting in the 1940s and the characteristics of patents with secrecy orders. Figure 1 presents the time series of monthly patent applications at the USPTO from the late 1930s to the early 1950s (in blue, measured by left axis), as well as monthly applications issued secrecy orders (in red, 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.

[Figure 1 about here]

Figure 2 shows the distribution of patenting and secrecy orders across one-digit NBER patent categories (Hall et al. 2001) during the wartime period. Although aggregate patenting declined during the war, its distribution across technology areas was relatively stable (Figure 2, Panel A). The distribution of secrecy orders, on the other hand, varied significantly over the course of the war, shifting from chemical patent classes in 1939/1940 to classes related to communications and electronics by 1945 (Panel B), reflecting the growing importance of radar and electronics to the war effort. These were also the technology areas most intensively affected by the secrecy order program as a fraction of annual patent applications (Panel C).

[Figure 2 about here]

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 ten classes by the fraction of applications between 1939 and 1945 issued a secrecy order; among these are classes related to radar, synthetic rubber, and catalytic cracking (for fuel production), all of which are technologies of both military and commercial value. At the height of the war, in 1942-1943, roughly half of filings in these classes were being ordered secret.

[Table 1 about here]

Even within classes, secrecy orders were inevitably not randomly issued: the historical record suggests that patent applications were evaluated carefully and in good faith, out of a concern for interfering with the usual functioning of intellectual property rights (Moore 1945), with more-sensitive and important inventions being the focus of the program. As a simple 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. Here and throughout Section 4, I condition on fixed effects for each patent's (i) primary class and filing year (for within-cohort comparisons) and (ii) grant year (to account for the fact that patents only become "citeable" once they are granted). The estimating equation for Table 2 is thus:

$$\mathrm{Y}_{ictg} = \beta_1 \cdot \mathbb{1}(\text{Secret})_i + \beta_2 \cdot \mathbb{1}(\text{Evaluated})_i + \alpha_{ct} + \gamma_g + \varepsilon_i \tag{1}$$

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), $\mathbb{1}(\text{Secret})_i$ indicates that patent i was ordered secret,

$\mathbb{1}(\text{Evaluated})_i$ 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 which were not. Patents with a secrecy order were cited even more, on average receiving more than 1.5x as many citations as the typical patent from the same class and year (+2.6 citations on an average of 4.6).

[Table 2 about here]

Immediate effect: Delayed grant and publication

Recall that the immediate effect of a secrecy order was to suspend examination and prohibit the filer from unauthorized invention disclosure for as long as the secrecy order was in effect. Although secrecy orders were sometimes rescinded early, the majority remained in place until the GRO took effect in late 1945. As a result, patents with a secrecy order filed early on in the war should have on average taken more time to grant than those filed near its end.

To verify that secrecy orders generated the predicted effect on pendency, Table 3 estimates the incremental grant lag (years from filing to grant) of patents filed each year 1939 and 1945 with a secrecy order, relative to others in the same primary class and year:

$$\text{Grant Lag}_{ict} = \beta_{1t} \cdot \mathbb{1}(\text{Secret})_i + \alpha_{ct} + \varepsilon_i \tag{2}$$

The effect of secrecy on time-to-grant is large early in the war – on average around 2.5 extra years for 1940 and 1941 applications, doubling the mean – and not significantly different from zero by 1945. Note that although the table includes 1939 filings for completeness, as many were ordered secret, patents filed in 1939 which received a secrecy order were necessarily still pending as of the enactment of P.L. 700 in July 1940, and their longer grant lags are thus in part selected – for this reason, later tables will focus on the July 1940 to June 1945 period.

[Table 3 about here]

Figure 3 shows the full distribution of grant lags for secret patents shifting down monotonically over time to match that of their non-secret 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 (Appendix Figure C.1), suggesting it was the secrecy order, rather than the evaluation, generating these delays.

[Figure 3 about here]

4 Invention Secrecy and Follow-on Invention

As we have already seen, simple comparisons between secret and non-secret patents' citations can be problematic because secrecy orders (and evaluations) were positively selected (Table 2). The empirical strategy I use to study follow-on invention will instead be to compare the outcomes of secret and non-secret patents *filed earlier versus later in the war*. Variation in filing dates in turn generates intent-to-treat variation in the duration of secrecy, due to the mass rescindment in late 1945.[13] I thus compare patents which were secret for a shorter versus longer time, differencing both against contemporaries in the same patent class and filing year. The initial sample for this analysis will be all patents filed between July 1, 1940, when P.L. 700 was enacted, and June 30, 1945, when the secrecy order program was mostly concluded. Restricting the sample to patents filed after July 1, 1940 causes us to lose some earlier filings which were still pending as of that date and were subsequently ordered secret, but because these are already selected on longer examination, I choose to focus on patents filed when P.L. 700 was in place and being actively applied.

Throughout this section, I estimate variants of the following specification via OLS:

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

where β_{1t} and β_{2t} are estimated by filing year and the other variables are defined as before. Y_{ictg} will alternately be (i) whether the patent was ever cited, (ii) whether the patent reached particular citation thresholds, or (iii) citation counts, estimated with a count model (each measured through 1979, by which point most patents will have realized the majority of their eventual citations, e.g. Hall et al. 2001). I estimate separate effects by filing year to enable comparisons between secret and non-secret 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

[13] Noncompliance (in the econometric sense) exists in the form of early rescindments, but as Section 1 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.

and their non-secret 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.

With this specification, contemporaneous trends in U.S. invention (e.g., the immigrant inventor effects documented by Moser et al. 2014), will be controlled for by the class-year fixed effects. But a remaining threat to this approach is the possibility of time-varying selection into secrecy, which could confound or even explain the results: if evaluators applied more stringent standards later in the war than earlier in the war, then what appears to be an effect of a shorter secrecy term may just be positive selection. The controls for whether each patent was evaluated for secrecy can partially address this concern, by either accounting for differential selection into evaluation or showing that there are no such patterns in the data. To more thoroughly tackle this possibility, I run robustness checks controlling for a series of patent- and assignee-level characteristics. As a placebo test, I also separately estimate Equation 3 for non-self citations and self citations, as secrecy should only affect the former, whereas selection will likely 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, and the measures will undercount follow-on 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). All else equal, the truncation of the citation record will more severely affect earlier applications (which have more years of "missing" citations) than later applications, but it should affect secret and non-secret patents of the same class and vintage in a similar way, such that the class-year fixed effects will account for these differences.

Forward citations

In the first column of Table 4, I estimate the probability of any forward citations for the full July 1940 to June 1945 sample. There are no clear differences in the likelihood that earlier or later secret patents are subsequently cited – and based on this evidence, one might be tempted to conclude either that invention secrecy did not have a meaningful effect on forward citations, or that the comparisons are muddied by other confounding patterns.

[Table 4 about here]

The latter concern may in fact have merit. This period was a time of national emergency: the U.S. economy and population were mobilized for a major war, with the Federal government contracting

with firms and universities around the country to supply the war effort, including supplying R&D on war-related technology – an effort led by the OSRD. In these circumstances, firms contributing to the scientific war effort may have been permitted to share information on otherwise-secret invention to further contract work. Contemporary records suggests this was the case in at least some industries: in his minutes from the August 1945 inter-agency meeting to discuss secrecy order rescindment, Moore (1945) quotes a representative of the Petroleum Administration for War who "pointed out that secrecy orders strictly interpreted would have hampered the petroleum industry enormously in its war effort, so they had worked out a system of general permits for the exchange of information." A similar pool was created in the synthetic rubber industry (Herbert and Bisio 1985, Morris 1989). This could well be true for other industries too.

In the next two columns I use data on the identities of OSRD contractors to split the sample into patents without versus with an OSRD contractor assignee, where a different pattern emerges. Non-OSRD contractor patents filed early in the war are significantly less likely than contemporaries to later be cited as prior art, but this effect reverses for later filings, with the effect approximately monotonic in the filing year; the point estimates suggest that patents with shorter secrecy terms (filed in 1945) are nearly 15% more likely to later be cited than those with longer secrecy terms (filed in 1940), with differences significant beyond the 5% level. 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 the secrecy condition itself. In contrast, there was no empirically-detectable effect of secrecy orders on inventions by OSRD contractors. The final two columns of the table show results from a triple-differences variant of Equation 3, where the focal variables ($\mathbb{1}(\text{Secret})_i$ and $\mathbb{1}(\text{Evaluated})_i$) are included alone and interacted with an indicator for patents of OSRD contractors, but where fixed effects can be estimated off of the pooled sample. The effects of secrecy orders manifest for patents from assignees who were not involved in the war effort, but these effects are eliminated for OSRD contractors.

In Table 5 I explore the robustness of these patterns to a variety of controls. Column (1) reproduces the result from Table 4 for non-OSRD contractors. Column (2) then controls for other observable patent characteristics, with fixed effects for the number of inventors and length of the patent (number of pages, number of drawings), which correlate with citations. Column (3) controls for other assignee characteristics, with fixed effects for firms and individuals, and fixed effects for the assignee's pre-war 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 specifications, the empirical patterns

are unchanged – although standard errors increase in Column (5), due to the more limited within variation available for estimating the focal parameters.

[Table 5 about here]

Appendix D presents additional results. Tables D.1 and D.2 reproduce the regressions in Table 4, first excluding secret patents which 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 separately estimates the effects for non-self and self citations, and citations from firms versus individuals, where we see that the results are driven by non-self citations, with no statistically discernable effects for self citations, and likewise by citations from firms rather than individuals.

Appendix Tables D.4 studies effects on forward citation levels, first in the form of indicators for different citation thresholds, which can be estimated via OLS with multi-level fixed effects (Columns 1 to 6) without the threat of an incidental parameters problem and is thus the preferred approach, and then for citation counts, estimated as a conditional fixed-effects Poisson with only filing year and grant year fixed effects, reported as incidence rate ratios (Column 7). 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 for patents of non-OSRD contractors, secret patents filed in 1945 receive roughly 1.65x as many citations as those filed in 1940, after controlling for cohort differences, and that this effect varies inversely with the duration of secrecy.

Alternative measure: Diffusion of new words

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

As a workaround, I therefore develop a content-based measure of follow-on invention, which can be constructed for patents throughout this period. The focus here will be new word stems in the

titles of patents filed between 1940 and 1945, as a measure of new ideas which entered the patent record during the war (see Section 2). We can then compare subsequent usage of stems which first entered the patent record in secret versus non-secret patents, as a measure of inventions which incorporate new ideas embodied in these patents – similar to the approach taken in 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 these words in patents.[14]

In preparing the data, I take the 1,129 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 which originated in secret patents against the remainder which did not. Comparisons in levels remain difficult, due to positive selection: new stems from secret patents are subsequently used more than their non-secret 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 6 for the 548 word stems which 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.

[Table 6 about here]

The results are similar to those in Tables 4 and 5. 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, although in this case the estimates are substantially noisier.

Mechanisms: Temporarily veiled or permanently forgotten?

The results invite the question of why temporary invention secrecy (of at most five years) would affect long-run citations. One possibility is that the results could be driven by a "lost generation"

[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 which build on and can be directly linked back to the IP-protected innovation, especially human gene sequences.

of follow-on invention that might have been produced in the 1940s had information not been suppressed. An alternative with perhaps more serious welfare implications is that these inventions were permanently forgotten. To try to understand which of these two mechanisms might be driving the results, in Appendix Table D.5 I estimate analogous regressions for the probability of being cited in subsequent cohorts of inventions, focusing on patents filed between 2 and 25 years later, to explore whether the differences between patents with shorter and longer secrecy terms in Tables 4 and 5 emerge over the short run or long run. The results provide suggestive evidence for a "lost generation" mechanism, rather than permanently forgotten: patents with shorter secrecy terms are more likely to be cited by patents filed 3-4 years later than are those with longer secrecy terms, but these differences fade when it comes to citations from later filings.

5 Effects on Commercialization

Secrecy orders prohibited the inventor from disclosing "the invention or any hitherto unpublished details" of the invention (Appendix B). Contemporary sources (including statute) are unclear on whether this restriction would have impeded the commercial use or sale of the invention, particularly when the invention is a component or a method of manufacture that would not be easily detected or reverse-engineered. However, in the case of inventions which are themselves final goods, such as drugs and specialty chemicals, this restriction could have conceivably interfered with commercialization and kept new inventions out of the product market.

The most accessible setting for testing this question is in the specialty chemicals industry. Much as they do now, large chemical manufacturers in the 1940s circulated product catalogs which listed their commercially available products and where we can search for chemical terms from the titles of patents which were subjected to secrecy orders. Although many such catalogs have likely not been preserved, several editions of the Du Pont Products Index (DPPI) are available from the Du Pont collection at the Hagley Museum. For the purposes of this paper, I extracted the text of five editions – 1938, 1944, 1946, 1949, and 1955-56 – to be used below.[15]

To build a sample of words to search for in these catalogs, I began with the set of words whose stems first entered the patent record in the title of a patent filed in the 1940 to 1945 period (as before) *and* was classified in a chemical patent class (according to the NBER classification system

[15]The Du Pont Products Index was the only major chemical manufacturer catalog from the 1940s that could be located (others company catalogs searched for included Dow Chemical and American Cyanamid). Du Pont was also the firm with (i) the most patents and (ii) the most secret patents in chemical classes in the 1940s. These editions were chosen to enable a search for keywords in the pre-war, mid-war, and short- and long-run post-war periods, but the Hagley collection includes many more volumes, spanning the 1910s to the 1980s.

of Hall et al. 2001). I then manually reviewed these words to identify those which were chemical compounds or processes – yielding a sample of 633 "chemical words" and 542 unique stems – and programmatically searched for these words and stems in each edition of the DPPI. The test is then to see whether the stems from secret versus non-secret patent titles were differentially likely to appear in each edition of the catalog.[16] Specifically, I regress an indicator for a stem's presence in the given edition of the DPPI on indicators for whether the stem originated in a patent which was issued a secrecy order or evaluated for secrecy, as follows:

$$\mathbb{1}(\text{Word is in DPPI})_i = \beta_1 \cdot \mathbb{1}(\text{Secret})_i + \beta_2 \cdot \mathbb{1}(\text{Evaluated})_i + \alpha + \varepsilon_i \tag{4}$$

where i indexes stems, and α is a constant (for stems from non-secret, non-evaluated patents). Table 7 shows the results: stems which 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 which first appeared in a patent which was evaluated for secrecy but not ordered secret. When compared against the baseline rate of ≈10% of non-evaluated stems appearing in the catalog, the effect size indicates that almost none of the words with stems from secret patents show up in 1944 and 1946. Results are similar for a sample of the full words themselves, rather than stems, when testing for the presence of each of these words in the DPPI volumes.

[Table 7 about here]

These results could reflect different underlying phenomena: they could be due to suppression of new Du Pont inventions from the product market; a reduction in Du Pont's licensing and sale of third party inventions; a reduction in Du Pont products using technology first introduced in third party inventions which are not yet disclosed; or even just concealing language. Distinguishing these channels is difficult, not only due to measurement challenges but also due to the sample size. In unreported results I split Table 7 into stems originating in the titles of Du Pont patents versus other patents, and find that the results are driven by the words from non-Du Pont patents, but the Du Pont-only sample is too small (with $N = 72$ stems, only 12 of which first appeared in the title of secret patents) to draw strong conclusions.[17]

[16] Note that whereas the specification in Section 4 leveraged intensive variation in the duration of secrecy, the regressions here and in the next section test whether secrecy orders were in fact binding for non-patent, *contemporary* outcomes during the war, for which the duration of secrecy is not material. Secrecy orders could potentially also be positively selected with respect to these outcomes, but this selection only risks biasing estimated effects upwards (i.e., in the more conservative direction, for negative effects), and should also manifest in patents evaluated for secrecy but not ordered secret, which provides a natural placebo below.

[17] Another natural question is whether the unavoidably noisy nature of the optical character recognition used to

6 Were secrecy orders effective at preventing disclosure?

Whether or not the consequences of the secrecy order program on invention were understood at the time, the original intent behind the policy was to prevent the disclosure of subject matter which might be "detrimental to the public safety or defense," as stated in the text of P.L. 700 and secrecy order notification letters (Appendix B). Other security measures were also in place during the war, including the traditional security classification for government and government-funded activities. But the question remains: as part of the broader security apparatus, were secrecy orders effective at keeping sensitive new technology out of the public's view?

To answer this question, I turn to the Google Books corpus as a data source which can measure the broader use (beyond the inventive sector) of new words whose stem first appeared in secret versus non-secret patents. Google makes available for download data on the annual usage of individual words and phrases (N-grams) in the books that have been scanned into the Google Books corpus as of 2012. For this exercise, I retrieved the annual usage of words with stems which entered the patent record in the title of a patent filed in the 1940 to 1945 period (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. 1,050 (93% of the original 1,129) stems from patent titles match to the Google Books data in this way. I then compare the annual frequency of stems first appearing in secret patents versus non-secret patents, by year, truncating to stems below the 90th percentile of pre-patent usage (in levels) in the Google Books corpus so as to eliminate already-common language – although the results below are similar for 75th, 90th, or 95th percentile truncation. Specifically, I run the following regression on a sample of 945 unique stems from 1935 to 1955, where i indexes stems and t indexes years, and standard errors are clustered by stem:

$$\text{Pct. of corpus}_{it} = \sum_{t=1936}^{1955} \beta_{1t} \cdot \mathbb{1}(\text{Secret})_i + \sum_{t=1936}^{1955} \beta_{2t} \cdot \mathbb{1}(\text{Evaluated})_i + \alpha_i + \delta_t + \varepsilon_{it} \tag{5}$$

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 non-secret patents, but that beginning in 1945, the use of words from secret patents in this broader literature discretely jumps, with the difference

extract text from the DPPI catalogs might be interfering with these results. Although the best available commercial software (ABBYY FineReader 14) was used for the OCR, its output is imperfect. The analysis described above was repeated with fuzzy matching to the DPPI catalogs, allowing matches with a Levenshtein edit distance of up to one character – though it is not obvious that this is an improvement, given that one character differences can represent distinct molecular structures (e.g., octane versus octene). The results with fuzzy matching are similar to those in Table 7 for the sample of words, but the effects fade for the sample of stems.

persistent through at least 195.[18] Though not presented here, no such differences are present for stems originating in patents evaluated for secrecy but not made secret (the β_{2t} parameters), which are precisely-estimated zeros. The sharp jump in 1945 in the use of technical words with stems from secret patents around the time that the secrecy orders were rescinded suggests the policy was indeed effective at achieving the intended objective.

[Figure 4 about here]

In Table 8 I estimate a difference-in-differences version of Equation 5, comparing usage in the pre- and post-1945 eras. The dependent variable in the first three columns is annual stem frequency (as before), and in the last three columns is the annual fraction of works in the corpus which include the stem; for each measure, the table presents results truncating the sample at alternative percentiles (75th, 90th, 95th) of pre-war usage. The table confirms that the difference-in-difference estimate is statistically significant at traditional levels, and that there is no such difference for stems from patents evaluated for secrecy but not ordered secret.

[Table 8 about here]

7 Implications and Conclusion

This paper thus finds that compulsory secrecy in World War II was effective at protecting sensitive invention from disclosure, but that it restricted commercialization and impeded follow-on invention, as measured in both the citation record and in the use of new terms appearing in patent titles. Taken together, these results suggest there are consequences to a compulsory secrecy policy to be weighed against the security concerns – and analogously, potential welfare consequences of voluntary trade secrecy over patenting, despite any private benefit to inventors.

