EFFECTS OF COPYRIGHTS ON SCIENCE*

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Copyrights establish intellectual property in cultural goods, such as music, literature, and science. Intended to encourage creativity, they can however also create significant costs for later generations of authors, inventors, and composers. This paper examines the effects of such costs on science, a field in which the creation of new knowledge depends critically on access to existing work. The empirical analysis examines an important historical change in copyrights as a result of WWII, when the Book Republication Program (BRP) allowed US publishers to violate German-owned copyrights. Using two complementary identification strategies, we find that this change led to a substantial increase in citations to affected books. Intensity regressions show that this increase was driven by reductions in the price of books. A geographic analysis of library holdings and citations suggests that lower prices for BRP books allowed a new group of researchers at less affluent institutions to use these books in their own research. Two alternative ways to measure science – new PhDs and new patents – confirm the main results.

KEYWORDS: COPYRIGHT, SCIENCE, AND ECONOMIC HISTORY.

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Copyrights establish intellectual property in cultural goods, such as music, literature, and science. Existing empirical analyses have highlighted the benefits of basic copyrights, which can encourage the creation of new content by increasing payments to authors.[1] Yet copyrights also impose deadweight loss, akin to monopolies for traditional goods.[2] Moreover, copyrights create significant costs for later generations of authors, inventors, and composers. This paper examines the effects of such costs on science, a field in which the creation of new knowledge depends critically on access to existing work (Scotchmer 1991).

In modern settings, systematic analyses of copyrights face two major empirical challenges. First, the extreme length of modern copyrights allows researchers to observe only exceptionally durable content off copyrights today. Because copyrights last nearly 100 years, cultural goods that are still for sale when they are *off copyright* are an extremely selected sample. A second major challenge is that modern changes in copyrights typically occur in response to lobbying, reflected in names like the 1998 US "Mickey Mouse Protection Act." This makes it extremely difficult to identify the causal effects of changes in copyrights today.

We address these issues by examining an important change in copyright laws as a result of World War II. In 1942, the Book Republication Program (BRP) allowed US publishers to violate German-owned copyrights and to reprint exact copies. By breaking publishers' monopoly for these books, the BRP led to a dramatic decline in price, 25 percent for the average BRP book. This event creates a unique opportunity to examine the effects of a change in access costs for the *same book* under two different copyright regimes. Despite its importance for the history of US science, this program has received little attention from historians and economists, in part because most of the related documentation remained classified until the 1970s.

To examine the effects of the BRP on science, we exploit two complementary identification strategies. The first strategy addresses the issue of selection by comparing changes in citations *to the same BRP book* from English-language authors (who benefitted directly from the American BRP) to changes in citations from authors who published in other languages (and did not benefit directly). Book fixed effects further control for differences in levels of citations across books. Interactions between research fields and year fixed effects

[1] Li et al. (2018) find that extensions in copyrights increase price by improving publishers' ability to practice intertemporal price discrimination. Contract data show that publishers increased payments to authors in response to stronger copyrights (MacGarvie and Moser 2013). Giorcelli and Moser (2018) find that basic levels of copyrights (but not extensions) can increase both the level and the quality of creative output.

[2] Consistent with such deadweight loss, Heald (2014) and Reimers (2018) have shown that books which are slightly less than 95 years old, and therefore still on copyright, are less likely to be available for sale today than books that are slightly older than 95.

control flexibly for differences in trends. A second empirical challenge arises because English-language citations may have increased mechanically with the growth of US science after World War II. To address this challenge, our second identification strategy compares *only English-language citations* between BRP and books with Swiss-owned copyrights. Swiss universities were well integrated into the German academic labor market, and many professors and students were Germans professors living in Switzerland. Yet, books with Swiss-owned copyrights were inaccessible to the BRP, because Switzerland was a neutral country. Triple-differences estimates combine the two identification strategies by comparing the differential change in citations to BRP books from English-language and other authors with the same differential change for Swiss books. These estimates imply a 67 percent increase in English-language citations to BRP books.

To examine the mechanism by which the BRP influenced science, we exploit unique data on changes in the price of BRP books. Intensity regressions suggests that each 10 percent decline in price led to an additional 45 percent increase in citations by English-language authors, compared with citations to the same book by other authors. Regressions that compare English-language citations to BRP and Swiss books yield comparable estimates: Each 10 percent decline in price is associated with an additional 39 percent increase in citations to BRP books compared with English-language citations to books with Swiss-owned copyrights.

Interactions between research fields and year fixed effects control for unobservable factors that may influence citations across fields and over time. For example, citations to some BRP books may have increased more because they were related to the research agenda of a German Jewish émigré.[3] We perform a series of additional tests to investigate the effects of émigrés. Notably, émigré books (or even émigré citations) only account for a small share of our data, less than 10 percent of books in math and less than 15 percent of citations. As a result, excluding émigrés does not substantially change the estimates. Moreover, results are robust to excluding citations from the academic descendants of an émigré (students and students of students). They are also robust to excluding citations from coworkers of émigrés. Interestingly, however, book-level analyses show that books by émigrés experienced an additional increase in citations. These results suggest important complementarities between copyrights and human capital.

[3] Émigrés brought new knowledge to the United States, and their arrival may have increased US innovation in their research fields (e.g., Moser, Voena, and Waldinger 2014).

Next, we examine complementarities with *physical* capital, exploiting differences across disciplines. Previous research on this period has found that human capital mattered more than physical capital for scientific production (Waldinger 2016). We reason that scientists' dependency on physical capital varies across disciplines, and we show that such differences can distort the effects of copyrights on science. Mathematicians, like David Hilbert, create new research with little more capital than a pen and a piece of paper. Therefore, access to a new book can create a large boost in creativity for mathematics. At the opposite extreme, chemists are heavily dependent on laboratory space and other types of physical capital. Hence, a change in access to existing knowledge may create less of an effect because limits on physical capital continue to bind. Predictions from a basic model of knowledge production and empirical estimates from triple-differences regressions confirm this prediction: The benefits of lower book prices were substantially more pronounced in math than in chemistry.

How did lower book prices increase citations? To examine these mechanisms, we first examine records of US library holdings in the National Union Catalog (Library of Congress, 1968-1981). These data reveal a striking difference in the diffusion for BRP and Swiss books: By 1956, BRP books had become available across both rich and poor libraries, whereas Swiss books remained concentrated in the holdings of two wealthy research libraries, Yale and Chicago. A geographic analysis further indicates that books which experienced a larger decline in price had become more diffused beyond the American Northeast. These patterns suggest that the BRP may have increased citations by improving access to BRP books.

Next, we examine *when* and *where* scientists started to use BRP books at new locations. First, we collect information on loans of BRP books from lending cards that are attached to the back of library books. These data show that scientists began to use BRP books around 1946, four years after the BRP. First loans of BRP books peak around 1955, matching the timing of the observed increase in citations. A geographic analysis shows that citations increased most around libraries that received BRP books. Scientists within 25 miles of a BRP book began to cite BRP books more after 1942 than scientists who were further away. Estimates attenuate with increasing distance from BRP books. Importantly, pre-trends in citations are comparable for locations with and without a BRP book.

Most of our analyses examine changes in scientific citations, which correspond closely to scientific knowledge used in R&D (Roach and Cohen 2012) and have become the standard measure for knowledge flows and follow-on science (e.g., Furman and Stern 2012; Iaria et al. 2018). Citations, however, may be a biased measure of knowledge flows (Paris et

al. 1998, Jannot et al. 2013). We examine the potential impact of such biases in more detail below. We also present results from two alternative measures for changes in US science: new PhDs and patents that use knowledge in BRP books. Data on newly minted PhDs in math confirm the expansion in the geographic scope of citations. Universities located within 25 miles of BRP books produce 2.2 times more PhDs per year after the BRP compared with universities located further away. An analysis of US patents indicates a 15 percent increase in patents that use BRP books. Notably, there are no significant differences in pre-trends for PhD theses or US patents across locations with and without BRP books.