The more difficult-to-answer question is whether these consequences should be interpreted as severe or relatively modest. The answer depends on whether a 10-15% higher probability of future citation (the result in Tables 4 and 5) should be considered economically large or small, and whether or not the extensive margin of citations – where secrecy orders appear to have been most binding – is

[18] Note that although a natural expectation secrecy would have also reduced usage of treated word stems during the war, many of these stems were new terms with little usage prior to 1945. Appendix Figure D.1 plots the time series of Google Books usage of four familiar stems which first entered the patent record in a secret patent: Radar, Penicillin, Antibiot, Fission. In all of these cases, usage is near zero prior to the first appearance in a patent, is low until 1945 (independent of the filing date), and then shoots up after the war.

important. Losing sight of patents that would have otherwise only been cited one or two times may not seem like much of a loss, but one could also argue that this margin is of first-order concern, as it represents the difference between being built upon or not. Moreover, the fact that that around 85% of patents from the period were eventually cited might suggest that the welfare costs were limited – but that remaining 15% could also be material. The answers to these questions are non-obvious, and beyond the scope of this paper, but deserve further study.

That said, the policy must also be interpreted in the context of its temporary nature: the systemic effects of secrecy could potentially be very different had these inventions been secret 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). As it were, 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 Appendix E), suggesting the impact on aggregate invention may have been limited, but pre-trends and the absence of a clean control group make conclusive inference impossible.

These questions are an important target for future research, as secrecy orders are still issued today – and although they are issued at lower frequency than in the 1940s, they are still highly disruptive to inventors and organizations that receive them (AUECO 2019). The more serious problem, however, is the recent explosion in scientific espionage and intellectual property theft by foreign actors, which the FBI considers to be the top counterintelligence threat in the U.S. today, and potential regulatory actions may include ramped-up secrecy measures.

Although the focus of this paper is on the effects of concealment, a final remaining question is whether compulsory secrecy had an incentive effect on inventors and organizations doing research in sensitive technology areas: by holding up patent rights and precluding commercialization, secrecy orders could discourage patenting and invention altogether. Concerns about the detrimental impact on domestic invention, such as stifling U.S. innovation and driving R&D abroad, were among those raised by the ABA and IPOA in their responses to the USPTO's 2012 request for comments. An answer to this question is important to understanding the consequences of compulsory secrecy in a fully holistic way, and would complement existing literatures on both the incentive effects of intellectual property rights and the decision to patent.

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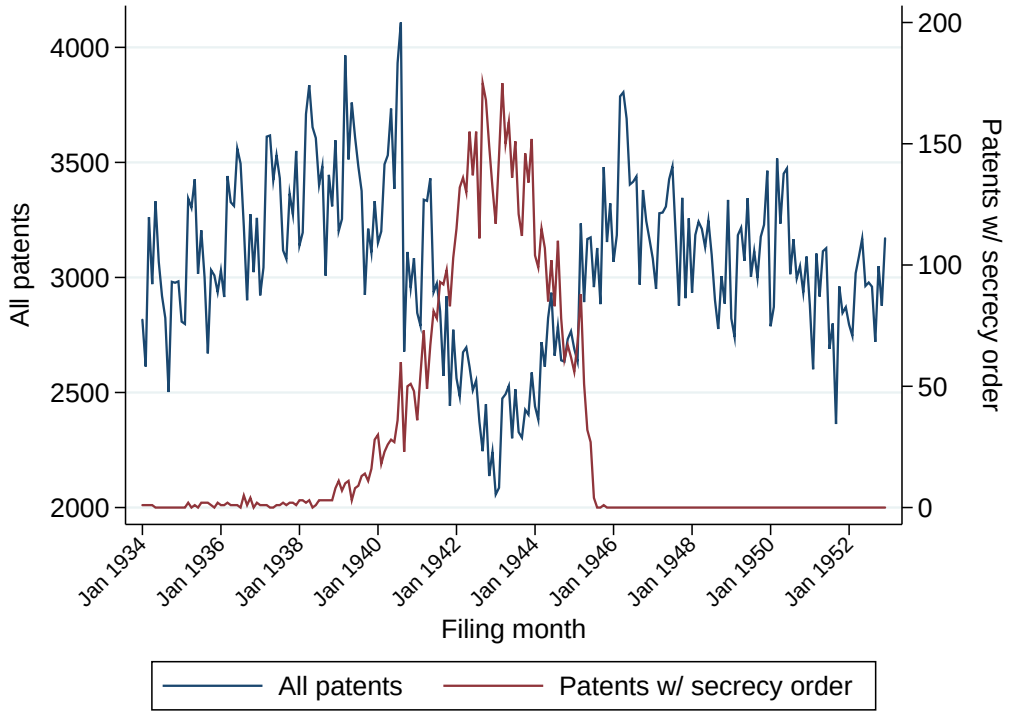
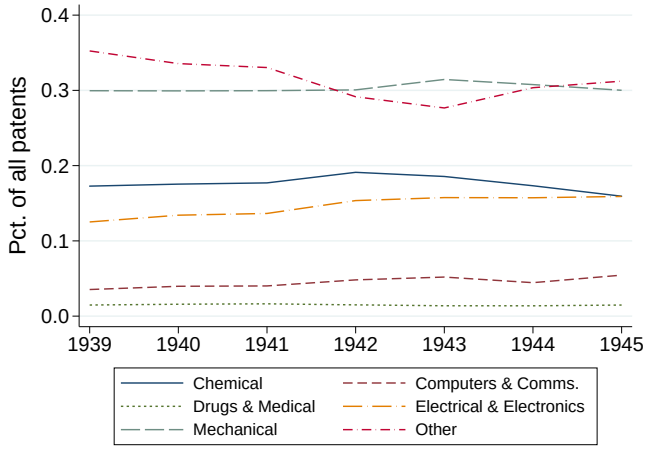
Figure 1: Monthly patent applications, 1935-1955



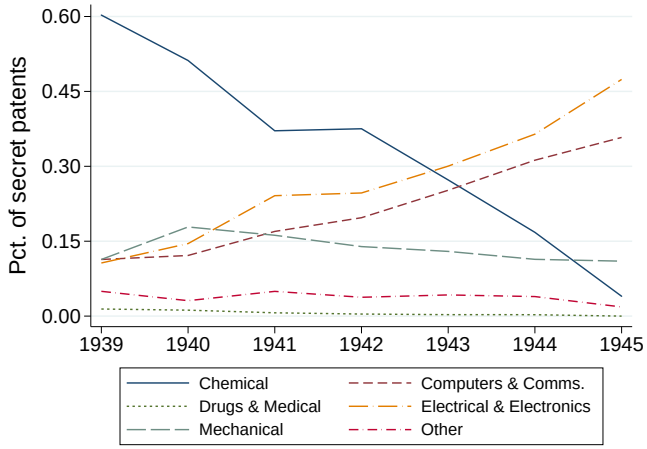
Notes: Figure shows monthly counts of (i) patent filings from 1935 to 1955 (in blue/left axis), and (ii) filings observed in the data as having been issued secrecy orders under P.L. 700 (in red/right axis).

Figure 2: Patterns in distribution of patent applications across NBER patent categories

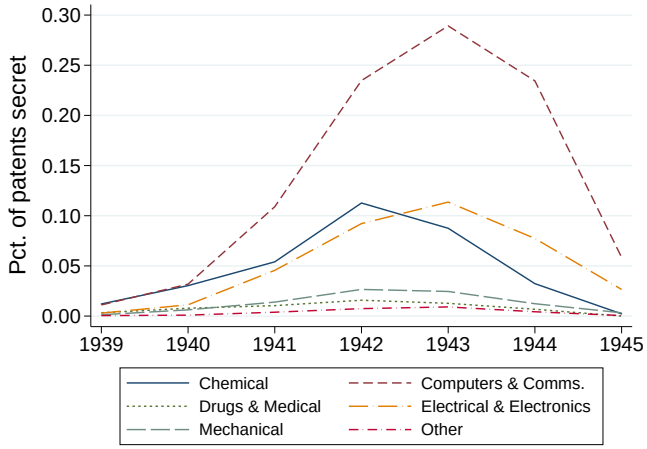
Panel (A): Fraction of applications in each top-level NBER category, 1939-1945



Panel (B): Fraction of secrecy orders in each top-level NBER category, 1939-1945

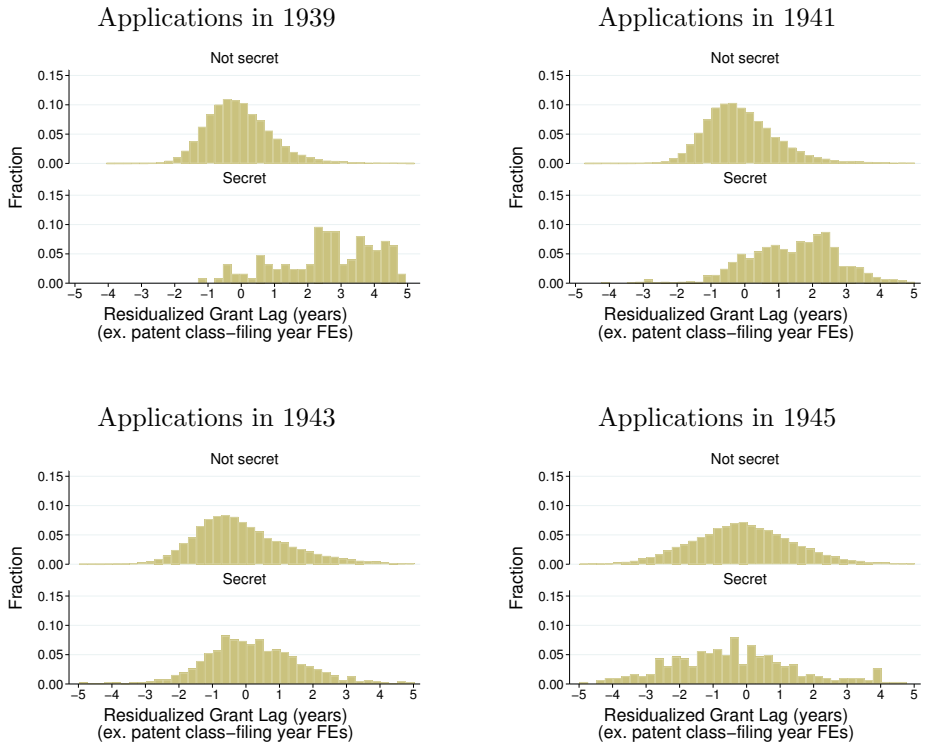


Panel (C): Fraction of applications in each top-level NBER category issued secrecy order



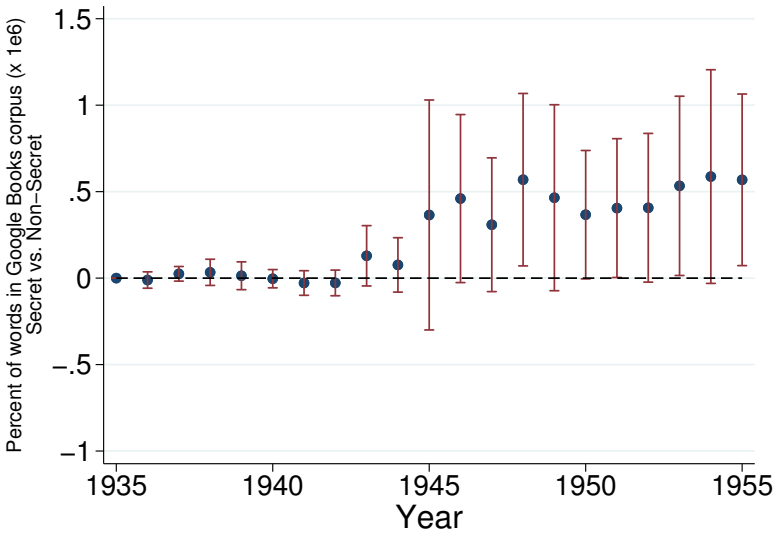
Notes: Panel (A) shows the distribution of patent filings across NBER categories in each year from 1939-1945. Panel (B) shows the annual distribution across NBER categories of filings known to have been issued secrecy orders. Panel (C) shows the rate at which filings in each top-level NBER category were issued secrecy orders over time.

Figure 3: Grant lags of applications placed under secrecy, vs. others, 1939-1945



Notes: Figure shows the distribution residual grant lags of patent applications with versus without secrecy orders, after controlling for patent class-year FEs. Note that 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).

Figure 4: Annual use of new word stems from secret vs. non-secret patent titles in the Google Books corpus



Notes: Figure shows estimated differences over time in the Google Books corpus frequency of word stems which first appeared in the title of a secret versus non-secret patent filed in the 1940-1945 period. In the underlying regression, observations are new stems in patent titles from this period, crossed by year, and the outcome variable is each stem's fraction of all words in the Google Books corpus in the given year. This outcome is regressed on indicators for the year, interacted with indicators for whether the stem was first used in the title of a patent which was (i) evaluated for secrecy and (ii) ordered secret. The figure plots effects for the latter. Specification includes stem fixed effects, such that comparisons are within stems, over time. Omitted category is 1935 for stems from both secret and non-secret patents. Sample censors stems at the 90th percentile of pre-patent usage in the Google Books corpus, to eliminate already-common language. Error bars represent 95% confidence intervals, computed from SEs clustered at the stem level.

Table 1: Top 10 patent classes with applications placed in secrecy, 1939-1945

USPC	Description	Pct. of Applications w/ Secrecy Order, 1939-1945	Max Pct. Secret in Any Year, 1939-1945
380	Cryptography	21.3%	71.4%
342	Directive radio wave systems/devices (radar)	16.2%	61.0%
585	Chemistry of hydrocarbon compounds	12.8%	51.9%
367	Acoustic wave systems/devices	11.7%	55.9%
526	Synthetic resins or natural rubbers	8.6%	62.4%
333	Wave transmission lines and networks	8.3%	51.8%
315	Electric lamp and discharge device systems	7.7%	42.4%
375	Pulse or digital communications	7.5%	37.0%
343	Radio wave antennas	7.0%	56.0%
331	Oscillators	6.4%	38.0%

Notes: Table lists the 10 patent classes with the highest fractions of applications in 1939-1945 issued secrecy orders, in descending order, and the maximal fraction of applications in any single year ordered secret. Data for eventually-granted patents only.

Table 2: Forward citations of secret vs. non-secret patents, 1939-1945

	Cites	Citers	Citing classes	Non-self	Self
Secrecy ordered	1.578***	1.232***	0.365***	1.419***	0.135***
	(0.343)	(0.272)	(0.078)	(0.316)	(0.038)
Secrecy evaluated	0.907***	0.603***	0.290***	0.728***	0.168***
	(0.109)	(0.076)	(0.036)	(0.098)	(0.018)
Constant	2.637***	2.615***	1.438***	2.471***	0.107***
	(0.130)	(0.115)	(0.046)	(0.121)	(0.019)
N	243193	243193	243193	243193	243193
R^2	0.09	0.09	0.12	0.09	0.06
Grant year FEs	X	X	X	X	X
Class-year FEs	X	X	X	X	X
Mean of DV	4.57	4.17	2.04	4.21	0.27
s.d. of DV	5.63	4.61	1.89	5.25	0.94

Notes: Table estimates differences in patents' forward citations, unique citing assignees, unique citing classes, non-self citations, and self citations for patents which were evaluated for secrecy and/or ordered secret. All columns control for (i) patent class by filing year and (ii) grant year fixed effects. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table 3: Effect of secrecy on patent grant lags, 1939-1945

	Applications filed in:						
	1939	1940	1941	1942	1943	1944	1945
Incremental grant lag (years)	3.272***	2.527***	2.309***	1.334***	0.834***	0.388***	0.205
	(0.189)	(0.103)	(0.073)	(0.064)	(0.074)	(0.110)	(0.173)
N	40739	40361	35207	29535	28502	32130	36719
R^2	0.17	0.20	0.23	0.22	0.20	0.20	0.21
Class FEs	X	X	X	X	X	X	X
Mean lag	2.25	2.31	2.42	2.70	2.99	3.48	4.06

Notes: Table estimates differences in patents' grant lags for secret versus non-secret patents, by filing year. All columns include patent class FEs, such that comparisons are between patents in the same class in the given year. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table 4: Effects of secrecy on probability of any forward citations, July 1940 to June 1945

				Triple difference	
	All	Non-OSRD	OSRD	Baseline	OSRD
Secrecy ordered	-0.006	-0.071**	0.040	-0.069**	0.113***
	(0.021)	(0.034)	(0.031)	(0.032)	(0.042)
* filed in 1941	-0.025	0.026	-0.048	0.022	-0.081
	(0.024)	(0.043)	(0.037)	(0.041)	(0.055)
* filed in 1942	0.017	0.052	-0.007	0.054	-0.073
	(0.023)	(0.040)	(0.033)	(0.038)	(0.049)
* filed in 1943	0.021	0.089**	-0.035	0.083**	-0.113**
	(0.023)	(0.042)	(0.030)	(0.040)	(0.049)
* filed in 1944	0.028	0.084*	-0.016	0.087**	-0.109**
	(0.026)	(0.044)	(0.034)	(0.042)	(0.050)
* filed in 1945	0.034	0.132***	-0.011	0.138***	-0.171***
	(0.028)	(0.042)	(0.043)	(0.040)	(0.051)
Secrecy evaluated	0.019	0.035*	-0.007	0.039**	-0.046*
	(0.014)	(0.018)	(0.022)	(0.017)	(0.025)
* filed in 1941	0.010	-0.001	0.023	-0.003	0.027
	(0.015)	(0.020)	(0.025)	(0.019)	(0.029)
* filed in 1942	-0.004	-0.018	0.012	-0.020	0.032
	(0.015)	(0.020)	(0.024)	(0.019)	(0.025)
* filed in 1943	0.009	-0.008	0.028	-0.013	0.042
	(0.016)	(0.021)	(0.024)	(0.019)	(0.027)
* filed in 1944	0.006	-0.016	0.025	-0.018	0.047*
	(0.017)	(0.023)	(0.025)	(0.022)	(0.028)
* filed in 1945	0.012	-0.002	0.016	-0.014	0.048
	(0.019)	(0.027)	(0.026)	(0.025)	(0.033)
Constant	0.705***	0.673***	0.984***	0.702***	0.702***
	(0.054)	(0.059)	(0.046)	(0.054)	(0.054)
N	162628	125335	37293	162628	
R^2	0.05	0.05	0.10	0.05	
Grant year FEs	X	X	X	X	
Class-year FEs	X	X	X	X	
Mean of DV	0.86	0.86	0.88	0.86	
s.d. of DV	0.34	0.35	0.32	0.34	

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 (see text for discussion). Columns (4) and (5) repeat this comparison in a pooled, triple-differenced sample. All columns control for (i) patent class by filing year and (ii) grant year fixed effects. Specifications estimated via OLS. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table 5: Effects of secrecy on probability of any forward citations: Robustness to alternative specifications (non-OSRD only)

	(1)	(2)	(3)	(4)	(5)
Secrecy ordered	-0.071**	-0.071**	-0.075**	-0.074**	-0.079
	(0.034)	(0.034)	(0.034)	(0.034)	(0.050)
* filed in 1941	0.026	0.022	0.028	0.022	0.024
	(0.043)	(0.042)	(0.043)	(0.042)	(0.065)
* filed in 1942	0.052	0.049	0.055	0.051	0.050
	(0.040)	(0.039)	(0.040)	(0.040)	(0.058)
* filed in 1943	0.089**	0.086**	0.090**	0.086**	0.097
	(0.042)	(0.041)	(0.043)	(0.042)	(0.062)
* filed in 1944	0.084*	0.077*	0.085**	0.080*	0.072
	(0.044)	(0.044)	(0.043)	(0.043)	(0.062)
* filed in 1945	0.132***	0.123***	0.132***	0.124***	0.141**
	(0.042)	(0.042)	(0.042)	(0.042)	(0.059)
Secrecy evaluated	0.035*	0.026	0.031*	0.023	0.026
	(0.018)	(0.018)	(0.018)	(0.018)	(0.028)
* filed in 1941	-0.001	0.003	-0.002	0.002	0.002
	(0.020)	(0.021)	(0.020)	(0.020)	(0.031)
* filed in 1942	-0.018	-0.013	-0.020	-0.015	-0.029
	(0.020)	(0.021)	(0.020)	(0.020)	(0.030)
* filed in 1943	-0.008	-0.005	-0.010	-0.007	-0.025
	(0.021)	(0.021)	(0.020)	(0.021)	(0.032)
* filed in 1944	-0.016	-0.010	-0.017	-0.012	-0.024
	(0.023)	(0.023)	(0.023)	(0.023)	(0.032)
* filed in 1945	-0.002	0.002	-0.007	-0.003	-0.026
	(0.027)	(0.027)	(0.026)	(0.027)	(0.038)
Constant	0.673***	0.544***	0.688***	0.552***	0.707***
	(0.059)	(0.060)	(0.063)	(0.065)	(0.101)
N	125335	125167	125335	125167	125167
R^2	0.05	0.06	0.05	0.06	0.54
Grant year FEs	X	X	X	X	X
Class-year FEs	X	X	X	X	X
Patent ctrls		X		X	X
Assignee ctrls			X	X	
Assignee FEs					X
Mean of DV	0.86	0.86	0.86	0.86	0.86
s.d. of DV	0.35	0.35	0.35	0.35	0.35

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 4. 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). Column (5) replaces these with assignee fixed effects. All columns control for (i) patent class by filing year and (ii) grant year fixed effects. Specifications estimated via OLS. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table 6: Effects of secrecy on diffusion of new word stems in patent titles

	Ln(Uses)	Uses≥10	Uses≥20	Uses≥30	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)
Constant	2.755***	0.525***	0.342***	0.256***	0.177***
	(0.052)	(0.024)	(0.021)	(0.020)	(0.016)
N	561	561	561	561	561
R^2	0.03	0.03	0.02	0.03	0.04
Filing year FEs	X	X	X	X	X
Mean of DV	2.82	0.54	0.35	0.28	0.19
s.d. of DV	1.23	0.50	0.48	0.45	0.40

Notes: Table estimates the subsequent usage of word stems which first appeared in the title of a patent filed in the 1940-1944 period, 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 contractor patents only (the 1945 year is omitted because there are no such stems which originated 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. All columns control for filing year fixed effects. The latter four specifications are estimated via OLS. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table 7: Presence of new chemical word stems in the Du Pont Products Index

	1938	1944	1946	1949	1955
Secrecy ordered	-0.025	-0.078***	-0.076**	-0.023	0.003
	(0.039)	(0.027)	(0.037)	(0.046)	(0.060)
Secrecy evaluated	-0.012	-0.020	-0.011	-0.030	-0.024
	(0.029)	(0.031)	(0.033)	(0.033)	(0.038)
Constant	0.081***	0.098***	0.109***	0.119***	0.152***
	(0.014)	(0.015)	(0.016)	(0.016)	(0.018)
N	544	544	544	544	544
R^2	0.00	0.01	0.01	0.00	0.00
Mean of DV	0.08	0.09	0.10	0.11	0.15
s.d. of DV	0.26	0.28	0.30	0.31	0.35

Notes: Table estimates the probability that a word stem which first appeared in the title of a patent filed in a chemical class in the 1940-1945 period appears in the Du Pont Products Index in 1938, 1944, 1946, 1949, and 1955, as a function of whether the first patent with the stem was evaluated for secrecy and/or ordered secret. The stems in this sample were further screened by the author to identify stems related to chemical content and processes. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. Heteroskedascity-robust SEs in parentheses.

Table 8: Annual use of new word stems from secret vs. non-secret patent titles in the Google Books corpus, difference-in-differences pre- vs. post-1945

	Percent of words (x1e6)			Percent of works (x1e3)		
	75th	90th	95th	75th	90th	95th
Secrecy ordered x post-1945	0.462**	0.415**	0.475**	5.707**	6.743***	6.502***
	(0.228)	(0.193)	(0.196)	(2.723)	(2.531)	(2.485)
Secrecy evaluated x post-1945	-0.006	-0.008	-0.011	0.052	-0.104	-0.036
	(0.013)	(0.019)	(0.021)	(0.238)	(0.316)	(0.563)
Post-1945	0.038***	0.060***	0.072***	0.885***	1.449***	1.862***
	(0.009)	(0.009)	(0.012)	(0.141)	(0.178)	(0.237)
Constant	0.042***	0.169***	0.377***	1.187***	4.748***	12.381***
	(0.007)	(0.007)	(0.008)	(0.098)	(0.103)	(0.121)
N	16989	20433	21567	16989	20433	21567
R^2	0.53	0.69	0.88	0.63	0.87	0.98
Stem FEs	X	X	X	X	X	X
Mean of DV	0.07	0.21	0.42	1.79	5.63	13.46
s.d. of DV	0.44	0.61	1.18	5.76	13.27	38.78

Notes: Table estimates a difference-in-difference of the pre- vs. post-1945 Google Books corpus frequency of word stems which first appeared in the title of a patent filed in the 1940-1945 period and was evaluated for secrecy and/or ordered secret. Columns (1) to (3) estimate effects on the fraction of words with a given stem, and Columns (4) to (6) estimate effects on the fraction of works with the given stem. Each column censors stems at the given percentile (75th, 90th, 95th) of pre-patent usage in the corpus, to eliminate already-common language. All columns include stem FEs. The table is effectively a difference-in-difference presentation of the results in Figure 4. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by stem in parentheses.

Web Appendix

A Data Appendix

A.1 Construction of patent datasets

A.1.1 Base data

The construction of the core patent-level dataset used in this paper begins with the USPTO historical master file (Marco et al. 2015), which provides a master list of granted patents with grant dates, patent class/subclass (USPC), and two-digit NBER category (Hall et al. 2001). In building this paper's dataset, I restrict the sample to patents granted between January 1, 1920 and December 31, 1979 – although most of the paper invokes only a subset of these. For all granted patents in this set, I obtain additional patent characteristics from the following sources:

- FreePatentsOnline.com (FPO): serial numbers, filing dates, and the network of forward and backward citations (front-page citations only)
- Derwent Innovation database (DI): (mostly) standardized assignee names[1]

A small subset of patents are missing filing dates and assignees. Table A.1 shows the number patents with missing data, by decade of grant. For the period sampled in this paper (1930-1960), approximately 2.4% of patents are missing a filing date and 2.5% missing an assignee (note: these percentages calculated for patents granted between 1930 and 1960, whereas the paper uses the sample of patents known to have been filed between 1930 and 1960).

Table A.1: Number of patents with missing data, by decade

		No filing date		No assignee data	
Decade of grant	**Patents**	**Number**	**Percent**	**Number**	**Percent**
1920-1929	414901	25738	6.2%	25918	6.2%
1930-1939	442842	11102	2.5%	11221	2.5%
1940-1949	307630	5470	1.8%	5546	1.8%
1950-1959	425985	12461	2.9%	12661	3.0%
1960-1969	567761	11203	2.0%	11363	2.0%
1970-1979	689027	2	0.0%	73	0.0%
Total	2848146	65976	2.3%	66782	2.3%

Notes: Table shows counts of patents with missing data, and their fraction of all patents, by decade (of grant).

Because secrecy orders were issued to patent applications, they are identified by serial number. For the purposes of this paper, it is thus critical to have accurate data on serial numbers. The

[1]Note that serial numbers, filing dates, and the network of patent citations were also retrieved from the Derwent database for comparison against the FPO data, as a validation exercise. The two data sources overwhelmingly agreed, and where they disagreed, spot checks revealed that FPO was consistently the more accurate of the two, and when there was an error in the FPO data, it typically reflected the occasional typographical error on the printed patent publication itself, such as two flipped digits, or a digit one unit off the correct value. Given their reliability, the data for this paper thus use serial numbers, filing dates, and citations from FPO.

application-level data (serials and filing dates) from FPO were therefore manually reviewed and validated for the period around the secrecy order program, by checking patents with serial numbers or filing dates which are out of sequence. The important feature of the USPTO's application numbering system for my purposes here is that applications are organized into application "series", which span several years, and identified by a serial number within that series, generally issued in the order in which patent applications arrive at the USPTO, with serial numbers never exceeding six digits. Application series increment, and serial numbers reset, at the beginning of a year in which the serial numbers from the previous series are expected to surpass 1,000,000. Series 2 begins January 1, 1935 and ends December, 1947 and is the focus of this data cleaning effort. I take all patents identified by FPO as belonging to Series 2 and sort these patents by serial. I then look for patents where the previous and next serial have the same filing date but the given patent has a different filing date, and then manually validate the serial and filing date for these patents. Out of over 370,000 patents in Series 2, corrections were made to 279 serials and 188 filing dates. Although these corrections are valuable for matching patents to secrecy orders, the low error rate for this sample also indicates that such errors are not widespread in the data.

A.1.2 Harmonizing assignee names

Although the assignee names from DI are largely already standardized, closer examination reveals that there are still variants on individual assignee names (e.g., BELL TELEPHONE LABOR INC with $> 10,000$ patents, and BELL TELPHONE LAB INC, BELL TEL PHONE LAB INC, and BELL TEIEPHONE LAB INC with 1 patent each). I undertake several procedures to further harmonize assignee names. I begin by sorting a unique list of assignees in alphabetical order, and for each assignee recording other nearby assignees up to 9 positions before and after in the sorted list. I then calculate the edit distance between the given assignee name and each of these nearby assignee names. When this edit distance is less than 25% of the length of the longer name in each pair, I flag that pair as a candidate for manual review. I then review all such matches for several categories of assignees, and standardize names when a match is found:

- Assignees with $\geq$15 patents between 1930 and 1960
- Assignees with at least 1 secrecy order
- Assignees which were OSRD contractors
- Assignees identified as government agencies (see next section)
- Assignees identified as universities or hospitals (see next section)
- Assignees which were synthetic rubber manufacturers
- Assignees which were spinouts from Standard Oil

This process is repeated (because each round of harmonization may bring new assignees into the set with $\geq$15 patents between 1930 and 1960) until no new matches are found.

This harmonization is neither perfect nor exhaustive, but it is believed to be effective for the purposes of this paper. It is also worth noting that for the vast majority of assignee names which

were standardized by this procedure, there was clearly a primary spelling for that assignee in the original DI data, with hundreds or thousands of associated patents in the case of large assignees, and at worst a handful of secondary spellings with one or two associated patents – such that the actual effects of both (i) performing this harmonization for the priority assignees above, and of (ii) *not* performing it for non-priority assignees, are likely minimal.

A.1.3 Determining assignee types

Assignees are then classified into four categories – firms, universities and hospitals, government agencies, and individuals – through a combination of rule-based and manual classification. I begin by classifying assignees as firms when the assignee name includes any of roughly 120 words which indicate firms (e.g., CO, CORP, INC, LTD, SPA, GMBH, etc., as well as technical words such as AERO, AUTO, CHEM, ENG, MACHINE, OIL, PROD, TECH, WORKS; full list available on request). I then manually classify remaining assignees with ≥ 15 patents between 1930 and 1960, as well as assignees whose name includes any of the following strings:

- COLLEGE, INST, UNIV, HOSP, RES FOUND
- US, CANADA, UK, FRANCE, GERMANY, SWITZERLAND, AUSTRALIA, JAPAN, ISRAEL, and assorted other countries
- ATOM (to identify international atomic energy commissions)

Assignees with > 200 patents in the 1920-1979 period which are thus far unclassified are then classified as firms. Any remaining unclassified assignees are classified as individuals.

This classification procedure was developed over several years, and although – like the name harmonization – it is neither perfect nor exhaustive, random spot checks suggest it is overwhelmingly effective at categorizing assignees into the right bins. In total, 60.1% of patents with an assignee in the 1920-1979 sample are assigned to a firm, 0.2% to a university, 0.8% to a government agency, and 39.1% to an individual (numbers sum to $>100\%$ because 5% of patents have multiple assignees, and 0.2% have assignees in multiple categories).

A.1.4 Identifying patents of OSRD contractors

As part of a broader data collection effort around U.S. science during World War II, I retrieved information on R&D contracts let by Office of Scientific Research and Development (OSRD), the primary R&D contracting agency during the war, from its archival collection at the U.S. National Archives and Records Administration (NARA). A complete list of contractors was compiled from contract lists and contractor directories. These contractors were then manually matched to the harmonized assignee names, making it possible to identify patents by government R&D contractors versus non-contractors. Contractors spanned all sectors of the economy but were primarily firms

and universities. Given that universities were not heavy filers of patents in this period, the vast majority of patents by OSRD contractors are by firms.[2]

A.1.5 Identifying patents with secrecy orders

Patent applications with secrecy orders were identified from the archival records of three U.S. government agencies: (i) the Office of Scientific Research and Development (OSRD), whose records yielded 4,837 serials with a secrecy order; (ii) the Office of Production Research and Development (OPRD), which yielded 2,047 serials; and (iii) the U.S. Army Office of the Judge Advocate General (JAG), which yielded 5,976 serials. These sets partly overlap, and collectively they identify a total of 8,475 patent applications which were at some point ordered secret. According to other contemporary records from the JAG office, a total of 11,182 secrecy orders were issued through June 14, 1945, when the war – and the secrecy program – were winding down and few new secrecy orders were being issued. The data thus identify roughly 75% of all secrecy orders. Undermeasurement is not a significant concern, particularly because it will only tend to attenuate comparisons between patents known to have been issued a secrecy order versus those not so observed. Of these 8,475 identified serials with secrecy orders, 6,352 (75%) were eventually granted.[3]

[2]The OSRD contract and contractor data can be found at:

- "Index to Contracts, 1941-1947" in RG 227 (Records of the Office of Scientific Research and Development), located in Stack Area 130, Row 20, Compartment 11, Shelf 1, Boxes 1-5. Online catalog entry at https://catalog.archives.gov/id/6882818.
- "Contractor Lists, 1940-1946" in RG 227 (Records of the Office of Scientific Research and Development), located in Stack Area 130, Row 20, Compartment 11, Shelf 4, Boxes 1-2. Online catalog entry at https://catalog.archives.gov/id/16955595.
- "Contract Ledgers, 1941-1946" in RG 227 (Records of the Office of Scientific Research and Development), located in Stack Area 130, Row 22, Compartment 18, Shelf 2-3, Boxes 1-6. Online catalog entry at https://catalog.archives.gov/id/6920064.

[3]The OSRD records which yielded data on secrecy orders can be found at:

- "D-1 Forms Used by the War Division of the Patent Office, 1942-1946" in RG 227 (Records of the Office of Scientific Research and Development), located in Stack Area 130, Row 20, Compartment 34, Shelf 3, Boxes 1-3. Online catalog entry at https://catalog.archives.gov/id/6882835.
- "Correspondence Relating to Secrecy Orders, 1942-1945" in RG 227 (Records of the Office of Scientific Research and Development), located in Stack Area 130, Row 20, Compartment 42-43, Shelf 7 and 1-3, Boxes 1-27. Online catalog entry at https://catalog.archives.gov/id/16955603.

The OPRD records which yielded data on secrecy orders can be found at:

- "Index to Patent Applications, 1945-1945" in RG 179 (Records of the War Production Board), Office of Production Research and Development, located in Stack Area 570, Row 64, Compartment 12, Shelf 4. Online catalog entry at https://catalog.archives.gov/id/567665.

The JAG records which yielded data on secrecy orders can be found at:

- "Records Pertaining to Patent Applications under Secrecy Orders Tendered to the Federal Government, 1941-1945" in RG 153 (Records of the Office of the Judge Advocate General), located in Stack Area 270, Row 2, Compartment 28, Shelf 6, Boxes 1-2. Online catalog entry at https://catalog.archives.gov/id/26335074.
- "Records Relating to Patents Tendered to the Federal Government Under Secrecy Orders, 1941-1949" in RG 153 (Records of the Office of the Judge Advocate General), located in Stack Area 270, Row 2, Compartment 28, Shelf 7, Box 1. Online catalog entry at https://catalog.archives.gov/id/17396215.
- "Patent cases, 1941-1952" in RG 153 (Records of the Office of the Judge Advocate General), located in Stack Area 270, Row 2, Compartment 28, Shelf 6, Box 1. Online catalog entry at https://catalog.archives.gov/id/17382698.

The OSRD records contain two sources of data on secrecy orders: a 27-box collection of secrecy determination forms ("Form D-1"), which were used to evaluate patent applications for secrecy, and miscellaneous agency correspondence discussing the secrecy order program and patent applications affected by it. Together with wartime administrative histories of the agencies involved, the D-1 forms and internal correspondence from the OSRD records provide a rich picture of how P.L. 700 was implemented at the USPTO, and how the review process was executed.

Recall from the historical background section of the paper that when a patent application arrived at the patent office, it was assigned to an examining division, and the primary examiner for that division would forward applications he or she viewed as a candidate for a secrecy order to the Patent Office War Division (POWD), where representatives from various other agencies (namely: the Army and Navy Patent Advisory Board, the War Production Board, the OSRD, and/or the Petroleum Administration for War) would review these applications and make a recommendation for or against secrecy. For every application sent to the POWD, a D-1 form was drawn up with identifying information including the serial, filing date, title, inventor, assignee, patent attorney, patent office examining division and primary examiner, and date of receipt at the POWD (see Figures A.1 and A.2 for examples). The application was then read by the relevant reviewers, who would each sign or stamp the form with their recommendation. Often, reviewers would defer to other reviewers' judgments (typically, to the armed services). If all reviewers declined to recommend secrecy, the application would be "disapproved" (for secrecy) and sent back to Washington; if any reviewer requested secrecy, the application was issued a secrecy order.

There are approximately 24,000 D-1 forms in the OSRD records. I had these forms scanned and transcribed via double entry with verification (under which discrepancies in the transcription are manually reviewed). Given the importance of these data, and that the original print on some of these forms is hard to read, I had them transcribed via the same procedure a second time by a distinct contractor. I then personally reviewed all differences between the two transcriptions and performed numerous checks to validate the data, making corrections as needed, and sometimes even catching typographical errors on the original forms themselves (these checks include: (i) ensuring serials are consistent with filing dates, (ii) ensuring that date of receipt is after filing date, (iii) ensuring that date of review is after date of receipt (although there are a few cases where it appears the application arrived at the POWD already-recommended for secrecy), (iv) harmonizing primary examiner name spellings and ensuring that examiner names and examining divisions were paired in a consistent way). Although most of the contents of each form were transcribed, currently the only data being used in this paper are the serial and the recommendation.