Our findings highlight the important tradeoff between the positive effects of copyrights on creativity (Giorcelli and Moser 2018) and the potential welfare loss that copyrights impose by restricting access to existing work (Reimers forthcoming, Nagaraj forthcoming). Exploiting exogenous variation in the adoption of copyright laws in Italy, Giorcelli and Moser (2018) find that basic levels of copyrights raised both the quantity and quality of new operas. Copyrights, however, also appear to negatively influence the availability of books that are for sale today (Reimers forthcoming) as well as access to images that appear on Wikipedia (Nagaraj forthcoming). In the context of early 20th-science, Iaira, Schwarz, and Waldinger (2018) find that a boycott of enemy science during World War I discouraged the creation of new science.[4] Our findings connect these two strands of research by examining the effects of intellectual property on knowledge flows and the creation of new science.

More broadly, our findings contribute to the literature on the effects of intellectual property rights on the creation of cumulative (or follow-on) science and innovation. Existing research on patents has found that policies which weaken patents can encourage cumulative invention (e.g., Galasso and Schankerman 2015, Moser and Voena 2012, Sampat and Williams forthcoming). Yet, results from analyses of patents do not generalize to copyrights, which create a very different type of property right. Compared with patents, copyrights are much more narrow and long-lived, avoiding many of the pitfalls that result from overly broad patents, but also creating new challenges due to their exceptionally long duration.

A growing interdisciplinary literature on open access has found that articles which are available for free are cited more by new research, suggesting that open access facilitates

[4] Related work on cumulative science has found that the creation of biological research centers, which facilitate access to biological materials, have encouraged follow-on science (Furman and Stern 2012). Exploiting the development of genetically engineered research mice, Murray et al (2017) show that access can also encourage researchers to pursue more diverse and exploratory projects.

follow-on science.[5] Based on this intuition, funding agencies increasingly require grant recipients to make new papers available for free.[6] Most closely related to our work, a recent working paper by Bryan and Ozcan (2018) finds that open access mandates from the National Institute of Health (NIH) have increased citations to biomedical research by inventors.

Our analysis extends the existing literature on open access in two ways. First, we exploit credibly exogenous historical variation in the enforcement of copyright laws to examine effects of copyrights on follow-on science. Second, we examine effects of *lower* prices. Compared with policies that enforce open access, lower prices (or subsidies) offer more flexible policy instruments to encourage follow-on science while maintaining incentives for publication. Our findings suggest that such policies may be particularly important for researchers at institutions that are less well-funded or in low-income countries.

The remainder of the paper is structured as follows. Section I summarizes relevant institutional details about the BRP. Section II describes the data on citations. Section III presents estimates of the aggregate effects of the BRP, and section IV investigates the effects of changes in price. Section V presents a geographic analysis of library holdings and changes in the location of citing authors. Section VI examines two alternative proxies for advances in science, and Section VII concludes.

I. Institutional Background

Until the BRP, German-owned copyrights were protected for the same length of time as American books - 56 years under the 1909 Copyright Act.[7] Germany was at the forefront of research in the sciences, and US researchers depended heavily on access to these books. At the onset of World War II, the President of the American Library Association Ralph Munn wrote to Secretary of State Hull

[5] For example, see the influential analyses of Lawrence (2001), Eysenbach (2006), and Evans and Reimer (2009). McCabe and Snyder (2014, 2015), however, show that even basic controls for quality reduce the correlation between open access and citations. Davis et al. (2008) address the issue of selection by randomly assign articles to open access across 11 journals of the American Physiological Society. They find that scientists are more likely to download (but not cite) open access articles within 12 months. This window may, however, be too short to capture the full effects on the creation of new knowledge. Our research addresses this issue by examining the full life-cycle of citations over a period of several decades.

[6] See, for example Bill & Melinda Gates Foundation Open Access Policy (http://www.gatesfoundation.org/how-we-work/general-information/open-access-policy, accessed December 3, 2015).

[7] The 1909 Act extended copyrights to all works of authorship, including music (Varian 2005, p. 124), and increased copyright length from 14 to 28 years, renewable for an additional 28 years. These terms remained in place until the 1976 Copyright Act. See Goldstein (2003) for a history of copyrights. Equal treatment had been established by international copyright treaties (April 15, 1892, United States Copyright Office, Circular 38A). The 1892 treaty extended the 1891 International Copyright Act, which had granted copyrights to foreign books that had been typeset in the United States (*Manufacturing Clause*, Columbia Law Association 1950, p. 686).

> "Germany has made, and is making, many contributions to man's knowledge […] The world of scholarship can not afford to be deprived of the German contribution to this knowledge" (cited in Richards 1981, p. 254).

In that year, the United States had spent a total of $1.5 million ($54.2 million in year 2016 dollars) on foreign books and journals, mostly by German scientists (Richards 1981, p. 253).

Throughout the mid 1940s, US libraries were able to source German books through agents in Switzerland and other neutral countries. In 1940, Thomas Fleming of the Columbia Medical School Library explained that "the British have been confiscating no publications sent to American libraries, and that is about all there is to the situation" (Richards 1981, p. 254). When the Department of State prohibited money transfers to Germany, the Federal Government's Interdepartmental Committee for the Acquisition of Foreign Publications and the library-sponsored Joint Committee began to transfer German publications onto microfilm to distribute across the United States (Richards 1981, p. 255).

On July 6, 1942, President Roosevelt's Executive Order No. 9193 authorized the US Alien Property Custodian to "direct, manage, supervise, control or vest […] Patents, patent applications, copyrights, copyright applications, trademarks, or trademark applications or rights" (Myron 1945, p. 76). Now a prominent group of librarians and scientists urged the Custodian to seize German-owned copyrights to reduce payments to Nazi Germany (Richards 1981, p. 255). Between 1942 and 1944, the Custodian seized all enemy-owned copyrights and patents.[8]

Starting in 1942, 36 US publishers bid on temporary licenses to republish exact copies of enemy-owned books (Myron 1945, p. 85). Two publishers, Dover and J.W. Edwards, won the largest number of bids (Bokas and Edwards 2011, p. 22). J.W. Edwards had already bought German machines that allowed quick republication, and licensed 650 titles from the Alien Property Custodian (Bokas and Edwards 2011, p. 23).[9] Licenses were limited to 6 months and non-extendable (Myron 1945, p. 85). As a result, publishers faced a threat of competitive entry, which effectively broke their monopoly on a book.[10]

[8] *Forty-sixth Annual Record of the Register of Copyrights* 1944, p. 8.
[9] "…considerable royalties amounting to many thousands of dollars were accumulated and remitted to the U.S. Government for the benefit of the original copyright owner" (Bokas and Edwards 2011, p. 25).
[10] Menu costs from printing catalogues were substantial, so that publishers could not adjust prices dynamically and instead charged a single price for each edition.

In the 1940s most scientists still read German, so that US publishers simply copied the original text (Ammon 2001).[11] For example, JW Edwards re-published an exact copy of Beilstein's (1918) *Handbuch der Organischen Chemie*, "a critical tool for every organic chemist working in a lab until the early 1970s." By the 1960s, many BRP books were translated to English. The first English version of Beilstein appeared in 1960 (Luckenback, 1981). As soon as English versions became available, US researchers began to use and cite them instead of the original BRP book. Limiting the analysis to citations to the German-language original, therefore estimates a lower bound of the true effects of the BRP.

II. DATA

Our main data include BRP books in chemistry and mathematics, a control group of Swiss books in the same fields, and all new articles and books that cite BRP and Swiss books between 1920 and 1970. Two alternative measures for scientific output capture new PhDs theses in mathematics and US patents that use knowledge in BRP books.

A. Information on Books in the BRP and Their Changes in Price

We collect the full list of all 334 BRP books from a 1944 publication of the Alien Property Custodian Office: *Book Republication Program: Titles Suggested for Republication, an Alphabetical List with a Subject Index*. For all 334 books, including 274 in chemistry and 60 in mathematics, the Custodian (1944, pp. 1-102) lists the title, author, research field, publication year, and publication city.[12] The first book in alphabetical order is

> Aberhalden, Emil, *Handbuch der Biologischen Arbeitsmethoden. Abt. 3: Physikalisch-chemische Methoden*. Berlin, Springer, 1928-30.3 vols. Field: Chemistry, Physical and Theoretical. Original price: $128.00. Reproduction: $84.50, set. Licensee: J.W. Edwards.