Of these ≈24,000 forms, 23,690 were for utility patent applications, covering 22,549 unique serials (some patent applications were evaluated multiple times), of which 3,557 were issued a secrecy order. Given that many more secrecy orders are known to have been issued during the war than are in this record set, it does not comprise an exhaustive list of applications formally reviewed for secrecy, let alone issued a secrecy order, but knowing patents which were evaluated for secrecy but disapproved allows us to specify a more refined control group than just the set of all patents which

were not secret. Presumably, the applications covered by these forms are those which were reviewed by an OSRD representative, but the precise sampling conditions are not known. Unfortunately, no additional D-1 forms could be located in other NARA collections.

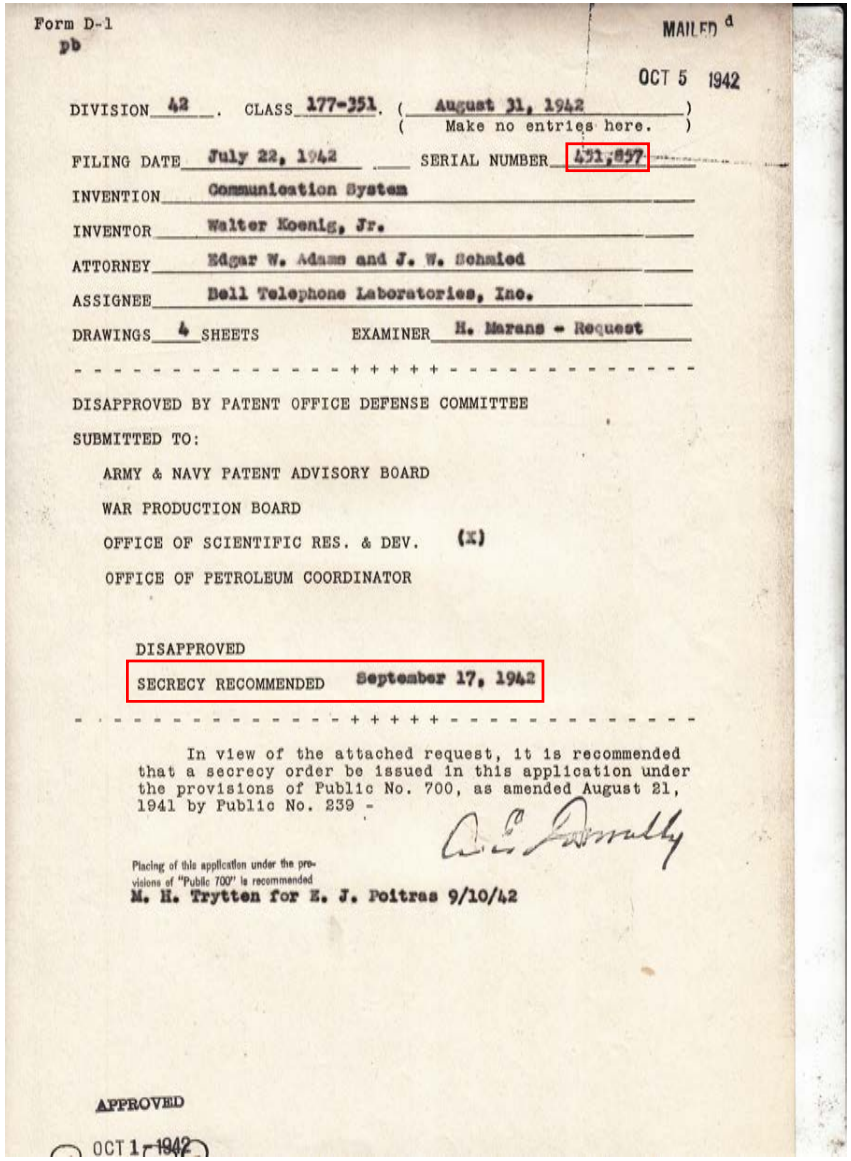
In addition to these forms, OSRD agency correspondence related to secrecy orders identifies 1,484 serials with a secrecy order. Most of this correspondence consists of letters between OSRD staff members notifying about the issuance of a secrecy order. The two sets of serials overlap, however, resulting in a total of 4,837 secrecy orders identified in OSRD records.

The next source of information on secrecy orders is an eight-box set of index cards in the archived records of the Office of Production Research and Development (OPRD), an agency whose mission was to promote the development of new materials and efficient methods for war production during World War II. According to documentation in the records, one set of index cards served as an index to patent applications "on which secrecy orders were imposed by the War Production Board and its predecessor agencies during the period 1941 to August 30, 1945." A second set indexed patent applications "on which no secrecy orders were issued... after examination by the War Production Board." A total of 2,047 unique serials appear in the set with secrecy orders, and 2,021 in the set without them. For unknown reasons, 135 serials appear in both sets. These serials are presumed to have been issued a secrecy order at some point in the war.

The final source of data on secrecy orders is a set of files from the records of the U.S. Army Judge Advocate General's office (JAG), which received patent applications with secrecy orders which were tendered to the government for its use, pursuant to the statutory terms of P.L. 700. These records contain lists of tendered inventions (see Figure A.3 for an example). The records also contain extensive agency correspondence that identifies additional serials with secrecy orders. In total, the lists of tendered inventions identify 5,957 unique serials with a secrecy order, and the correspondence identifies 928 serials. As with the other agencies, the two sets of serials overlap, resulting in a total of 5,976 secrecy orders found in JAG records.

I supplement these sources with a distinct list of patents associated with Manhattan Project research, obtained by an independent researcher via FOIA request to the U.S. Department of Energy and publicly hosted at the digital archives of the Woodrow Wilson Center (see Streifer 2017). This document lists 1,070 nuclear energy-related patent applications and 887 granted patents from the World War II period, including many designs for nuclear reactors. None of these patents were included in the NARA records described above, and although no formal indication of secrecy was included in this document, the median grant lag for patents on this list is almost 12 years (10th percentile = 4.74 years). Because nuclear energy research is especially distinctive, and the narrative record suggests that these patents were exempted from the 1945 General Rescinding Order (which otherwise generates key variation used in this paper) and remained secret long after the war ended, I exclude them from the analysis throughout the paper.

Figure A.1: Sample secrecy determinations from OSRD records with secrecy recommended



Form D-1
pb

MAILED d

OCT 5 1942

DIVISION 42 . CLASS 177-351. (August 31, 1942)
(Make no entries here.)

FILING DATE July 22, 1942 SERIAL NUMBER 451,897

INVENTION Communication System

INVENTOR Walter Koenig, Jr.

ATTORNEY Edgar W. Adams and J. W. Schmied

ASSIGNEE Bell Telephone Laboratories, Inc.

DRAWINGS 4 SHEETS EXAMINER H. Marans - Request

DISAPPROVED BY PATENT OFFICE DEFENSE COMMITTEE

SUBMITTED TO:

ARMY & NAVY PATENT ADVISORY BOARD

WAR PRODUCTION BOARD

OFFICE OF SCIENTIFIC RES. & DEV. (X)

OFFICE OF PETROLEUM COORDINATOR

DISAPPROVED

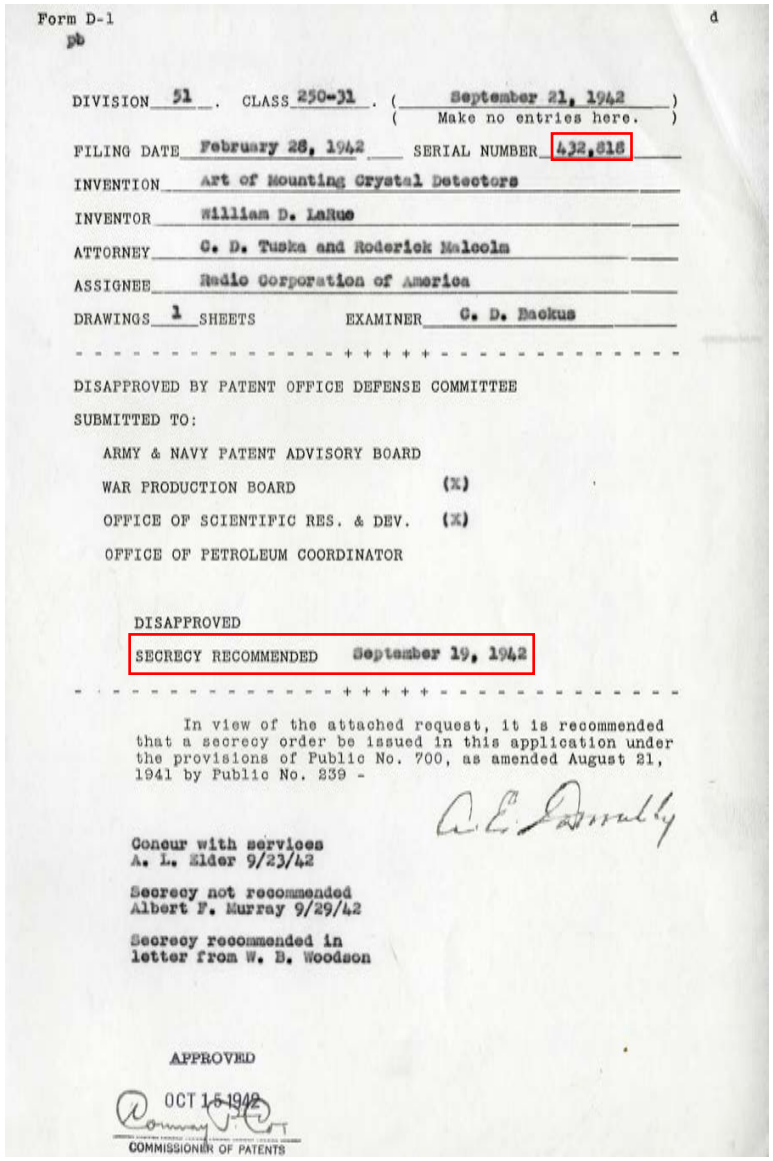
SECRECY RECOMMENDED September 17, 1942

In view of the attached request, it is recommended that a secrecy order be issued in this application under the provisions of Public No. 700, as amended August 21, 1941 by Public No. 239 -

Placing of this application under the provisions of "Public 700" is recommended
M. H. Trytten for E. J. Poitras 9/10/42

APPROVED

OCT 15 1942



Form D-1
pb

d

DIVISION 51 . CLASS 250-31 . (September 21, 1942)
(Make no entries here.)

FILING DATE February 28, 1942 SERIAL NUMBER 432,816

INVENTION Art of Mounting Crystal Detectors

INVENTOR William D. LaRue

ATTORNEY C. D. Tuska and Roderick Malcolm

ASSIGNEE Radio Corporation of America

DRAWINGS 1 SHEETS EXAMINER C. D. Backus

DISAPPROVED BY PATENT OFFICE DEFENSE COMMITTEE

SUBMITTED TO:

ARMY & NAVY PATENT ADVISORY BOARD

WAR PRODUCTION BOARD (X)

OFFICE OF SCIENTIFIC RES. & DEV. (X)

OFFICE OF PETROLEUM COORDINATOR

DISAPPROVED

SECRECY RECOMMENDED September 19, 1942

In view of the attached request, it is recommended that a secrecy order be issued in this application under the provisions of Public No. 700, as amended August 21, 1941 by Public No. 239 -

Concur with services
A. L. Elder 9/23/42

Secrecy not recommended
Albert F. Murray 9/29/42

Secrecy recommended in
letter from W. B. Woodson

APPROVED

OCT 15 1942

COMMISSIONER OF PATENTS

MAILED

AUG 13 1945

FORM D-1S Feb '44

DIVISION 54 . CLASS 315-12 . REC'D IN WAR DIV. July 16, 1945
(Examiner Leave Blank)

FILING DATE July 14, 1944 SERIAL NUMBER 544,947

INVENTION ELECTRON-OPTICAL APPARATUS

INVENTOR Christian G. Larsen

ATTORNEY Edwin H. Martin

ASSIGNEE Farnsworth Television and Radio Corporation

DRAWINGS 1 SHEETS EXAMINER O. S. Strachan

DISAPPROVED BY PATENT OFFICE WAR COMMITTEE

SUBMITTED TO ADVISORY AGENCIES

SECRECY (DISAPPROVED
(RECOMMENDED August 6, 1945

RECOMMENDATION, SIGNATURE, AGENCY & DATE
Every expert examining the indicated application must sign this form, and should indicate an express recommendation as to secrecy.

Submitted for:

A & N P A B
A
S.C.

Placing of this application under the provisions of "Public 700" is recommended
J.W.Greer 7-23-45

N

O S R D

In view of the attached request, it is recommended that a secrecy order accompanied by permit A be issued in this application under the provisions of Public No. 700, as amended.

P A W

W P B

Edward A. Haggett Jr.
Patent Office War Division

Approved, Date AUG 11 1945

Conder C Fahey
Assistant Commissioner of Patents

Form D-1
ebf

COPY

MAILED d

JAN 12 1944

DIVISION 20 . CLASS 154-43 . (December 3, 1943)
(Make no entries here.)

FILING DATE December 14, 1942 SERIAL NUMBER 468,993

INVENTION IMPACT RESISTANT PLASTIC PRODUCT

INVENTOR Edwin R. Laning

ATTORNEY Albert Sperry

ASSIGNEE Joseph Stokes Rubber Co., Inc.,

DRAWINGS 1 SHEETS EXAMINER L. M. Brown

DISAPPROVED BY PATENT OFFICE DEFENSE COMMITTEE

SUBMITTED TO:

ARMY & NAVY PATENT ADVISORY BOARD X

WAR PRODUCTION BOARD X

OFFICE OF SCIENTIFIC RES. & DEV. X

OFFICE OF PETROLEUM COORDINATOR

DISAPPROVED

SECRECY RECOMMENDED December 21, 1943

In view of the attached request, it is recommended that a secrecy order be issued in this application under the provisions of Public No. 700, as amended August 21, 1941 by Public No. 239, and June 16, 1942 by Public No. 609.

C. E. Somerby

Concur with services
D. Z. Beckler 12-7-43
J. P. Wilkins 12-8-43

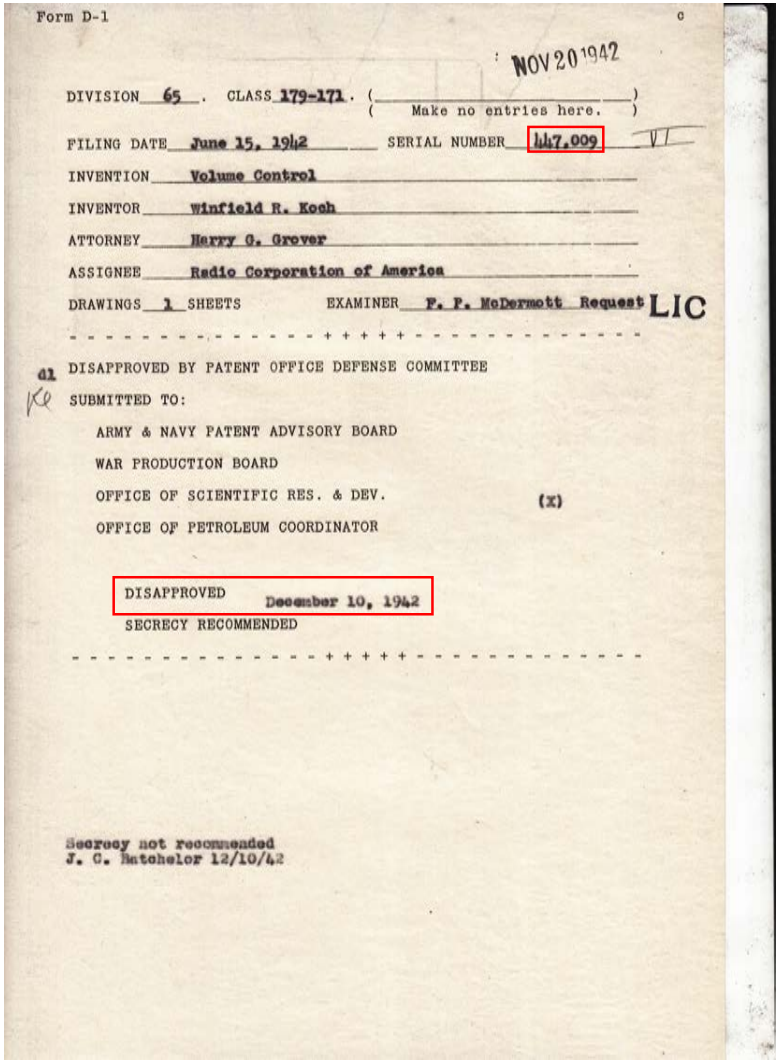
Placing of this application under the provision of "Public 700" is recommended
L. T. Phelan 12-13-43

Secrecy recommended in letter from
J. H. Byers 12-21-43
for F. E. Bailey

Secrecy not recommended
H. P. Grace Q.M.C.

APPROVED
JAN 11 1944
COMMISSIONER OF PATENTS

Figure A.2: Sample secrecy determinations from OSRD records, with secrecy disapproved



Form D-1

NOV 20 1942

DIVISION 65 . CLASS 179-171 . (Make no entries here.)

FILING DATE June 15, 1942 SERIAL NUMBER 447,009

INVENTION Volume Control

INVENTOR Winfield R. Koch

ATTORNEY Harry G. Grover

ASSIGNEE Radio Corporation of America

DRAWINGS 1 SHEETS EXAMINER F. P. McDermott Request LIC

DISAPPROVED BY PATENT OFFICE DEFENSE COMMITTEE

SUBMITTED TO:

ARMY & NAVY PATENT ADVISORY BOARD

WAR PRODUCTION BOARD

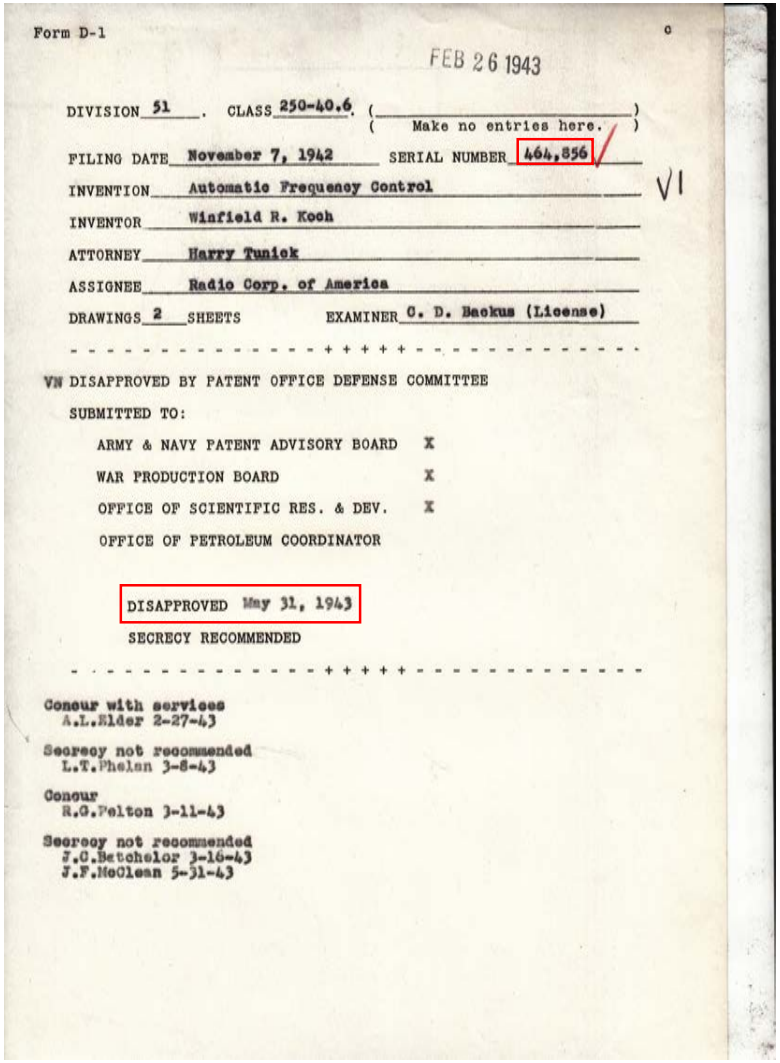
OFFICE OF SCIENTIFIC RES. & DEV. (X)

OFFICE OF PETROLEUM COORDINATOR

DISAPPROVED December 10, 1942

SECRECY RECOMMENDED

Secrecy not recommended
J. C. Batchelor 12/10/42



Form D-1

FEB 26 1943

DIVISION 51 . CLASS 250-40.6 . (Make no entries here.)

FILING DATE November 7, 1942 SERIAL NUMBER 464,856

INVENTION Automatic Frequency Control

INVENTOR Winfield R. Koch

ATTORNEY Harry Tunick

ASSIGNEE Radio Corp. of America

DRAWINGS 2 SHEETS EXAMINER C. D. Backus (License)

DISAPPROVED BY PATENT OFFICE DEFENSE COMMITTEE

SUBMITTED TO:

ARMY & NAVY PATENT ADVISORY BOARD X

WAR PRODUCTION BOARD X

OFFICE OF SCIENTIFIC RES. & DEV. X

OFFICE OF PETROLEUM COORDINATOR

DISAPPROVED May 31, 1943

SECRECY RECOMMENDED

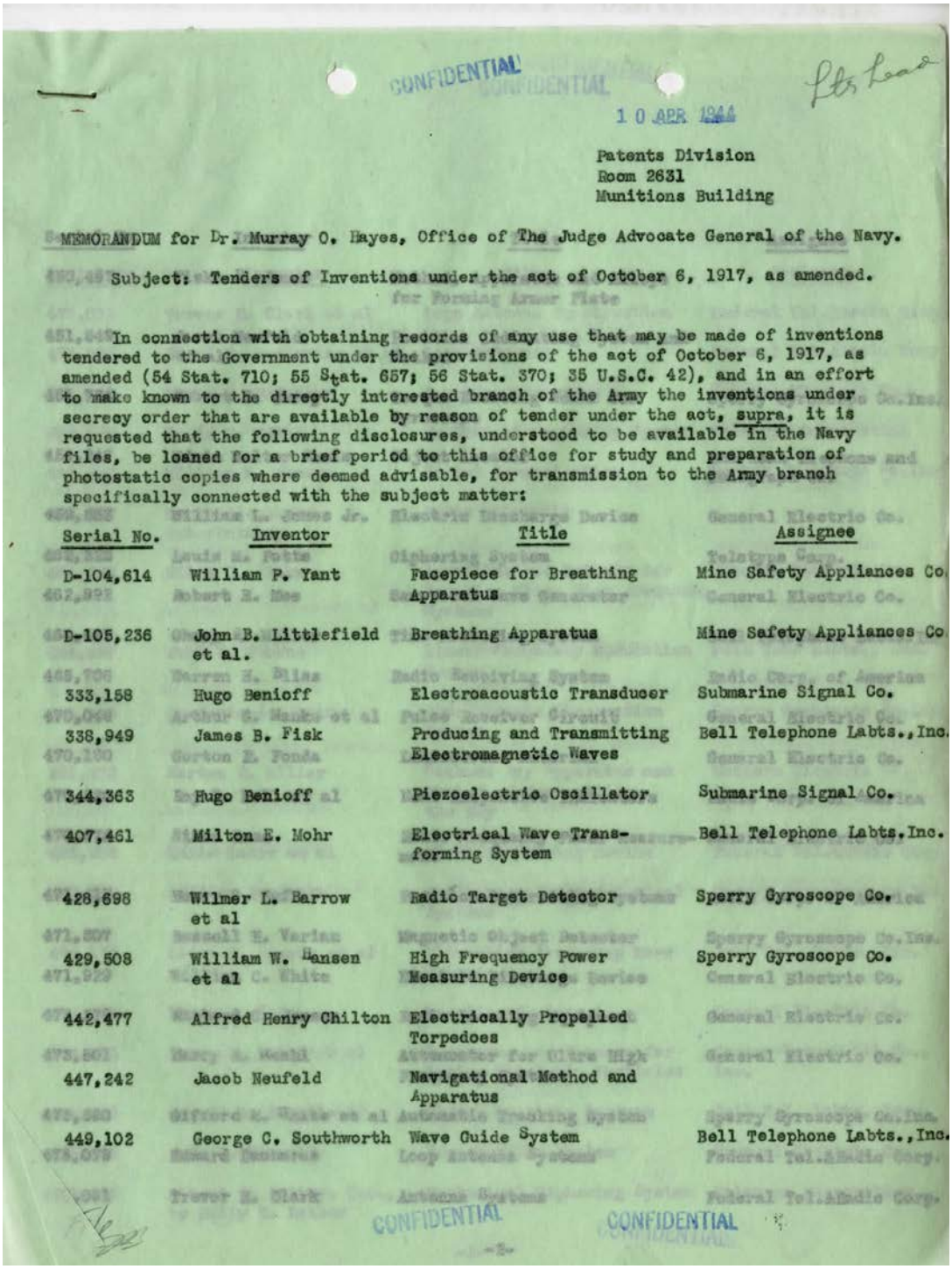
Concur with services
A.L.Elder 2-27-43

Secrecy not recommended
L.T.Phelan 3-8-43

Concur
R.G.Pelton 3-11-43

Secrecy not recommended
J.C.Batchelor 3-16-43
J.F.McClean 5-31-43

Figure A.3: Sample page from lists of tendered inventions in JAG records



CONFIDENTIAL

10 APR 1944

Patents Division
Room 2631
Munitions Building

MEMORANDUM for Dr. Murray O. Hayes, Office of The Judge Advocate General of the Navy.

Subject: Tenders of Inventions under the act of October 6, 1917, as amended.

In connection with obtaining records of any use that may be made of inventions tendered to the Government under the provisions of the act of October 6, 1917, as amended (54 Stat. 710; 55 Stat. 657; 56 Stat. 370; 35 U.S.C. 42), and in an effort to make known to the directly interested branch of the Army the inventions under secrecy order that are available by reason of tender under the act, supra, it is requested that the following disclosures, understood to be available in the Navy files, be loaned for a brief period to this office for study and preparation of photostatic copies where deemed advisable, for transmission to the Army branch specifically connected with the subject matter:

Serial No.	Inventor	Title	Assignee
D-104,614	William P. Yant	Facepiece for Breathing Apparatus	Mine Safety Appliances Co.
D-105,236	John B. Littlefield et al.	Breathing Apparatus	Mine Safety Appliances Co
333,158	Hugo Benioff	Electroacoustic Transducer	Submarine Signal Co.
338,949	James B. Fisk	Producing and Transmitting Electromagnetic Waves	Bell Telephone Labts., Inc.
344,363	Hugo Benioff	Piezoelectric Oscillator	Submarine Signal Co.
407,461	Milton E. Mohr	Electrical Wave Transforming System	Bell Telephone Labts. Inc.
428,698	Wilmer L. Barrow et al	Radio Target Detector	Sperry Gyroscope Co.
429,508	William W. Hansen et al	High Frequency Power Measuring Device	Sperry Gyroscope Co.
442,477	Alfred Henry Chilton	Electrically Propelled Torpedoes	
447,242	Jacob Neufeld	Navigational Method and Apparatus	
449,102	George C. Southworth	Wave Guide System	Bell Telephone Labts., Inc.

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A.2 Textual analysis: new words in patent titles

The text-based analysis in this paper requires additional data on patents' content. For the pre-1976 period, patent text is not available in a clean, USPTO-issued machine-readable format. Google Patents makes available OCR full text for historical patents, but the quality of the character recognition is less than great and generally declines going further back in time, due to older documents and lower-quality typesetting, which increases the OCR error rate. Other data sources, including Derwent Innovation, also provide the full text of pre-1976 patents, but with the same limitations. To minimize concerns about how the OCR quality and spelling errors may influence the results of the paper, particularly given the focus on identifying and measuring the subsequent use of new words in the patent record, I therefore seek out a cleaner source of data.

Google also makes available, via the Google Cloud Platform and its BigQuery web service, additional textual and text-based patent data. I used this service to retrieve titles (which are cleanly transcribed) and top terms (according to Google, "the top 10 salient terms extracted from the patent's title, abstract, claims, and description) of patents granted from 1920-1979. For each patent, Google also provides a 64-element machine-learned component vector which can be used to compute pairwise similarity measures (according to Google: this component vector is "based on document contents and metadata, where two documents that have similar technical content have a high dot product score of their embedding vectors" and "trained on full text bag of words to predict CPCs using the WSABIE classification model" – in other words, a model designed to predict each patent's classification from its content and metadata). I take these vectors off-the-shelf and use them to calculate the measure of similarity invoked at the end of Section 4.[4]

New words (more specifically, new stems) are identified from patent titles as follows. After loading the patent titles, I remove numeric tokens, punctuation, and special characters. I then tokenize the remaining text in the title, splitting it into a list of constituent "words". I then loop over this list and drop (i) words which match a set of stop words, (ii) words with < 4 or > 25 characters, and (iii) words with a numeric character.[5] The remaining words are then stemmed by the NLTK toolkit and reduced to a set of unique stems for each patent. To restrict our focus to stems which are neither exceedingly common nor vanishingly rare, and to minimize the computational burden of the remaining steps, I further reduce these stems to those (i) used by at least 5 patents but no more than 20% of patents in the complete 1920-1979 sample, and (ii) used by at least one patent filed between 1940 and 1945, since the stems of interest will be from this set.

After reshaping the data to patent-stem pairs, the next step is to identify stems which were *first* used in a patent filed between 1940 and 1945 – that is, stems which are ostensibly new to the patent

[4]Patent titles are from the BigQuery *Patents* dataset (patents-public-data → patents → publications → title_localized; see https://console.cloud.google.com/bigquery?p=patents-public-data&d=patents&t=publications), and top terms and component vectors from the *Google Patents Research* dataset (patents-public-data → google_patents_research → publications → top_terms, embedding_v1; see https://console.cloud.google.com/bigquery?p=patents-public-data&d=google_patents_research&t=publications)

[5]Stop words used in this step are a combination of off-the-shelf stop words from the NLTK toolkit for Python, stop words from Iaria et al. (2018), and stop words from Younge and Kuhn (2016).

record when they are used in the title of a patent filed in the early 1940s. The 1920 to 1939 period is used to define a stock of "existing" stems; this interval is considered sufficient for constructing an existing stock of words, since it includes nearly one million patents and covers the 20+ most recent years of invention. The final step is to then reduce the data to stems which were first used in a patent filed in the 1940 to 1945 period. The empirical output from this procedure is a dataset of these stems and the patents using them between 1940 and 1979.

Table A.2 lists the most-heavily used new stems from the 1940 to 1945 period, highlighting in red those which were first appeared in the title of a secret patent, and in light red those which ever appeared in a secret patent. The term *semiconductor* entered the patent record during this period, as did *radar*, *ultrasonic*, *monomer* and *elastomer*, and *antibiotics* and *penicillin*. As this table demonstrates, the stemming procedure is also imperfect, as both "elastom" and "elastomer" enter this table, the former likely stemmed from "elastomer" itself, and the latter from words like "elastomerization". There is no perfect solution to this problem, as iterative stemming will often reduce words down to unrecognizable objects and cause unrelated words to get binned together into the same stem of stems. I thus limit the text cleaning procedure to one round of stemming, so that similar words (e.g., singular and plural variants of a noun) will be grouped into a common stem, at the same time recognizing the limitations of the methods.

Table A.2: Most heavily used new stems in patent titles, 1940-1945

	Stem	Subseq. uses (1940-1979)		Stem	Subseq. uses (1940-1979)
1.	semiconductor	6935	9.	antibiot	940
2.	disc	3260	10.	phosphon	894
3.	radar	2255	11.	elastomer	848
4.	ultrason	2017	12.	curabl	810
5.	monom	1366	13.	cryogen	771
6.	elastom	1237	14.	readout	672
7.	waveguid	1160	15.	penicillin	627
8.	electrophotograph	1158	16.	recognit	601

Notes: Red = Stem *first* used in title of secret patent. Light red = Stem *ever* used in title of secret patent.

This same procedure was repeated for patents' top terms, as well as for the union of titles and top terms. Although my focus in the paper is on titles only, the results in Sections 4 and 5 are similar when the analysis is based on these top terms. (The analysis was not repeated for the union of titles and top terms; because they each measure distinct features of patents, their union is a strange object and was not considered suitable for analysis.)

Other textual data sources

In addition to looking for these words in the patent record, the paper also studies two other corpora: Du Pont product catalogs, and the Google Books N-gram database.

The Du Pont Products Index (DPPI) was a Du Pont product catalog published at regular intervals, and is used to look for focal chemical terms in Du Pont literature as a proxy for the product market. The 1938 edition of the DPPI is available online from Hathitrust, and working with the Hagley Museum in Wilmington, Delaware, which houses the Du Pont archival collection, I had four other editions of the DPPI digitized: 1944, 1946, 1949, and 1955-56, all of which are now available as well. These catalogs were then converted to text using ABBYY FineReader 14, which is subject to similar limitations as the OCR of historical patents previously discussed, although the OCR quality is higher because the scans are higher-resolution and the source documents have cleaner typesetting. The implications of using OCRed text for this part of the paper, and some robustness checks explored in light of these issues, are discussed in the paper.[6]

As explained in the paper, I make use of the Google Books N-gram data, which are freely available for download, to measure the use of focal technical words in the broader public discourse.[7] These data provide annual usage of unique N-grams in the Google Books corpus. This paper uses the data on 1-grams (i.e., words), matching words from patent titles to words in this set (specifically, I identify all words in patent titles whose stem entered the patent record in a patent filed between 1940 and 1945, link these to words in the N-grams data, and measure their use by year, in levels and as a fraction of all words in the Google Books corpus in the given year).

A.3 What's being measured by patent citations

Although researchers from Jaffe et al. (1993) to Galasso and Schankerman (2015) have used prior art references to measure linkages and follow-on invention, several papers have also highlighted the limitations of modern citation data, including the fact that citations can be strategic and that a large fraction are added by examiners rather than applicants (Alcacer et al. 2009, Sampat 2010, Cotropia et al. 2013, Roach and Cohen 2013), which is a concern because examiner-added citations may not measure intellectual inputs to invention. An additional wrinkle that more directly affects this paper is that the citation record only begins in 1947, as the USPTO did not require published patents to list references to prior art until February 4, 1947. Given the myriad issues, it is useful to include a more detailed discussion of what patent citations measure.

Prior art references have been an integral part of the patent examination process since well before the 1947 requirement that they be printed on the final page (now front page) of the patent document itself. The 1940 USPTO Rules of Practice, for example, instructs that:

[6] For the 1938 volume, see https://catalog.hathitrust.org/Record/001042925; for the 1944, 1946, 1949, and 1955-56 volumes, see https://digital.hagley.org/islandora/search/%22Du%20Pont%20Products%20Index%22?type=edismax&f%5B0%5D=-RELS_EXT_isMemberOfCollection_uri_ms%3A%28%22info%3Afedora/islandora%3Aead%22%29.

[7] Data and documentation available at http://storage.googleapis.com/books/ngrams/books/datasetsv2.html.

> Upon taking up an application for action on the merits the examiner shall make a thorough investigation of the prior art, with respect to the invention sought to be protected in the application. Upon the rejection of an application for want of novelty, the examiner must cite the best references at his command. When the reference shows or describes inventions other than that claimed by the applicant, the particular part relied on must be designated as nearly as practicable. The pertinence of the reference, if not obvious, must be clearly explained and the anticipated claim specified.

Thus, although the patent citation data used in modern research are drawn from published, front-page/final-page references, and these begin only in 1947, it is not that prior art references were not previously made, but rather that they are not easily observed (a paper trail would have been kept in the examination file, not on the patent document itself). Moreover, prior to 1992, when the USPTO issued a new rule establishing applicants' "duty to disclose" information material to patentability (37 CFR §1.56), these references appear to have been made primarily (if not exclusively) by patent examiners, in the course of examination. Given the functional role they played, forward citations will identify closely-related subsequent invention, not information flows per se – but this is enough to measure *de facto* follow-on invention for the purposes of this paper.

Examiner-added citations: curse or blessing?

That patent citations in this period come from examiners is also important: as Moser et al. (2017) show with modern data, patent examiners use physical traits (rather than performance) to identify patents that should be cited as prior art, which provides reassurance that citations in this paper will be measuring intellectual proximity (even within patent classes, since most specifications include patent class fixed effects) rather than quality or importance.

Given that modern examiners rely on the results of prior art searches and may draw on a smaller pool of "favorite" examples of prior art during patent examination (e.g., Cockburn et al. 2002), a remaining concern is that differences in forward citations attributed to secrecy orders in Section 4 might actually just be driven by differences in what information the future examiners making these references knew or had access to with respect to earlier patents with secrecy orders. This concern is mostly obviated by the fact that secrecy orders were rescinded long before any of the citing patents in my data were granted (November 1945 versus February 1947), such that secrecy is not standing in the way of these inventions being found or cited as prior art. But a reasonable question is whether secrecy orders could have affected what enters the set of examiners' frequently-cited prior art, and could this then explain the patterns found in the paper.

However, this seems unlikely for two reasons. First, if secrecy orders kept certain patents out of the pool of prior art that examiners tended to cite, this would likely have applied equally to earlier and later applications – since it is a function of the secrecy order, not the timing. More importantly, it is my understanding that examiners had access to applications with secrecy orders, since these could still be used for interference (although formal notification and interference proceedings would be delayed until the priority application came off secrecy order).

B Historical Appendix

This appendix provides supplementary material to accompany the discussion of the secrecy order program in Section 1 of the paper. Figure B.1 shows the text of Public Law 700, enacted July 1, 1940, which authorized the USPTO to issue secrecy orders. Figures B.2 to B.4 show examples of secrecy order notification letters mailed to inventors. Figure B.5 shows an announcement of the General Rescinding Order printed in the USPTO Official Gazette (the USPTO's weekly newsletter, accessible by subscription) on September 18, 1945.

Figure B.1: Public Law 700

[CHAPTER 501]

AN ACT

July 1, 1940
[H. R. 10058]
[Public, No. 700]

To amend the Act relating to preventing the publication of inventions in the national interest, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act of Congress approved October 6, 1917 (40 Stat. 394, ch. 95, U. S. C., title 35, sec. 42), be amended to read as follows:

Withholding of patents in national interest.