The average BRP book was 5 years old in 1944. Without the BRP, German publishers would have had exclusive rights to the average book for another 51 years, until 1995.[13]

The Custodian lists the BRP price charged by US publishers for all 334 books. For 319 BRP books (96 percent), the Custodian also lists the original price immediately *before*

[11] J.W. Edwards alone published 700 books and 140 journals, "most of which have been published under license by the Alien Property Custodian Office" (Bokas and Edwards 2011, p. 23). Editions ranged from 200 and 500 copies (Bokas and Edwards 2011, p. 25).
[12] Most (323 of 334 BRP books) were published in German; 5 were English translations. Prices declined less for these 5 books (by 16.9 percent), and citations increased more (from 0.388 to 0.838 per year).
[13] The 1909 Act offered 56 years (28 years initially plus the option to renew the copyright for another 28 years). One extremely old book, Pier Andrea Saccardo's (1881) *Sylloge Fungorum* presents a system for classifying mushrooms by spore color and form, which remained the standard until the field switched to analyzing DNA.

the BRP.[14] Under the pre-BRP copyright regime, German publishers sold 319 books for an average of $41.40 (equivalent to $1,300 in 2016, Appendix Figure A1).

Under the BRP, book prices declined by an average of 24.97 percent ($\Delta p_i = 1 - BRP\ price/\ original\ price$, Appendix Table A1).[15] The book with the largest price decline, Saccardo's *Sylloge fungorum,* sold for an original price of $2,000 ($63,000 in 2016) and for $200 ($5,420) under the BRP. Beilstein's (1918) *Handbuch der Organischen Chemie* also sold for an original price of $2,000. Under the BRP, Edwards Brothers offered Beilstein "for $400 a set, and the company sold more than 600 sets to laboratories, researchers, and academicians" (Bokas and Edwards, 2011 p. 25).[16] Price declines were similar across disciplines, with 24.3 percent in chemistry and 27.4 percent in mathematics.

B. Books with Swiss-Owned Copyrights

The second identification strategy uses English-language citations to books with Swiss-owned copyrights to control for unobservable factors that may have increased English-language citations to German-language books after 1942. To construct this control group, we collect all Swiss books in section 51 "Mathematik" and section 54 "Chemie" from the catalogs of the Swiss National Library (founded in 1895). The Library holds 1,683 books in chemistry that were published between 1921 and 1942, and 447 books in mathematics.

C. Citations: Articles and Books that Cite BRP and Swiss Books, 1920-1970

The main outcome variable is citations, which are the standard proxy for cumulative innovation in science (Meho and Yang 2007). Roach and Cohen (2012), for example, show that citations to scientific articles correspond closely to scientific knowledge that firms use in their own R&D. Meho and Yang (2007) show that Google Scholar is the most complete source of citations to foreign language books, even though it is also the most computationally intensive.[17] Google Scholar searches "articles, theses, books, abstracts and court opinions

[14] Thirteen of the remaining 15 books were published after 1941.
[15] Prices declined for 242 of 271 BRP books with information on the original price. Another 20 books experienced no change in price, and 9 chemistry books became more expensive under the BRP, increasing by 17.47 percent from an average of $36.46.
[16] Equivalent to $63,000 in 2016. Using unskilled wage labor value conversions, Williamson 2016.
[17] Meho and Yan (2007) compare citations to the work of 25 faculty members from three sources: the Institute for Scientific Information (ISI, or Web of Science), Scopus, and Google Scholars. Google Scholar has better coverage, but also requires substantially greater efforts of data collection (with a total of 3,000 hours compared with 1000 for the Web of Science and 200 for Scopus).

from academic publishers, professional societies, online repositories, universities, and other web sites."[18]

We begin by searching Google Scholar for the title (such as *Die Chemie des Pyrrols*) and author (such as "Fischer") of each BRP book.[19] This search yields a total of 11,249 citations. Among 334 BRP books, 291 (87 percent) are cited at least once. Among 2,130 Swiss books, 486 books (23 percent) are cited at least once. Google's effectiveness, however, may vary across cohorts of publication years. To account for this issue, all regressions include control for the publication year of citing articles.

To measure the effect of the BRP conservatively, we only include citations to the original German version of BRP books. Excluding translations estimates a lower bound of the effects of the BRP. Successful BRP books were more likely to be translated, and citations to the original book slowed as soon translation became available. For example, citations to Courant and Hilbert's (1931) *Methoden der Mathematischen Physik* declined after the publication of *Methods of Mathematical Physics* (vol. II, 1966). By 2016, the English version of *Methods* had received more than 16,000 citations. Among 334 mathematics and chemistry books, 291 receive at least one citation.

A potential drawback of citations is that they may be biased by unobservable changes in tastes.[20] Paris et al. (1998) document a region-based bias in citations, and Jannot et al. (2013) show that scientists are more likely to cite statistically significant results. The most severe threat in our empirical setting is that US scholars may have withheld citations to German authors during the war and resumed citing German authors afterwards. For World War I, Iaria et al (forthcoming) show that US boycott of scientists from Central countries led to a decline in the transmission of knowledge, measured by new articles and Nobel-nominated work of scientists who had previously cited foreign or domestic research. To examine the severity of bias during World War II, we analyze data on preferences for ethnically-themed goods, such as German foods and operas, and baby names with strong ethnic connotations. These measures document a strong and persistent change in ethnic preferences during World War I, but not for World War II. For example, the share of

[18] For books with multiple editions, we collect citations to the edition whose publication year is closest to the publication year of the original book. Less than five percent of books have multiple editions in the same year; for these books we examine the edition with the largest number of citations.
[19] Fischer (1881–1945) received the Nobel Prize in chemistry for determining the structures of pigments in blood and bile as well as chlorophyll in leaves; these substances are derived from pyrrole.
[20] Citations may initially be biased against novel findings. For research published in the Web of Science, Wang et al (2017) show that articles which make more first-time ever combination across journals are less likely to be cited in the short run, but more likely to enter the top one percent of highly cited papers in the long run.

German-language operas dropped from 50 to 7 percent at the beginning of World War I, but declined only slightly in World War II (Appendix Figure A2, also Moser 2012b).

D. US Library Holdings of BRP and Swiss Books

Historical library holdings are recorded in the *National Union Catalog (NUC), pre-1956 imprints*, a "cumulative author list representing Library of Congress printed cards and titles reported by other libraries" (Library of Congress, 1968-1981). To collect these data, we have accessed physical copies of the NUC at the Hoover Institution Library & Archive. These records allow us to identify books that had entered at least one US library by 1956.

Among 291 BRP books with at least one citation, 283 are in the NUC, including 228 of 236 books in chemistry and all 55 books in mathematics. Among 486 Swiss books with at least one citation, 247 Swiss books are in the NUC, including 161 of 373 Swiss chemistry books and 86 of 113 Swiss math books. We examine the restricted data set of NUC books in the main specifications and use the full sample of 11,249 citations to 291 BRP and 486 Swiss books in robustness checks (e.g., Appendix Table A17).

E. English-Language vs. Other Authors

To distinguish citations by authors who were differentially affected by the BRP, we identify the publication language of all citing publications. Among 9,053 citations to 283 BRP books between 1920 and 1970, 5,067 originate from English-language publications. Among 1,788 citations to 247 Swiss books, 1,014 originate from English-language publications. With 243 English-language citations, Courant and Hilbert's *Methoden der Mathematischen Physik* (1931) is the most cited book (Appendix Table A2).