"Whenever the publication or disclosure of an invention by the granting of a patent might, in the opinion of the Commissioner of Patents, be detrimental to the public safety or defense he may order that the invention be kept secret and withhold the grant of a patent for such period or periods as in his opinion the national interest requires: *Provided*, That the invention disclosed in the application for said patent may be held abandoned upon it being established before or by the Commissioner that in violation of said order said invention has been published or disclosed or that an application for a patent therefor has been filed in a foreign country by the inventor or his assigns or legal representatives, without the consent or approval of the Commissioner of Patents.

Proviso.
Deemed abandoned if published, etc.

Right of patentee to sue for compensation.

"When an applicant whose patent is withheld as herein provided and who faithfully obeys the order of the Commissioner of Patents above referred to shall tender his invention to the Government of the United States for its use, he shall, if and when he ultimately receives a patent, have the right to sue for compensation in the Court of Claims, such right to compensation to begin from the date of the use of the invention by the Government: *Provided*, That the Secretary of War or the Secretary of the Navy or the chief officer of any established defense agency of the United States, as the case may be, is authorized to enter into an agreement with the said applicant in full settlement and compromise for the damage accruing to him by reason of the order of secrecy, and for the use of the invention by the Government."

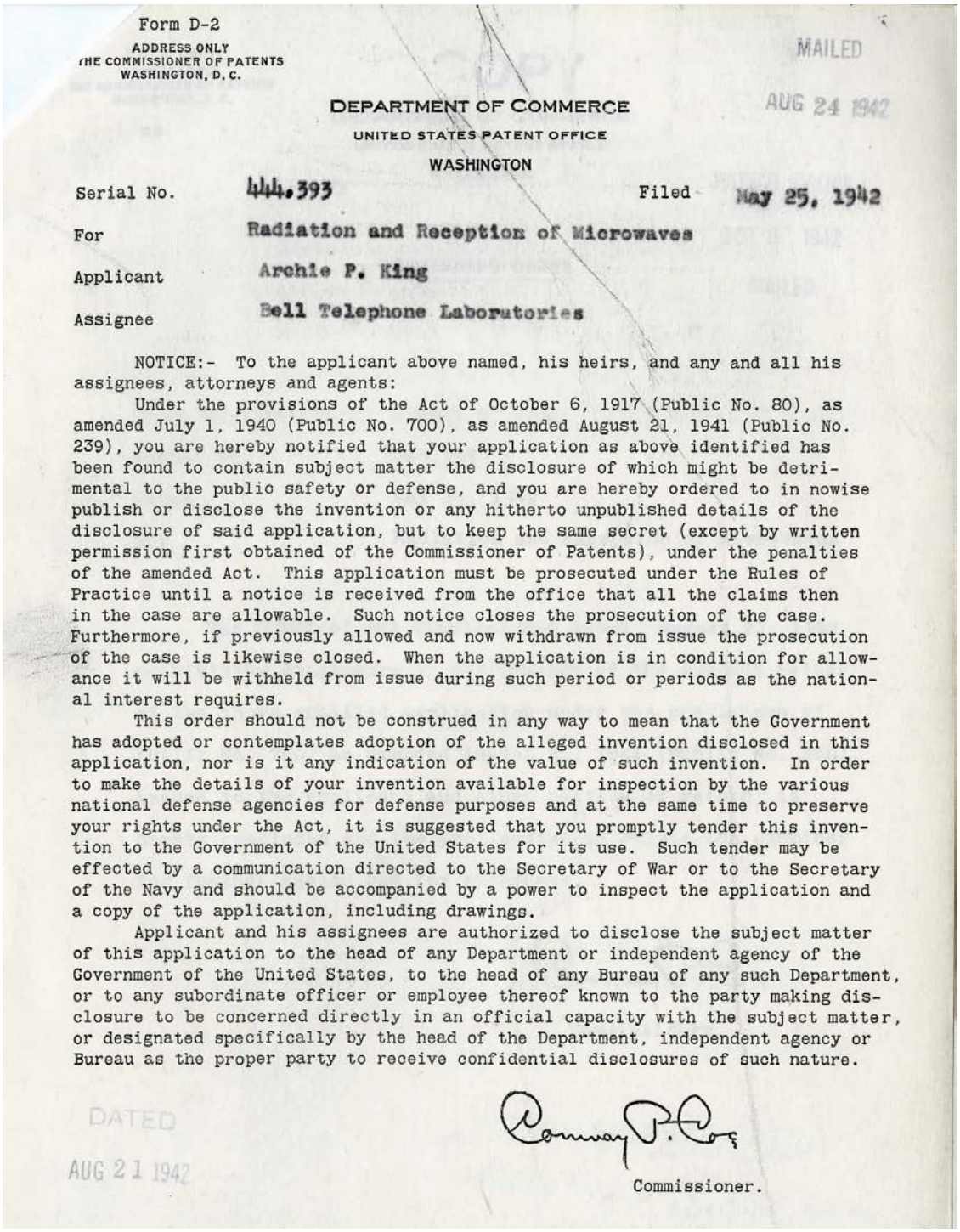
Proviso.
Settlement with applicant for damage, etc.

Effective date; period in force.

SEC. 2. This Act shall take effect on approval and shall remain in force for a period of two years from such date.

Approved, July 1, 1940.

Figure B.2: Example Secrecy Order: Bell Labs



Form D-2

ADDRESS ONLY
THE COMMISSIONER OF PATENTS
WASHINGTON, D. C.

MAILED

AUG 24 1942

DEPARTMENT OF COMMERCE

UNITED STATES PATENT OFFICE

WASHINGTON

Serial No. 444,393 Filed May 25, 1942

For Radiation and Reception of Microwaves

Applicant Archie P. King

Assignee Bell Telephone Laboratories

NOTICE:- To the applicant above named, his heirs, and any and all his assignees, attorneys and agents:

Under the provisions of the Act of October 6, 1917 (Public No. 80), as amended July 1, 1940 (Public No. 700), as amended August 21, 1941 (Public No. 239), you are hereby notified that your application as above identified has been found to contain subject matter the disclosure of which might be detrimental to the public safety or defense, and you are hereby ordered to in nowise publish or disclose the invention or any hitherto unpublished details of the disclosure of said application, but to keep the same secret (except by written permission first obtained of the Commissioner of Patents), under the penalties of the amended Act. This application must be prosecuted under the Rules of Practice until a notice is received from the office that all the claims then in the case are allowable. Such notice closes the prosecution of the case. Furthermore, if previously allowed and now withdrawn from issue the prosecution of the case is likewise closed. When the application is in condition for allowance it will be withheld from issue during such period or periods as the national interest requires.

This order should not be construed in any way to mean that the Government has adopted or contemplates adoption of the alleged invention disclosed in this application, nor is it any indication of the value of such invention. In order to make the details of your invention available for inspection by the various national defense agencies for defense purposes and at the same time to preserve your rights under the Act, it is suggested that you promptly tender this invention to the Government of the United States for its use. Such tender may be effected by a communication directed to the Secretary of War or to the Secretary of the Navy and should be accompanied by a power to inspect the application and a copy of the application, including drawings.

Applicant and his assignees are authorized to disclose the subject matter of this application to the head of any Department or independent agency of the Government of the United States, to the head of any Bureau of any such Department, or to any subordinate officer or employee thereof known to the party making disclosure to be concerned directly in an official capacity with the subject matter, or designated specifically by the head of the Department, independent agency or Bureau as the proper party to receive confidential disclosures of such nature.

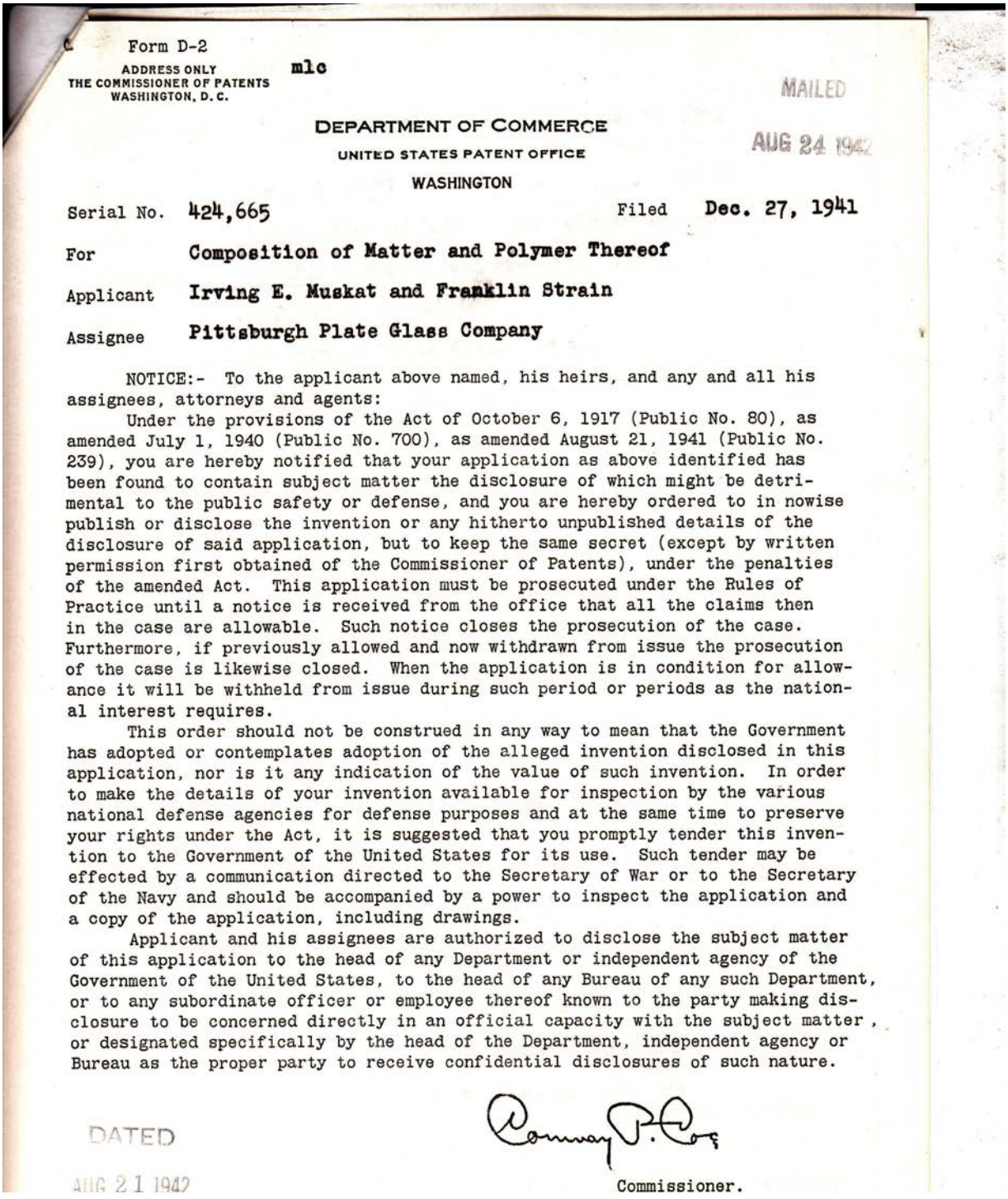
DATED

AUG 21 1942

Conway P. Coe

Commissioner.

Figure B.3: Example Secrecy Order: Pittsburgh Plate Glass Co.



Form D-2

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WASHINGTON, D. C.

mlc

MAILED

AUG 24 1942

DEPARTMENT OF COMMERCE

UNITED STATES PATENT OFFICE

WASHINGTON

Serial No. 424,665 Filed Dec. 27, 1941

For Composition of Matter and Polymer Thereof

Applicant Irving E. Muskat and Franklin Strain

Assignee Pittsburgh Plate Glass Company

NOTICE:- To the applicant above named, his heirs, and any and all his assignees, attorneys and agents:

Under the provisions of the Act of October 6, 1917 (Public No. 80), as amended July 1, 1940 (Public No. 700), as amended August 21, 1941 (Public No. 239), you are hereby notified that your application as above identified has been found to contain subject matter the disclosure of which might be detrimental to the public safety or defense, and you are hereby ordered to in nowise publish or disclose the invention or any hitherto unpublished details of the disclosure of said application, but to keep the same secret (except by written permission first obtained of the Commissioner of Patents), under the penalties of the amended Act. This application must be prosecuted under the Rules of Practice until a notice is received from the office that all the claims then in the case are allowable. Such notice closes the prosecution of the case. Furthermore, if previously allowed and now withdrawn from issue the prosecution of the case is likewise closed. When the application is in condition for allowance it will be withheld from issue during such period or periods as the national interest requires.

This order should not be construed in any way to mean that the Government has adopted or contemplates adoption of the alleged invention disclosed in this application, nor is it any indication of the value of such invention. In order to make the details of your invention available for inspection by the various national defense agencies for defense purposes and at the same time to preserve your rights under the Act, it is suggested that you promptly tender this invention to the Government of the United States for its use. Such tender may be effected by a communication directed to the Secretary of War or to the Secretary of the Navy and should be accompanied by a power to inspect the application and a copy of the application, including drawings.

Applicant and his assignees are authorized to disclose the subject matter of this application to the head of any Department or independent agency of the Government of the United States, to the head of any Bureau of any such Department, or to any subordinate officer or employee thereof known to the party making disclosure to be concerned directly in an official capacity with the subject matter, or designated specifically by the head of the Department, independent agency or Bureau as the proper party to receive confidential disclosures of such nature.

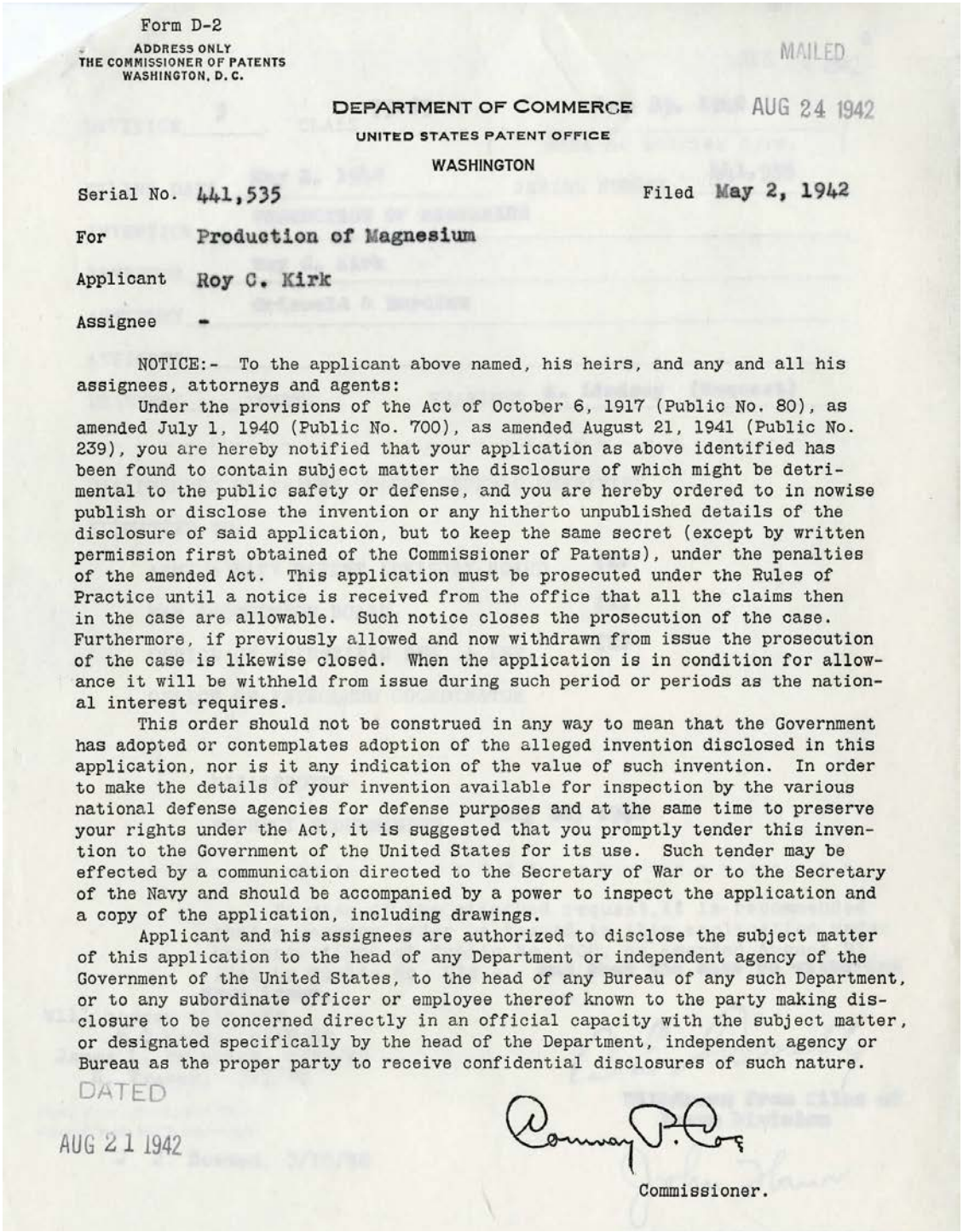
DATED

AUG 21 1942

Conway P. Coe

Commissioner.

Figure B.4: Example Secrecy Order: Individual



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AUG 24 1942

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Serial No. 441,535 Filed May 2, 1942

For Production of Magnesium

Applicant Roy C. Kirk

Assignee -

NOTICE:- To the applicant above named, his heirs, and any and all his assignees, attorneys and agents:

Under the provisions of the Act of October 6, 1917 (Public No. 80), as amended July 1, 1940 (Public No. 700), as amended August 21, 1941 (Public No. 239), you are hereby notified that your application as above identified has been found to contain subject matter the disclosure of which might be detrimental to the public safety or defense, and you are hereby ordered to in nowise publish or disclose the invention or any hitherto unpublished details of the disclosure of said application, but to keep the same secret (except by written permission first obtained of the Commissioner of Patents), under the penalties of the amended Act. This application must be prosecuted under the Rules of Practice until a notice is received from the office that all the claims then in the case are allowable. Such notice closes the prosecution of the case. Furthermore, if previously allowed and now withdrawn from issue the prosecution of the case is likewise closed. When the application is in condition for allowance it will be withheld from issue during such period or periods as the national interest requires.

This order should not be construed in any way to mean that the Government has adopted or contemplates adoption of the alleged invention disclosed in this application, nor is it any indication of the value of such invention. In order to make the details of your invention available for inspection by the various national defense agencies for defense purposes and at the same time to preserve your rights under the Act, it is suggested that you promptly tender this invention to the Government of the United States for its use. Such tender may be effected by a communication directed to the Secretary of War or to the Secretary of the Navy and should be accompanied by a power to inspect the application and a copy of the application, including drawings.

Applicant and his assignees are authorized to disclose the subject matter of this application to the head of any Department or independent agency of the Government of the United States, to the head of any Bureau of any such Department, or to any subordinate officer or employee thereof known to the party making disclosure to be concerned directly in an official capacity with the subject matter, or designated specifically by the head of the Department, independent agency or Bureau as the proper party to receive confidential disclosures of such nature.