To check whether English-language citations are a useful proxy for citations from US scholars, we collect data on publication cities for four highly cited books, including two BRP books (Alexandroff and Topf, 1935, *Topologie* and van der Warden, 1931, *Moderne Algebra*) and two Swiss books (Stiefel 1936, *Mannigfaltigkeiten (Manifolds),* and Leser 1939, *Invariantentheorie Algebraische Formen*). These data indicate that the large majority of English-language publications (73 percent) originate from the United States.

F. Research Fields

To control for variation in citations across research fields, we match the classification of research topics in the reports of the US Alien Property Custodian (1944) with the classification of topics in the Swiss National Library. The Custodian (1944) assigns 228

chemistry books to 38 topics, such as "catalysis," and 55 mathematics books to 14 topics, such as "non-Euclidean geometry." The Swiss National Library distinguishes 128 topics within chemistry and 28 topics within mathematics. We match these two systems to create 25 mutually exclusive research fields within chemistry and 8 within mathematics.

For BRP books in chemistry, compounds are the most common research field, followed by organic chemistry and metals (Appendix Table A4). In mathematics, general mathematics and geometry are the most common research field. In each of these fields prices decline after 1942, and citations to BRP books increase (Appendix Table A4).

III. Effects of the BRP

To investigate the effects of the BRP, we pursue two complementary identification strategies. The first strategy addresses selection by comparing changes in citations from English-language authors (who benefitted directly from the US-based BRP) with changes in citations from other-language authors (who were less likely to benefit) to the *same book*.

A. Comparing Citations to the same BRP Book by English-language and Other Authors

Before the BRP, counts of new publications that cite BRP books in English and other languages are similar in levels and trends (Figure 1); 0.26 publications in English and 0.30 publications in other languages cite the average BRP book per year until 1941 (Appendix Table A5). After 1941, English-language publications increase to 0.566 per year, a 118 percent increase from pre-BRP levels. At the same time, citations to the same books by authors writing in other languages only increase to 0.391, a 30 percent increase (Appendix Table A5).[21] This differential increase is particularly remarkable given that many US scientists continued to publish in German until the late 1960s (e.g. Ammon 2001, p. 465), causing their citations to be counted in the control. Notably, citations to the German-language BRP books (such as *Methoden der Mathematischen Physik,* Appendix Figure A3) decline after the introduction of English translations, suggesting that translations were the closest substitute to BRP books.

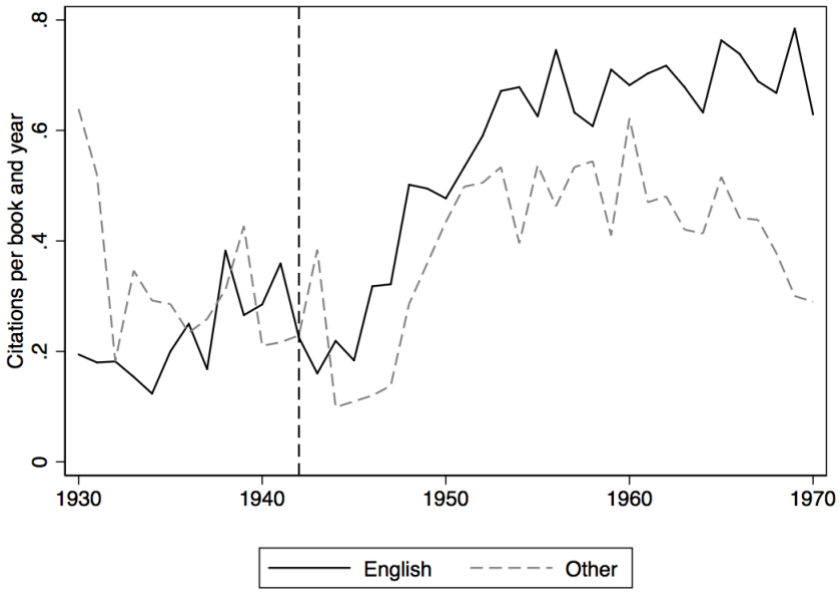
To estimate the effects of the BRP, we first estimate OLS regressions:

$$cites_{ilt} = \alpha\, English_l + \beta\, English_l \times post_t + book_i + \tau_t + \varepsilon_{ilt} \quad (1)$$

[21] Including 8 BRP books *not in the NUC*, English-language citations increase by 117 percent from 0.256 to 0.557, and citations from other languages increase by 31 percent from 0.294 to 0.386.

where the dependent variable $cites_{ilt}$ measures citations to book i in language l (English vs. other languages) and year t. The variable $English_l$ indicates new scientific publications in English that cite BRP books and $post_t$ indicates years after 1941. The control group are citations to the same BRP book by authors writing in *other* languages. A vector of $book_i$ fixed effects controls for book-specific differences in levels of citations across books. Citation year fixed effects τ_t control for variation in scientific output over time, e.g., as a result of variation in funding for research (e.g., Azoulay et al. 2016) [22]

FIGURE 1 – CITATIONS TO BRP BOOKS
FROM NEW WORK IN ENGLISH VERSUS OTHER LANGUAGES



Notes: *English* are citations to BRP books by English-language authors by the publication year of the citing publication. *Other* are citations from authors publishing in other languages). Citations are collected from Google Scholar (http://scholar.google.com, accessed July 1st-September 25th, 2014), and manually assigned to a publication language.

The identifying assumption for this test is that changes in English-language and other citations to BRP books would have been similar in the absence of the BRP. If this assumption is satisfied, the coefficient β estimates the causal effect of the BRP. Comparisons of English-language and other citations support the identifying assumption: trends in English-language and other citations were nearly identical until 1942 (Figure 1).

OLS estimates indicate that citations to BRP books increased by an additional 0.211 per book and year after 1941 compared with citations from other languages (Table 1, column

[22] For example, Azoulay et al (2016) show that funding from the U.S. National Institutes of Health for basic biomedical research encourages patenting by private sector firms.

1, significant at 1 percent). Relative to a pre-BRP average of 0.263 English-language citations for BRP books, this implies an 80 percent increase in citation in response to the BRP.[23] Controlling for interactions between research fields and the publication years of BRP books yield an estimate of 0.229 (Table 1, column 2, significant at 1 percent), which implies an 87 percent increase. Additional tests control for variation in citations across the life cycle of a book, through interactions between the publication years of BRP books and the year of citation. These regressions yield an estimate of 0.228 (Table 1, column 3, significant at 1 percent). Estimates of a specification with the natural logarithm of citations as the dependent variable yield very similar results (Appendix Table A6, column 1).[24]

TABLE 1 – OLS, EFFECT OF BRP ON CITATIONS – ENGLISH VS. OTHER LANGUAGE

	(1)	(2)	(3)	(4)
English	-0.036	-0.034	-0.034	-0.034
	(0.042)	(0.039)	(0.039)	(0.042)
English x post	0.211***	0.229***	0.228***	0.229***
	(0.066)	(0.061)	(0.060)	(0.067)
Citation year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation year FE	No	No	Yes	No
Publication year FE	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.357	0.401	0.384	0.117
N	19,680	19,162	19,162	19,162
Pre-1942 mean	0.263	0.268	0.268	0.268
Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1				

Notes: The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same book from authors in other languages. The variable *post* equals one for years after 1941.

B. Flexible Controls for Variation across Research Fields and Over Time

A potential challenge to the identifying assumption is that scientific output varies across research fields and over time. For example, research output may vary due to variation in funding (e.g., Azoulay et al. 2016, Tabakovic and Wollmann 2016) or as a result of

[23] Restricting the sample to 1960 yields an estimate of 0.151 additional citations (significant at 5 percent), while restricting it to 1950 shows 0.119 additional citations (significant at 5 percent).