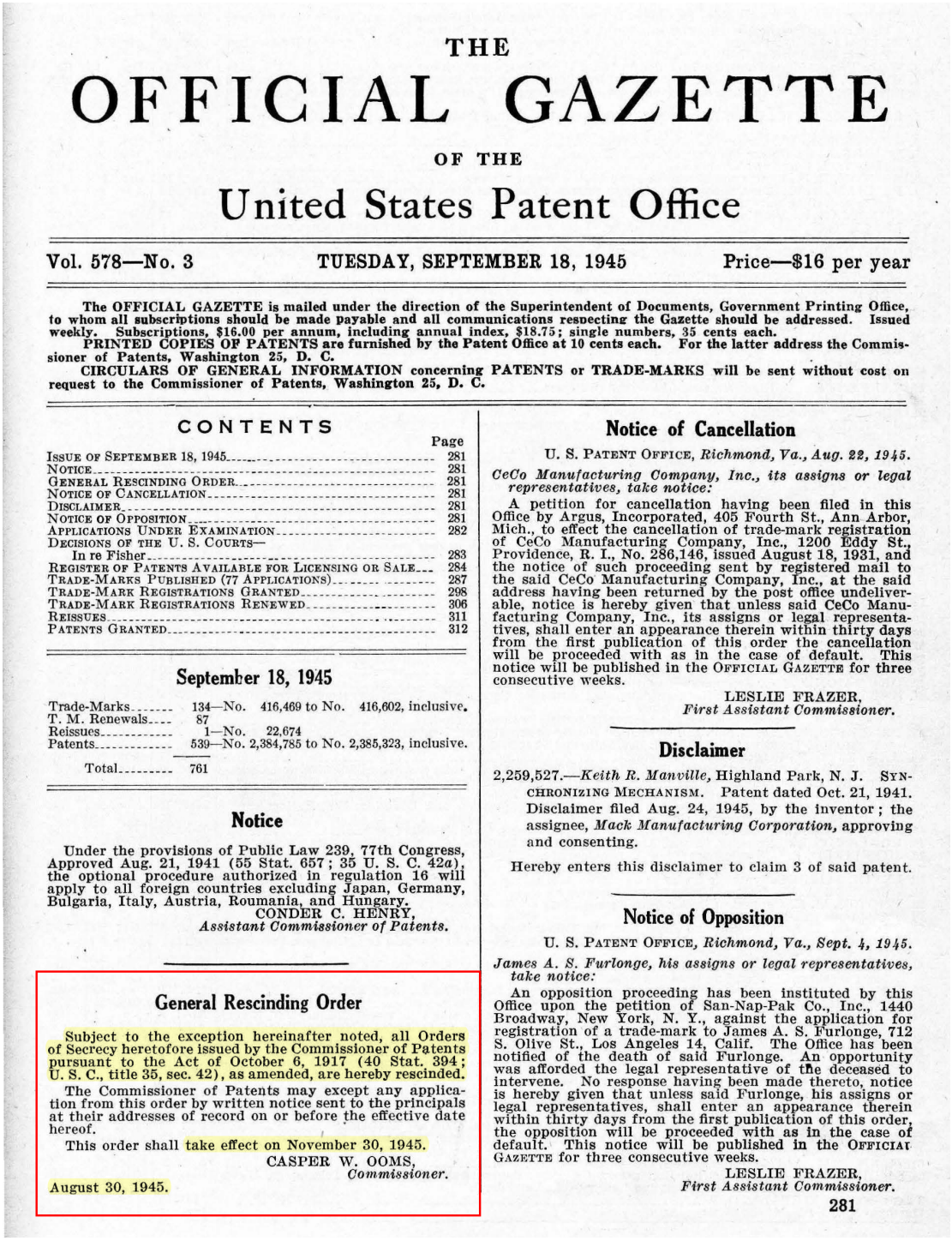
DATED

AUG 21 1942

Conway P. Coe

Commissioner.

Figure B.5: Notice of General Rescinding Order in USPTO Official Gazette



THE

OFFICIAL GAZETTE

OF THE

United States Patent Office

Vol. 578—No. 3 TUESDAY, SEPTEMBER 18, 1945 Price—$16 per year

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PRINTED COPIES OF PATENTS are furnished by the Patent Office at 10 cents each. For the latter address the Commissioner of Patents, Washington 25, D. C.

CIRCULARS OF GENERAL INFORMATION concerning PATENTS or TRADE-MARKS will be sent without cost on request to the Commissioner of Patents, Washington 25, D. C.

CONTENTS

September 18, 1945

Trade-Marks	134	No. 416,469 to No. 416,602, inclusive.
T. M. Renewals	87	
Reissues	1	No. 22,674
Patents	539	No. 2,384,785 to No. 2,385,323, inclusive.
Total	761	

Notice

Under the provisions of Public Law 239, 77th Congress, Approved Aug. 21, 1941 (55 Stat. 657; 35 U. S. C. 42*a*), the optional procedure authorized in regulation 16 will apply to all foreign countries excluding Japan, Germany, Bulgaria, Italy, Austria, Roumania, and Hungary.

CONDER C. HENRY,
Assistant Commissioner of Patents.

General Rescinding Order

Subject to the exception hereinafter noted, all Orders of Secrecy heretofore issued by the Commissioner of Patents pursuant to the Act of October 6, 1917 (40 Stat. 394; U. S. C., title 35, sec. 42), as amended, are hereby rescinded.

The Commissioner of Patents may except any application from this order by written notice sent to the principals at their addresses of record on or before the effective date hereof.

This order shall take effect on November 30, 1945.

CASPER W. OOMS,
Commissioner.

August 30, 1945.

Notice of Cancellation

U. S. PATENT OFFICE, *Richmond, Va., Aug. 22, 1945.*

CeCo Manufacturing Company, Inc., its assigns or legal representatives, take notice:

A petition for cancellation having been filed in this Office by Argus, Incorporated, 405 Fourth St., Ann Arbor, Mich., to effect the cancellation of trade-mark registration of CeCo Manufacturing Company, Inc., 1200 Eddy St., Providence, R. I., No. 286,146, issued August 18, 1931, and the notice of such proceeding sent by registered mail to the said CeCo Manufacturing Company, Inc., at the said address having been returned by the post office undeliverable, notice is hereby given that unless said CeCo Manufacturing Company, Inc., its assigns or legal representatives, shall enter an appearance therein within thirty days from the first publication of this order the cancellation will be proceeded with as in the case of default. This notice will be published in the OFFICIAL GAZETTE for three consecutive weeks.

LESLIE FRAZER,
First Assistant Commissioner.

Disclaimer

2,259,527.—*Keith R. Manville,* Highland Park, N. J. SYNCHRONIZING MECHANISM. Patent dated Oct. 21, 1941. Disclaimer filed Aug. 24, 1945, by the inventor; the assignee, *Mack Manufacturing Corporation,* approving and consenting.

Hereby enters this disclaimer to claim 3 of said patent.

Notice of Opposition

U. S. PATENT OFFICE, *Richmond, Va., Sept. 4, 1945.*

James A. S. Furlonge, his assigns or legal representatives, take notice:

An opposition proceeding has been instituted by this Office upon the petition of San-Nap-Pak Co., Inc., 1440 Broadway, New York, N. Y., against the application for registration of a trade-mark to James A. S. Furlonge, 712 S. Olive St., Los Angeles 14, Calif. The Office has been notified of the death of said Furlonge. An opportunity was afforded the legal representative of the deceased to intervene. No response having been made thereto, notice is hereby given that unless said Furlonge, his assigns or legal representatives, shall enter an appearance therein within thirty days from the first publication of this order, the opposition will be proceeded with as in the case of default. This notice will be published in the OFFICIAL GAZETTE for three consecutive weeks.

LESLIE FRAZER,
First Assistant Commissioner.

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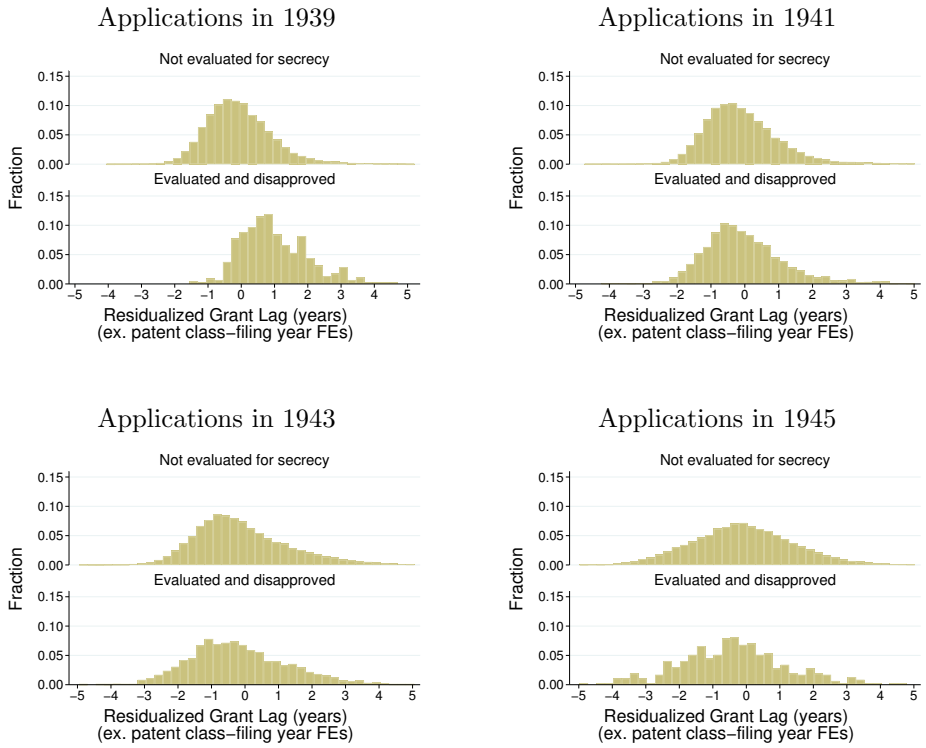
C Additional Descriptives

This appendix section provides descriptive results which supplement those in the paper.

Figure C.1 provides a counterpart to Figure 3 in the paper, comparing the grant lags of (i) patents formally evaluated for secrecy but not ordered secret, versus (ii) those not evaluated for secrecy. The figure shows little difference in grant lags as a result of simply being *evaluated* for secrecy (note that 1939 filings are included in this figure for completeness, because many were evaluated for secrecy, but a necessary condition was that they were still pending as of July 1940 – such that this set is selected on longer pendency). Recall, on the other hand, that Figure 3 compared the grant lags of secret versus non-secret patents, and showed that secret patents on average took longer to issue than their non-secret counterparts in the same class and filing year, with the difference diminishing over time. The results suggest that it was secrecy orders – rather than secrecy evaluations – which were the cause of the time-varying delays in patent grant and publication.

Figure C.1: Grant lags of non-secret applications evaluated for secrecy, vs. others, 1939-1945



Notes: Figure shows the distribution residual grant lags of patent applications evaluated for secrecy but not issued a secrecy order versus those not evaluated for secrecy, after controlling for patent class-year FEs. Note that patent applications 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).

Table C.1 provides a more detailed look at who the OSRD contractors are, providing context for the analysis in Section 4 which splits patents into subsamples of OSRD and non-OSRD firms – i.e., firms which were performing R&D under contract for the war effort, versus those which were not – to draw out differences in the effects. The table examines the set of all assignees who filed a patent in the 1940s, and the patents filed in this period with a known assignee. Out of nearly 135,000 unique assignees, roughly 21,000 were firms. Of these, the majority (66%) filed no patents in the 1930s, and nearly 90% filed fewer than 10 patents. Many of the OSRD assignees, on the other hand, were among the most active filers in this era. Nearly 85% were firms, and the distribution skews towards large, R&D-intensive outfits like Bell Labs, General Electric, Westinghouse, Du Pont, and so on. Although OSRD assignees comprise only 0.2% of assignees in the 1940s, they account for 19.1% of patents, and nearly 35% of patents filed by firms.

Table C.1: Characteristics of OSRD and non-OSRD patent filing in the 1940s

	All assignees		**Non-OSRD assignees**		**OSRD assignees**	
	Number	**Percent of firms**	**Number**	**Percent of firms**	**Number**	**Percent of firms**
Patents	375,681		303,769		71,912	
Assignees	134,794		134,488		306	
Firms	21,117	100.0%	20,862	100.0%	255	100.0%
with 0 patents in 1930s	13,851	65.6%	13,808	66.2%	43	16.9%
with 1-5 patents	3,984	18.9%	3,949	18.9%	35	13.7%
with 6-10 patents	1,043	4.9%	1,028	4.9%	15	5.9%
with 11-20 patents	905	4.3%	891	4.3%	14	5.5%
with 21-50 patents	783	3.7%	740	3.5%	43	16.9%
with 51-100 patents	292	1.4%	256	1.2%	36	14.1%
with 101-200 patents	143	0.7%	119	0.6%	24	9.4%
with 501+ patents	85	0.4%	57	0.3%	28	11.0%
with 201-500 patents	85	0.4%	57	0.3%	28	11.0%
with 501+ patents	31	0.1%	14	0.1%	17	6.7%

OSRD percent of...	
Assignees	0.2%
Patents	19.1%
Patents by firms	34.7%

Notes: Table shows characteristics of assignees who filing in the 1940s, focusing on the number of all / non-OSRD / OSRD assignees, the number which were firms, and the fraction of those with zero, few, or many patents in the prior decade. The table illustrates that the OSRD contractors are disproportionately large, R&D-intensive firms.

D Robustness Checks and Supplementary Results

This appendix section provides additional results which supplement those in the paper.

Table D.1: Effects of secrecy on probability of any forward citations excl. secrecy orders rescinded prior to the General Rescinding Order (August 30, 1945)

				Triple difference	
	All	Non-OSRD	OSRD	Baseline	OSRD
Secrecy ordered	-0.013	-0.074*	0.034	-0.075*	0.113**
	(0.025)	(0.042)	(0.034)	(0.040)	(0.049)
* filed in 1941	-0.019	0.017	-0.039	0.019	-0.073
	(0.028)	(0.052)	(0.039)	(0.050)	(0.063)
* filed in 1942	0.022	0.050	-0.004	0.055	-0.069
	(0.027)	(0.045)	(0.037)	(0.044)	(0.055)
* filed in 1943	0.029	0.088*	-0.026	0.085*	-0.106*
	(0.027)	(0.047)	(0.035)	(0.045)	(0.055)
* filed in 1944	0.036	0.085*	-0.010	0.092*	-0.108**
	(0.029)	(0.050)	(0.037)	(0.048)	(0.054)
* filed in 1945	0.042	0.135***	-0.005	0.144***	-0.171***
	(0.030)	(0.049)	(0.044)	(0.047)	(0.057)
Secrecy evaluated	0.020	0.034*	-0.006	0.038**	-0.045*
	(0.014)	(0.018)	(0.022)	(0.017)	(0.025)
* filed in 1941	0.009	-0.000	0.023	-0.003	0.025
	(0.015)	(0.020)	(0.025)	(0.019)	(0.029)
* filed in 1942	-0.004	-0.018	0.012	-0.020	0.031
	(0.015)	(0.020)	(0.024)	(0.019)	(0.025)
* filed in 1943	0.009	-0.007	0.027	-0.012	0.041
	(0.016)	(0.021)	(0.024)	(0.019)	(0.027)
* filed in 1944	0.006	-0.015	0.024	-0.018	0.045
	(0.017)	(0.023)	(0.024)	(0.022)	(0.028)
* filed in 1945	0.011	-0.001	0.015	-0.013	0.047
	(0.019)	(0.027)	(0.026)	(0.025)	(0.033)
Constant	0.704***	0.673***	0.983***	0.702***	0.702***
	(0.054)	(0.059)	(0.046)	(0.054)	(0.054)
N	161938	124998	36940	161938	
R^2	0.05	0.05	0.10	0.05	
Grant year FEs	X	X	X	X	
Class-year FEs	X	X	X	X	
Mean of DV	0.86	0.86	0.88	0.86	
s.d. of DV	0.34	0.35	0.32	0.34	

Notes: Table estimates a variant on Table 4 of the paper, excluding secret patents which were granted before the General Rescinding Order (August 30, 1945), and thus whose secrecy orders were rescinded early. See table notes in the body of the paper for additional explanation. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table D.2: Effects of secrecy on probability of any forward citations excl. patents in weapons-related classes (firearms/ammunition/ordnance/explosives)

				Triple difference	
	All	Non-OSRD	OSRD	Baseline	OSRD
Secrecy ordered	-0.007	-0.081**	0.040	-0.078**	0.124***
	(0.022)	(0.035)	(0.032)	(0.033)	(0.043)
* filed in 1941	-0.023	0.038	-0.050	0.033	-0.096*
	(0.025)	(0.044)	(0.038)	(0.043)	(0.056)
* filed in 1942	0.015	0.058	-0.010	0.058	-0.083
	(0.023)	(0.041)	(0.034)	(0.040)	(0.051)
* filed in 1943	0.022	0.106**	-0.040	0.098**	-0.134***
	(0.024)	(0.043)	(0.031)	(0.041)	(0.050)
* filed in 1944	0.027	0.090*	-0.018	0.090**	-0.118**
	(0.026)	(0.046)	(0.035)	(0.044)	(0.052)
* filed in 1945	0.030	0.133***	-0.016	0.140***	-0.178***
	(0.028)	(0.043)	(0.044)	(0.041)	(0.051)
Secrecy evaluated	0.013	0.028	-0.012	0.031*	-0.045*
	(0.014)	(0.018)	(0.023)	(0.017)	(0.026)
* filed in 1941	0.019	0.012	0.028	0.007	0.024
	(0.015)	(0.020)	(0.026)	(0.019)	(0.029)
* filed in 1942	0.002	-0.011	0.019	-0.013	0.030
	(0.015)	(0.020)	(0.024)	(0.019)	(0.026)
* filed in 1943	0.016	-0.002	0.035	-0.007	0.045
	(0.016)	(0.021)	(0.024)	(0.020)	(0.028)
* filed in 1944	0.014	-0.008	0.032	-0.011	0.049*
	(0.017)	(0.024)	(0.025)	(0.023)	(0.029)
* filed in 1945	0.020	0.007	0.024	-0.006	0.050
	(0.019)	(0.027)	(0.027)	(0.026)	(0.034)
Constant	0.714***	0.683***	0.983***	0.711***	0.711***
	(0.054)	(0.059)	(0.046)	(0.054)	(0.054)
N	160313	123436	36877	160313	
R^2	0.05	0.05	0.10	0.05	
Grant year FEs	X	X	X	X	
Class-year FEs	X	X	X	X	
Mean of DV	0.86	0.86	0.88	0.86	
s.d. of DV	0.34	0.35	0.32	0.34	

Notes: Table estimates a variant on Table 4 of the paper, excluding patents in weapons-related classes with strictly military application (USPC 42, 86, 89, 102, and 149, covering firearms, ammunition, ordnance, and explosives). See table notes in the body of the paper for additional explanation. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table D.3: Effects of secrecy on probability of assorted types of forward citations