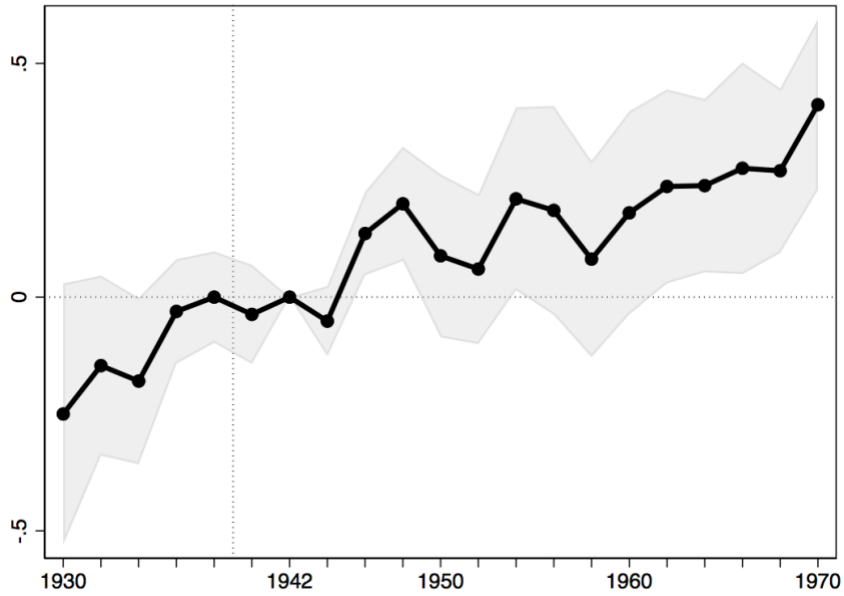
[24] A problem with the log specifications is that they drop observations of book-years with zero citations. Among 19,680 year-book-language pairs of the dependent variable, 15,504 (78 percent) take a value of zero. To keep these observations in the log regressions, we add a tiny number (0.0000001) to stay as close to zero as possible.

scientific breakthroughs, independent of the BRP. If such changes favor English-language publications in BRP fields after 1941, then the basic difference-in-differences test overstates the effect of the BRP.

To address this issue, we re-estimate the baseline regressions with an interaction between *research fields* and *citation years* of BRP books. These tests confirm the main results: English-language citations increase by an additional 0.229 per book and year (Table 1, column 2, significant at 1 percent), which implies an 85 percent increase. In alternative specifications with a linear pre-trend for English-language publications the estimated effect of the BRP is large, at 0.211 (Appendix Table A7, column 1, significant at 1 percent).

Consistent with the visual evidence in Figure 1, time-varying effects indicate no significant differences in citations before the BRP (Figure 2). Estimates increase and become significant in 1947, with an estimate of 0.200 in 1947-48 (p-value 0.00) and 0.210 in 1953-54 (p-value 0.03). They remain large and statistically significant until 1969-70, with 0.412 additional citations (p-value 0.00). Compared with a pre-BRP mean of 0.263, this implies a 157 percent increase in English-language citations to BRP books.

FIGURE 2 – TIME-VARYING EFFECTS, ENGLISH VS. NON-ENGLISH CITATIONS TO BRP BOOKS



Notes: Estimates of β_s (with a 95-percent confidence interval) in the OLS regression $cites_{ilt} = \Sigma_s \beta_s English_l * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{ilt}$ for two-year intervals 1921-1922,…,1969-70, with years 1940-41 as the excluded period. The dependent variable $cite_{ilt}$ counts citations to 283 BRP books i in language l (English vs. non-English) in year t. The indicator *English* equals 1 for citations from English-language authors. $Book_i$ is a vector of book fixed effects; μ_{ft} are field-by-citation year fixed effects, and τ_t are year fixed effects. Standard errors are clustered at the book level.

C. Comparing BRP and Swiss books: Matching Estimates

Our second identification strategy compares change after 1942 in English-language citations to BRP books with changes in English-language citations to Swiss books. This approach addresses the potential issue that English-language citations may have increased mechanically after World War II if the research output of US scholars increased after World War II, relative to other authors. Tabakovic and Wollmann (2016), for example, show that both the number and the quality of scientific publications increase in response to exogenous increases in research funding as a result of football wins. In the post-war United States, geopolitically motivated investments in science may have led to an increase in English-language publications, mechanically increasing English-language citations.

To address this issue, we compare changes in citations by English-language authors to BRP books with changes in citations by English-language authors to Swiss books. Like German chemists and mathematicians, Swiss scientists - such as Alexander Ostrowski (1893-1986) and Eduard L. Stiefel (1909-1978) - were leaders in their fields, and they published primarily in German.[25] Unlike German-owned books, however, books with Swiss-owned copyrights were not eligible for the BRP due to Switzerland's neutrality during the war.

A challenge for this second identification strategy is that publishers chose books for the BRP. Archival records for J.W. Edwards explain that "Edwards Brothers' editor, Bernard A Uhlendorf (formerly employed by the University of Michigan Library) was responsible for choosing the titles appropriate for EB's publication program" (Bokas and Edwards 2011, p. 25), but they give no further details on the process of selection. If publishers picked books with high expected demand, estimates will overstate the effects that the BRP would have had on a randomly selected book.

To help address selection, we control for differences in levels and in trends of citations between BRP and Swiss books. Book fixed effects control for differences in levels. To help control for differences in trends, we implement Mahalanobis propensity score matching (Abadie and Imbens 2011) to match BRP books with a comparable sample of Swiss books. Specifically, we match BRP books with Swiss books in the same research fields and with comparable pre-BRP stocks of (non-English) citations (Appendix Table A9).

[25] Stiefel's (1935) dissertation *Richtungsfelder und Fernparallelismus in n-dimensionalen Mannigfaltigkeiten* describes n-dimensional (Stiefel) manifolds $V_k(\mathrm{R}^n)$, or the set of all orthonormal k-frames in R^n. Stiefel was a co-inventor of the conjugate gradient method and the study of characteristic classes. He founded the Swiss Institute of Applied Mathematics, whose objective was to design and construct an electronic computer.

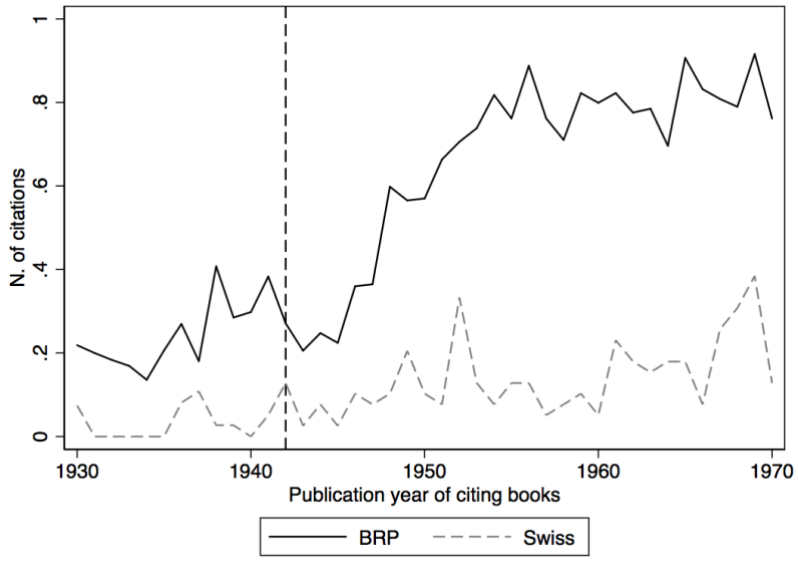
Swiss books in this matched sample receive fewer citations than BRP books, but exhibit comparable trends in citations until the BRP (Figure 3).[26] After 1942, citations to BRP books grow to 0.360 in 1946 and 0.888 in 1956, while citations to Swiss books increase much less. Citations to BRP books remain high around 0.800 per book year until 1970, while citations to Swiss books remain below 0.400.

OLS regressions with for the matched sample estimate

$$cite_{it} = \beta\, BRP_i * post_t + book_i + \tau_t + \varepsilon_{it} \quad (2)$$

where the dependent variable $cite_{it}$ measures citations to BRP and Swiss books by new English-language publications to book i per year t between 1920 and 1970, and the indicator variable *BRP* equals 1 for books that US publishers reprinted under BRP.

FIGURE 3 – CITATIONS TO A MATCHED SAMPLE OF BRP AND SWISS BOOKS



Notes: Citations for a matched sample of 214 BRP books and 39 Swiss books. Books are matched with a Mahalanobis propensity score procedure using research *fields* and the stock of *pre-1942 Non-English citations* as matching variables.