	All	Non-self	Self	Firms	Indivs.
Secrecy ordered	-0.071**	-0.062*	0.004	-0.095**	0.020
	(0.034)	(0.036)	(0.046)	(0.040)	(0.070)
* filed in 1941	0.026	0.022	-0.014	0.063	-0.039
	(0.043)	(0.044)	(0.049)	(0.044)	(0.069)
* filed in 1942	0.052	0.051	-0.010	0.084*	-0.042
	(0.040)	(0.042)	(0.048)	(0.045)	(0.073)
* filed in 1943	0.089**	0.093**	0.034	0.102**	-0.003
	(0.042)	(0.043)	(0.050)	(0.048)	(0.074)
* filed in 1944	0.084*	0.076*	0.040	0.134**	0.050
	(0.044)	(0.046)	(0.058)	(0.055)	(0.080)
* filed in 1945	0.132***	0.125***	0.059	0.143**	0.101
	(0.042)	(0.044)	(0.071)	(0.070)	(0.088)
Secrecy evaluated	0.035*	0.041**	0.036*	0.057***	0.019
	(0.018)	(0.019)	(0.019)	(0.022)	(0.025)
* filed in 1941	-0.001	-0.005	0.005	-0.001	0.016
	(0.020)	(0.021)	(0.023)	(0.025)	(0.032)
* filed in 1942	-0.018	-0.023	-0.011	-0.009	-0.020
	(0.020)	(0.021)	(0.021)	(0.024)	(0.031)
* filed in 1943	-0.008	-0.018	-0.017	0.004	-0.027
	(0.021)	(0.022)	(0.024)	(0.029)	(0.029)
* filed in 1944	-0.016	-0.018	-0.028	-0.007	-0.037
	(0.023)	(0.023)	(0.024)	(0.029)	(0.032)
* filed in 1945	-0.002	-0.007	0.005	0.003	-0.041
	(0.027)	(0.027)	(0.035)	(0.041)	(0.047)
Constant	0.673***	0.665***	0.030	0.419***	0.543***
	(0.059)	(0.060)	(0.026)	(0.069)	(0.061)
N	125335	125335	125335	125335	125335
R^2	0.05	0.05	0.05	0.11	0.10
Grant year FEs	X	X	X	X	X
Class-year FEs	X	X	X	X	X
Mean of DV	0.86	0.84	0.11	0.69	0.60
s.d. of DV	0.35	0.37	0.32	0.46	0.49

Notes: Table expands on Tables 4 and 5 in the paper, estimating effects on the likelihood of various types of forward citations. Column (1) repeats the baseline result for all citations. Columns (2) and (3) examine non-self and self citations, respectively. Columns (4) and (5) examine citations from firms and individuals. See table notes in the body of the paper for additional explanation. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table D.4: Effects of secrecy on (i) probability of exceeding various thresholds in the number of forward citations, and (ii) forward citation counts

	OLS						Poisson
	≥1	≥2	≥4	≥6	≥8	≥10	Count
Secrecy ordered	-0.071**	-0.071*	0.027	0.074	0.037	0.007	1.011
	(0.034)	(0.043)	(0.060)	(0.054)	(0.047)	(0.042)	(0.149)
* filed in 1941	0.026	0.045	-0.043	-0.084	-0.067	-0.007	0.989
	(0.043)	(0.045)	(0.060)	(0.057)	(0.055)	(0.055)	(0.196)
* filed in 1942	0.052	0.050	-0.030	-0.055	0.017	0.040	1.239
	(0.040)	(0.050)	(0.064)	(0.063)	(0.057)	(0.044)	(0.203)
* filed in 1943	0.089**	0.093*	0.040	0.033	0.049	0.076	1.253
	(0.042)	(0.052)	(0.065)	(0.057)	(0.052)	(0.047)	(0.262)
* filed in 1944	0.084*	0.142**	0.048	0.011	0.026	0.062	1.309**
	(0.044)	(0.059)	(0.075)	(0.069)	(0.058)	(0.050)	(0.162)
* filed in 1945	0.132***	0.173***	0.126	0.057	0.132	0.127	1.660***
	(0.042)	(0.064)	(0.088)	(0.111)	(0.112)	(0.114)	(0.213)
Secrecy evaluated	0.035*	0.062***	0.057**	0.041	0.044*	0.024	1.233***
	(0.018)	(0.022)	(0.028)	(0.026)	(0.024)	(0.020)	(0.077)
* filed in 1941	-0.001	-0.004	0.016	0.034	0.036	0.040*	1.071
	(0.020)	(0.025)	(0.033)	(0.029)	(0.027)	(0.024)	(0.076)
* filed in 1942	-0.018	-0.026	-0.012	0.015	-0.001	0.006	0.926
	(0.020)	(0.023)	(0.032)	(0.029)	(0.028)	(0.022)	(0.054)
* filed in 1943	-0.008	-0.027	-0.007	0.009	0.000	0.006	0.971
	(0.021)	(0.030)	(0.033)	(0.031)	(0.028)	(0.025)	(0.063)
* filed in 1944	-0.016	-0.010	-0.001	0.005	-0.018	-0.018	0.992
	(0.023)	(0.029)	(0.036)	(0.033)	(0.031)	(0.024)	(0.073)
* filed in 1945	-0.002	-0.027	-0.005	0.009	-0.008	0.011	1.047
	(0.027)	(0.042)	(0.049)	(0.048)	(0.047)	(0.043)	(0.110)
Constant	0.673***	0.511***	0.324***	0.155***	0.067*	0.032	
	(0.059)	(0.065)	(0.060)	(0.049)	(0.035)	(0.025)	
N	125335	125335	125335	125335	125335	125335	125322
R^2	0.05	0.06	0.07	0.07	0.06	0.06	
Filing year FEs							X
Grant year FEs	X	X	X	X	X	X	X
Class-year FEs	X	X	X	X	X	X	
Mean of DV	0.86	0.70	0.44	0.28	0.18	0.11	4.44
s.d. of DV	0.35	0.46	0.50	0.45	0.38	0.32	5.24

Notes: Columns (1) to (6) expand on Tables 4 and 5 in the paper, estimating effects on the likelihood of exceeding various thresholds in forward citations, as indicated in the header of each column. See table notes in the body of the paper for additional explanation. Column (7) estimates effects on forward citation counts with a conditional fixed-effects Poisson model to account for the count nature of the dependent variable, limiting the fixed effects to filing year and grant year only (due to the limitations of the estimation method). Column (7) reports incidence-rate ratios for ease of interpretation. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table D.5: Effects of secrecy on probability of citation in a given year since filing

	2 years	3 years	4 years	5 years	10 years	15 years	20 years	25 years
Secrecy ordered	0.004	-0.076	-0.019	0.045	0.017	-0.033	0.041	0.015
	(0.036)	(0.054)	(0.052)	(0.056)	(0.044)	(0.033)	(0.043)	(0.028)
* filed in 1941	0.003	0.050	0.029	0.015	-0.003	0.048	-0.052	-0.021
	(0.041)	(0.067)	(0.053)	(0.064)	(0.048)	(0.043)	(0.043)	(0.032)
* filed in 1942	-0.034	0.081	0.077	-0.005	-0.005	0.028	-0.029	-0.011
	(0.038)	(0.057)	(0.055)	(0.062)	(0.047)	(0.041)	(0.048)	(0.032)
* filed in 1943	0.019	0.170***	0.091	0.021	0.029	0.049	-0.019	-0.002
	(0.045)	(0.063)	(0.064)	(0.058)	(0.052)	(0.040)	(0.044)	(0.028)
* filed in 1944	0.063	0.133**	0.056	0.023	0.006	0.066	-0.027	-0.013
	(0.054)	(0.058)	(0.067)	(0.065)	(0.056)	(0.042)	(0.046)	(0.032)
* filed in 1945	0.094	0.243***	0.170**	0.099	-0.000	0.042	-0.021	0.039
	(0.064)	(0.079)	(0.080)	(0.108)	(0.090)	(0.059)	(0.064)	(0.042)
Secrecy evaluated	0.024**	0.080***	0.075***	0.035	0.010	0.003	-0.008	-0.018
	(0.011)	(0.021)	(0.024)	(0.024)	(0.021)	(0.016)	(0.017)	(0.014)
* filed in 1941	0.010	-0.004	-0.001	0.017	0.028	0.019	0.024	0.024
	(0.014)	(0.023)	(0.029)	(0.030)	(0.023)	(0.020)	(0.019)	(0.017)
* filed in 1942	0.020	-0.028	-0.025	-0.004	0.034	0.019	0.018	0.015
	(0.016)	(0.021)	(0.028)	(0.028)	(0.023)	(0.017)	(0.019)	(0.017)
* filed in 1943	0.021	-0.049*	-0.040	-0.015	0.018	-0.005	0.022	0.027*
	(0.019)	(0.027)	(0.028)	(0.029)	(0.022)	(0.019)	(0.020)	(0.016)
* filed in 1944	0.022	-0.065**	-0.044	-0.025	0.004	0.016	-0.000	0.012
	(0.022)	(0.026)	(0.031)	(0.030)	(0.027)	(0.022)	(0.021)	(0.014)
* filed in 1945	0.042	-0.059*	-0.064*	-0.036	-0.029	0.040	0.009	0.020
	(0.030)	(0.031)	(0.037)	(0.037)	(0.034)	(0.030)	(0.026)	(0.020)
Constant	0.103***	0.155***	0.191***	0.203***	0.149***	0.114***	0.082***	0.055***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	125335	125335	125335	125335	125335	125335	125335	125335
R^2	0.08	0.07	0.05	0.04	0.03	0.03	0.03	0.03
Class-year FEs	X	X	X	X	X	X	X	X
Mean of DV	0.09	0.14	0.18	0.19	0.16	0.12	0.09	0.06
s.d. of DV	0.28	0.34	0.38	0.40	0.36	0.32	0.28	0.23

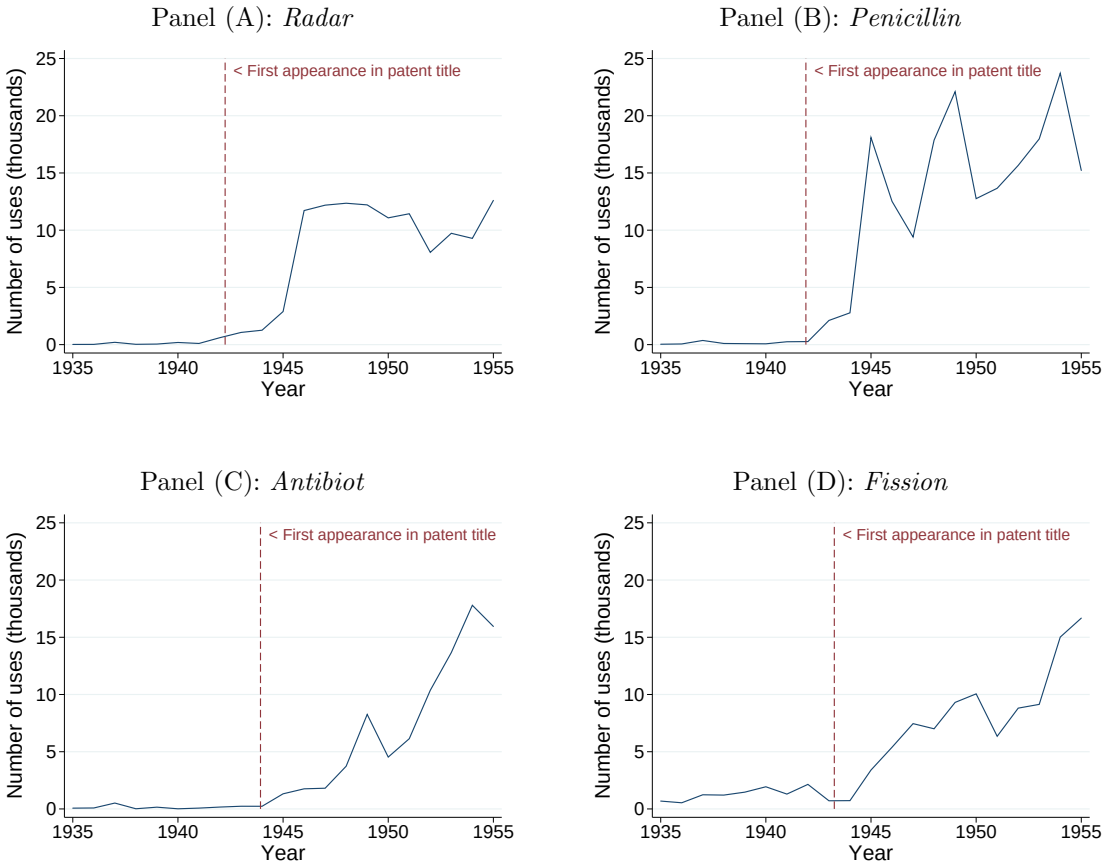
Notes: Columns (1) to (7) estimate effects on the likelihood of receiving any forward citations from future patents filed in a given number of years (in this table: 2, 3, 4, 5, 10, 15, 20, and 25) since the focal patent's filing. All columns control for post-February 1947 examination lags (i.e., time elapsed between February 1947, when the citation record begins, and grant), to account for the fact that patents are not citeable until issued, and these delays can mechanically reduce citations within fixed windows since filing. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by patent class in parentheses.

Table D.6: Annual use of new word stems from secret vs. non-secret patent titles in the Google Books corpus, difference-in-differences, w/ multiple periods

	Percent of words (x1e6)			Percent of works (x1e3)		
	75th	90th	95th	75th	90th	95th
Secrecy ordered x 1940-1945	0.102	0.073	0.111	1.155	0.961	0.521
	(0.092)	(0.079)	(0.092)	(0.800)	(0.753)	(1.426)
Secrecy ordered x post-1945	0.518*	0.455**	0.536**	6.337**	7.267**	6.786**
	(0.271)	(0.229)	(0.230)	(3.098)	(2.865)	(2.977)
Secrecy evaluated x 1940-1945	0.016	-0.011	0.016	0.132	-0.361	1.147
	(0.020)	(0.023)	(0.029)	(0.257)	(0.331)	(0.789)
Secrecy evaluated x post-1945	0.003	-0.014	-0.002	0.124	-0.301	0.589
	(0.022)	(0.027)	(0.032)	(0.349)	(0.444)	(0.863)
1940-1945	0.030***	0.070***	0.079***	0.752***	1.468***	1.322***
	(0.006)	(0.012)	(0.012)	(0.127)	(0.235)	(0.254)
Post-1945	0.054***	0.099***	0.115***	1.295***	2.250***	2.583***
	(0.010)	(0.013)	(0.015)	(0.185)	(0.274)	(0.316)
Constant	0.020*	0.129***	0.328***	0.721***	3.955***	11.511***
	(0.011)	(0.011)	(0.012)	(0.143)	(0.182)	(0.212)
N	16989	20433	21567	16989	20433	21567
R^2	0.53	0.69	0.88	0.63	0.87	0.98
Stem FEs	X	X	X	X	X	X
Mean of DV	0.07	0.21	0.42	1.79	5.63	13.46
s.d. of DV	0.44	0.61	1.18	5.76	13.27	38.78

Notes: Table expands on Table 8 of the paper by separating the pre-1940, 1940-1945, and post-1945 periods in estimating difference-in-differences effects for Google Books corpus stem frequency. See table notes in the body of the paper. *, **, *** represent significance at the 0.1, 0.05, and 0.01 levels, respectively. SEs clustered by stem in parentheses.

Figure D.1: Usage of select stems from secret patents in Google Books corpus, 1935-1955



Notes: Figure plots annual uses of the given word stems in the Google Books corpus from 1935 to 1955. All are examples of words which first appeared in the title of a patent which was ordered secret. The dashed vertical line marks the filing date of the first patent with the given stem in its title.

E The Aggregate View

Given the scale of the secrecy order program in key fields of invention, it could have plausibly had systemic consequences for innovation in affected technology areas. For example, by curtailing the spread of information about new invention, secrecy orders may have increased barriers to entry in the affected fields or slowed technological progress, and by delaying the granting of property rights over new inventions and evidently hindering commercialization, the program may have distorted incentives for R&D or patenting in sensitive subject matter.

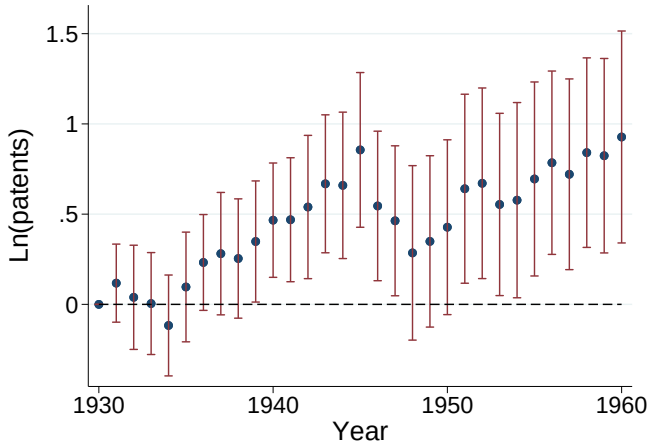
In the results below, I examine aggregate patenting over time at the patent class level, comparing classes which were more versus less affected by secrecy orders in the 1940s, where class-level treatment is defined as the fraction of patents filed between July 1940 and June 1945 which were issued a secrecy order (which I term the class-level "secrecy rate"). Because this measure is skewed (with a few classes heavily affected by secrecy orders, and many only modestly or not at all affected), and sensitive to small numbers, I bin classes into treatment quartiles. The baseline specification for these tests takes the following form, where i indexes patent classes and t indexes years, run on a sample of all patent classes between 1930 and 1960, and controlling for quartiles of the analogously-defined class-level evaluation rate, similar to previous specifications:

$$Ln(Patents)_{it} = \sum_{q=1}^{4} \sum_{t=1931}^{1960} [\beta_{qt}^{1} \cdot \mathbb{1}(\text{Class } i \text{ in secrecy rate quartile } q) + \beta_{qt}^{2} \cdot \mathbb{1}(\text{Class } i \text{ in evaluation rate quartile } q)] + \alpha_i + \delta_t + \varepsilon_{it}$$

This regression compares patent classes in different quartiles of the class-level secrecy rate, with the omitted category being the set of classes in which no patents in the 1940 to 1945 period received a secrecy order (38.4% of 429 classes), and the omitted year being 1930, such that β_{qt}^{1} should be interpreted as the mean difference in the given year between classes in secrecy rate quartile q versus classes without any secrecy orders, relative to the difference in 1930, controlling for secrecy evaluation rates. Standard errors are clustered at the patent class level.

Figure E.1 plots the effects for the top quartile of classes (the β_{4t}^{1} parameters). Even after controlling for selection into evaluation, the most-affected classes were growing quickly before, during, and after the war – although there is a noticeable level decline in 1946-1948, just after the war (and secrecy program) concluded, after which growth resumes on its previous trend. Although this drop-off could potentially be related to secrecy, a causal interpretation is difficult given the myriad adjustments taking place in the immediate aftermath of the war, and it may simply reflect the demobilization of the American research effort in World War II.

Figure E.1: Changes over time in log patenting in patent classes in the top quartile of secrecy order issuance rate from 1940-1945, relative to classes without secrecy orders



Notes: Figure shows the estimated mean difference in log patents for classes in the highest quartile of class-level wartime secrecy rates (defined as the fraction of patents filed in a given class between 1940 and 1945 which were issued a secrecy order), relative to classes without any secrecy orders, by year. Error bars represent 95% confidence intervals, computed from SEs clustered at the patent class level.

Appendix references

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