OLS estimates show that an additional 0.386 new publications by English-language authors per year cite BRP books between 1941 and 1970 compared with Swiss books (Table 2, column 1, significant at 1 percent). Relative to a pre-BRP mean of 0.283, this implies a 136 percent increase in citations.[27]

[26] In the final years of the war, the allied bombing campaign destroyed research facilities in Germany. We observe bombing as a decline in citations to BRP books compared with Swiss books. Bombings reached a peak of 130 tons per month at the beginning of 1945 (Webster and Frankland 1961, Annex, Waldinger 2016).
[27] Restricting the sample to 1960 yields an estimate of 0.322 additional citations (significant at 1 percent), while restricting it to 1950 shows 0.108 additional citations (significant at 10 percent).

Estimates are robust to controlling flexibly for idiosyncratic variation in citations across research fields, with interactions for *research fields * citation year* fixed effects (Table 2, column 2, significant at 1 percent), and for a book's age, with an interaction for *publication year * citation year* fixed effects (Table 2, column 3, significant at 10 percent), which implies a 86 percent increase. Estimates are also robust to using the natural logarithm of citations as the dependent variable (Appendix Table A6, column 4).[28]

TABLE 2 – OLS, EFFECT OF BRP ON ENGLISH-LANGUAGE CITATIONS. BRP VS. SWISS BOOKS (MATCHED SAMPLE)

	(1)	(2)	(3)	(4)
BRP				0.116
				(0.143)
BRP x post	0.386***	0.376**	0.188*	0.438***
	(0.101)	(0.156)	(0.102)	(0.117)
Citation year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation year FE	No	No	Yes	No
Publication year FE	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.558	0.622	0.58	0.182
N	9,365	9,365	9,111	9,365
Pre-1942 mean	.283	.283	0.218	.283

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures English-language citations to book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group includes 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. BRP and Swiss books are matched using the Mahalanobis propensity score algorithm with fields and pre-1942 average non-English language citations per year as matching variables.

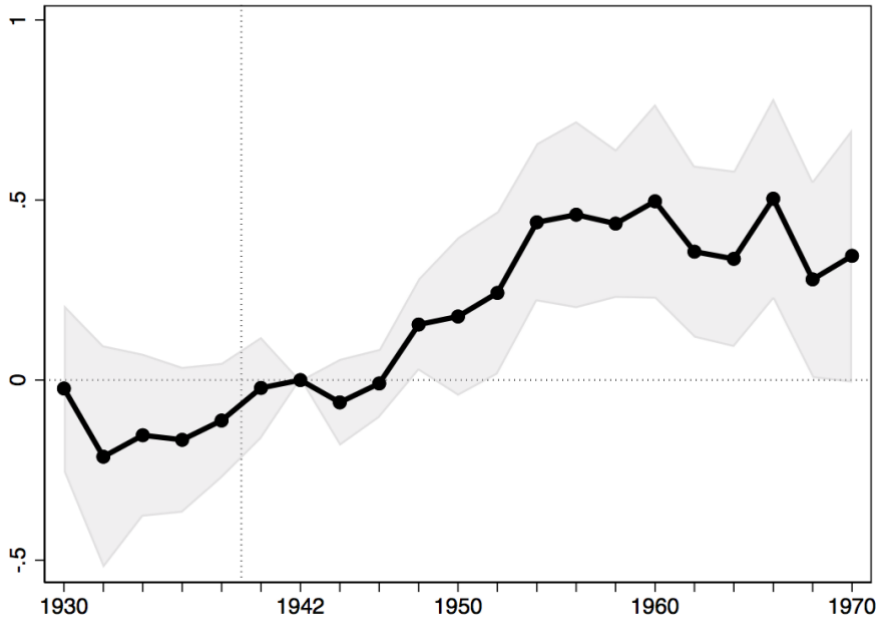
OLS estimates show that an additional 0.386 new publications by English-language authors per year cite BRP book after 1941 compared with Swiss books (Table 2, column 1, significant at 1 percent). Relative to a pre-BRP mean of 0.283, this implies a 136 percent increase in citations.

To control flexibly for idiosyncratic variation in citations across research fields, we again re-estimate all regressions with an interaction for *research fields * citation year* fixed

[28] Estimates for all 293 BRP books and 247 Swiss books show 0.392 additional new articles or books cite BRP books after 1941 (Appendix Table A10). An additional test restricts the sample to books in the Library of Congress; estimates are robust to this restriction (Appendix Table A11).

effects. These estimates suggest that English-language citations increased by an additional 0.376 citations per year for BPR books (Table 2, column 3, significant at 1 percent), which implies a 133 percent increase. Estimates are also robust to using the natural logarithm of citations as the dependent variable (Appendix Table A6, column 4).[29]

FIGURE 4 – TIME-VARYING EFFECTS, BRP VS. SWISS, MATCHED SAMPLE



Notes: Estimates of β_s with a 95-percent confidence interval in the OLS regression $cites_{it} = \Sigma_s \beta_s BRP_i * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{it}$ for two-year intervals 1921-1922,…,1969-70, with years 1941-42 as the excluded period. The dependent variable $cite_{it}$ counts English-language citations to 214 BRP and 39 Swiss book i in year t. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war$Book_i$ is a vector of book fixed effects. $Book_i$ is a vector of book fixed effects; μ_{ft} are field-by-citation year fixed effects, and τ_t are year fixed effects. Standard errors are clustered at the book level.

Time-varying estimates with these interactions indicate no differences until 1941, but show a substantial increase in citations to BRP books after 1942. Preceding the BRP, estimates are not significant and range from -0.075 in 1931-32 (p-value 0.64, Figure 4) to 0.137 in 1941-42 (p-value 0.17). After 1942, estimates increase to 0.291 in 1947-48 (p-value 0.01) and 0.596 in 1954-56 (p-value 0.00). Estimates remain large and significant until 1969-70, with 0.482 additional citations (p-value 0.00). Compared with a pre-BRP mean of 0.283, this implies a 170 percent increase (Figure 4).

[29] Estimates for all 293 BRP books and 247 Swiss books show 0.392 additional new articles or books cite BRP books after 1941 (Appendix Table A10). An additional test restricts the sample to books in the Library of Congress; estimates are robust to this restriction (Appendix Table A11).

TABLE 3 – OLS, EFFECT OF BRP ON ENGLISH-LANGUAGE VS. OTHER CITATIONS. BRP VS. SWISS BOOKS (MATCHED SAMPLE)

	(1)	(2)		(4)
English	-0.035**	-0.035**	-0.035**	-0.035**
	(0.014)	(0.015)	(0.015)	(0.014)
BRP				0.167
				(0.112)
English x BRP	0.002	0.002	0.002	0.002
	(0.048)	(0.046)	(0.045)	(0.047)
BRP x post	0.118*	0.127	-0.034	0.156**
	(0.061)	(0.077)	(0.067)	(0.070)
English x post	0.115**	0.115**	0.115**	0.115**
	(0.045)	(0.048)	(0.047)	(0.045)
English x BRP x post	0.202**	0.202**	0.202**	0.202**
	(0.088)	(0.086)	(0.085)	(0.087)
Citation year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation year FE	No	No	Yes	No
Field * Citation year FE	No	Yes	No	No
Publication year FE	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.372	0.414	0.400	0.132
N	18,730	18,730	18,730	18,730
Pre-1942 Mean	.300	.300	.300	.300

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: BRP and Swiss books are matched using the Mahalanobis propensity score algorithm with fields and pre-1942 average non-English language citations per year as matching variables. The dependent variable measures citations to book *i* per year *t* and language *c* (English vs. other) between 1920 and 1970. The indicator *English* equals 1 for citations by *English-language* authors. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941.

D. Combining the Two Identification Strategies

Our preferred estimates combine the two identification strategies, by comparing the differential change in citations to BRP books from *English-language* and *other* authors with the same differential change for *Swiss* books. Triple-differences OLS regressions estimate:

$$cite_{ilt} = \beta_1 English_l + \beta_2 English_l * BRP + \beta_3 English_l * post_t + \beta_4 BRP_i * post_t + \beta_5 English_l * BRP_i * post_t + book_i + \tau_t + \varepsilon_{ilt} \quad (3)$$

Here, the coefficient β_5 captures the differential increase in citations from English-language authors compared with other authors, for citations to BRP books compared with a similar set of Swiss books.[30] The identifying assumption is that the difference between citations by English-language authors and citations by other authors would have been similar for BRP and the comparable set of Swiss books in the absence of the BRP.

Estimates of β_5 indicate that BRP books receive an additional 0.202 English-language citations per year after the BRP compared with Swiss books. Compared with an average of 0.300 English-language citations per year for BRP books until 1941, this implies a 67 percent increase (Table 3, column 1, significant at 5 percent). Estimates are robust to controlling for differential changes in citations across research fields and over time (with interactions between research fields and citation year fixed effects, Table 3, column 2, significant at 5 percent) and for age effects (with interactions between publication year and citation year fixed effects, Table 3, column 3, significant at 5 percent).

D. Controlling for the Influence of Émigrés

Previous research has shown that US invention increased in research fields that received German Jewish émigrés (Moser et al. 2014). In the same way, scientific output (and thereby citations) may have increased in the fields of émigrés after 1932. When German-trained scientists came to the United States from Germany, they brought knowledge that is complementary to the German science books, amplifying the effects of price. To control for this and other unobservable factors that may affect citations over time, the main specifications include interactions between research fields and year fixed effects.

The effects of the émigrés, however, are interesting in their own right, and this section presents a series of additional tests to investigate their influence. Importantly, émigré authors of BRP books only account for a small share of citations, and all results are robust to excluding their citations (e.g., Appendix Table A12, column 2, with an estimate of 0.508 for *English * post*, significant at 5 percent). To identify BRP books whose authors were German Jewish émigrés we first searched for all authors in the *International Biographical Dictionary of Central European Émigrés* (Strauss et al. 1983) and in the records of the Mathematics Genealogy Project.[31] Four BRP books were written by a total of five émigrés, and all of them were mathematicians: Richard Courant, Max Herzberger, John von Neumann, George Pólya,

[30] As above, books are matched using propensity score matching with two matching variables: research fields and pre-BRP non-English citations.

[31] Four of five émigrés from Straus (1983) appear as an advisor of at least one US PhD student in the MGP after 1932. Max Herzberger (who is only listed in Straus) worked in the private sector and did not advise students.

and Gabór Szego (Appendix Table A13). Their books account for less than 10 percent of books in mathematics and less than 15 percent of citations to BRP math books.

FIGURE 5A – CITATIONS TO BRP BOOKS BY ÉMIGRÉS VS OTHER BRP BOOKS

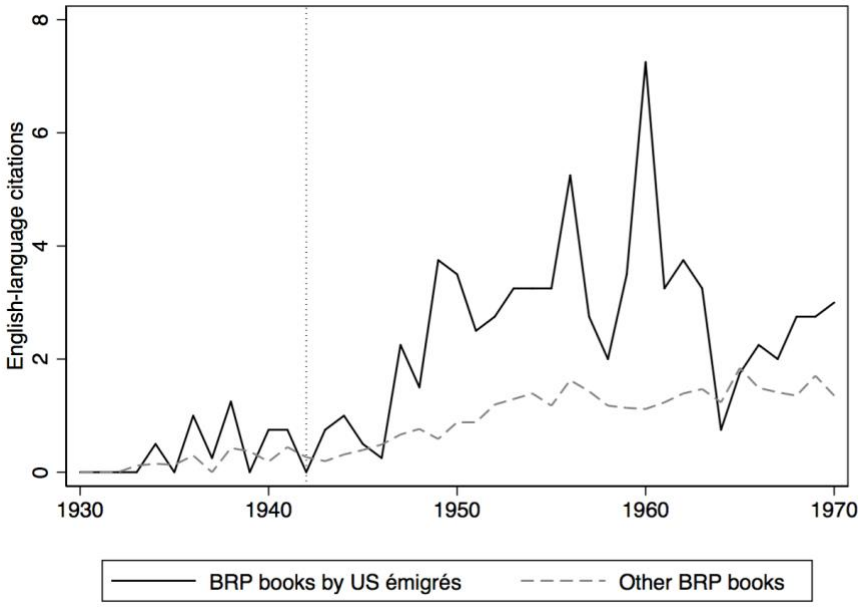
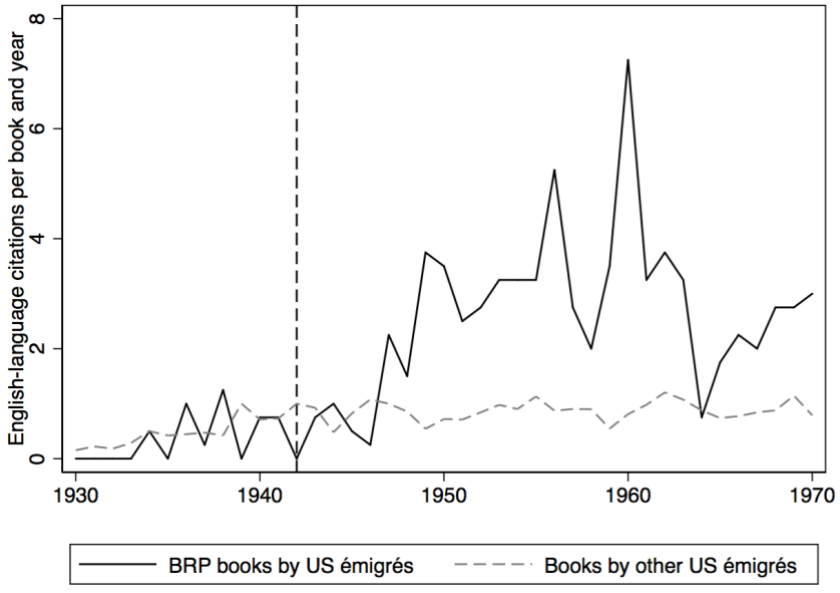


FIGURE 5B – CITATIONS TO BRP BOOKS BY ÉMIGRÉS VS OTHER BOOKS BY ÉMIGRÉS



Notes: Panel A shows English-language citations per year to five BRP books by English-language citations per book and year for five BRP books by seven mathematicians who emigrated to the United States after 1932 (*BRP books by US emigres*, black line) and by all other BRP books (*Other BRP books,* grey dashed line). Panel B shows English-language citations to the same *BRP books by US emigres* (black line) and by other 115 German émigrés to the US whose work was not included in the BRP (*Books by other émigrés*). Data on émigrés from the *Dictionary of Central European Émigrés* (Straus et al. 1983), the *American Men of Science* (Cattell 1956), and the Mathematics Genealogy Project.

An additional test examines whether the observed increase in citations to BRP books may have been driven by the colleagues of émigré authors of BRP books. Citations by colleagues of émigré authors only account for 0.1 percent of our citations data; excluding them does not affect the estimates (estimate of *English * post* equal to 0.606, Appendix Table A12, column 3, significant at 5 percent).[32]

Results are also robust to excluding the academic descendants of émigrés authors of BRP books. To perform this test, we identify the students of émigrés and the students of their students from the records of the Mathematics Genealogy Project. Less than 0.1 percent of all citations to math books are by academic descendants of émigré authors of BRP books; all results are robust to excluding their citations (Appendix Table A12, column 4).

Finally, we exclude citations from any universities that employed an émigré scholar, even if that émigré was not an author of a BRP book. This test allows us to control for cultural influences or differences in education that may led German-born authors (and, possibly the people who worked with them) to cite BRP books. To perform this test, we first collect the names of all American scientists who were born and educated in Germany from Cattell (1956). Among 1,029 American mathematicians in 1956, 27 were born and educated in Germany; among 6,664 chemists, 129 were born and educated in Germany. The coworkers of German-born émigrés account for 0.3 percent of citations; excluding them does not substantially change our estimates (Appendix Table A12, column 5). Moreover, a geographic analysis of citations (shown below in Section V.C) is robust to controlling for geographic proximity to émigrés.

Taken together, these tests confirm that the observed increase in citations to BRP books cannot be explained by the arrival of the émigrés. Yet, the interaction between lower book prices and human capital is important and interesting in its own right. Book-level analyses show that books by émigrés experienced an additional increase in citations compared with other BRP books (Figure 5A) and with other non-BRP books by émigrés (Figure 5B). These results suggest important complementarities between copyrights and human capital.

IV. Effects of Price

A key benefit of the empirical setting is that prices are observable under different copyright regimes for the same book, in the same year, when knowledge in the book is still

[32] Specifically, we exclude scholars at New York University (which employed Richard Courant), Stanford (George Pólya and Gábor Szegő), and Washington University in St. Louis (Gábor Szegő).

relevant and new. For BRP books, prices declined by an average of 25 percent when competing publishers were allowed to enter. Here, we exploit this change to examine the effects of reductions in price.

FIGURE 5A – CITATIONS TO BRP BOOKS BY ÉMIGRÉS VS OTHER BRP BOOKS

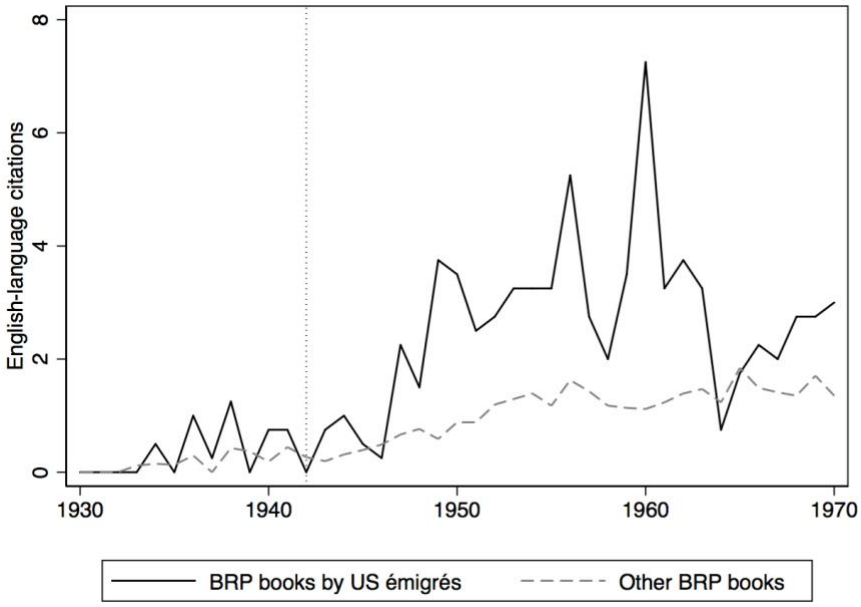
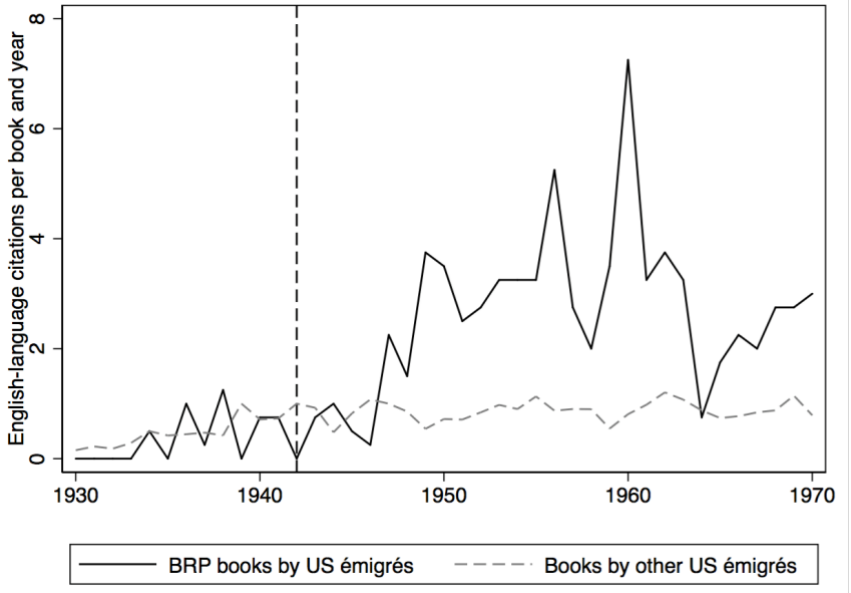


FIGURE 5B – CITATIONS TO BRP BOOKS BY ÉMIGRÉS VS OTHER BOOKS BY ÉMIGRÉS



Notes: Panel A shows English-language citations per year to five BRP books by English-language citations per book and year for five BRP books by seven mathematicians who emigrated to the United States after 1932 (*BRP books by US emigres*, black line) and by all other BRP books (*Other BRP books,* grey dashed line). Panel B shows English-language citations to the same *BRP books by US emigres* (black line) and by other 115 German émigrés to the US whose work was not included in the BRP (*Books by other émigrés*). Data on émigrés from the *Dictionary of Central European Émigrés* (Straus et al. 1983), the *American Men of Science* (Cattell 1956), and the Mathematics Genealogy Project.

Predictions from a purposefully straightforward model of cumulative knowledge production guide the empirical analysis. Two identical generations of researchers produce new knowledge in periods *t-1* and *t*. The concept of cumulative science (Scotchmer 1991) is captured by allowing second-generation scientists in period *t* to build on knowledge y_{t-1} created by researchers in the first generation *t-1*. Normalizing the price of new knowledge y_t to equal 1, scientists receive a sure payoff y_t if they produce new knowledge; this payoff can take the form of a money, peer recognition, or any other rewards that scientists value.

To access existing knowledge y_{t-1}, second-generation scientists pay a price p. Here, p represents the price of a book, but p could also be viewed as an access fee for a compilation of knowledge or an online depository of scientific articles. To reflect the indivisibility of existing knowledge, we assume that scientists pay p to use any quantity of existing knowledge. In other words, scientists must buy the entire book, or pay the full fee to access any part of the collection.

In addition to existing knowledge y_{t-1}, scientists use capital k_t, which is available at the rental rate r. Unlike existing knowledge, capital is divisible. Scientists are price takers for p and r. Depending on input prices p and r, scientists either invest in follow-on science, and receive $y_t = f(y_{t-1}, k_t)$, or they do nothing, and receive a payoff of zero.

Second-generation scientists choose k_t^* to maximize net payoffs $y_t - p - rk_t^*$. They invest in creating new knowledge only if p is below a threshold price p' such that

$$f(y_{t-1}, k_t^*) - p' - rk_t^* \geq 0 \quad \text{or } p' = f(y_{t-1}, k_t^*) - rk_t^* \qquad (4)$$

This implies – under a general set of production functions - that scientists produce more new knowledge when p is low. For a Cobb-Douglas production function $y_t = y_{t-1}^{1-\alpha} k_t^{\alpha}$, the threshold price equals

$$p' = \alpha^{\alpha/1-\alpha}(1-\alpha)\, y_{t-1}\, r^{-\alpha/1-\alpha}$$

A. Comparing Citations by English-language with Other Authors

To test empirically how changes in price influence the creation of new science, we re-estimate the baseline equation (1) with an interaction term for changes in price:

$$cites_{ilt} = \alpha\, English_l + \beta\, English_l \times post_t + \theta \Delta p_i * English_l * post_t + book_i + \tau_t + \varepsilon_{ilt} \qquad (5)$$

where Δp_i measures the difference between the original price and the republication (BRP) price for BRP book i normalized by the original price.

OLS estimates show that a 10 percent decline in price is associated with 0.119 additional citations (Table 4, column 1, significant at 1 percent). Compared with a pre-BRP mean of 0.264 annual citations for BRP books, this implies a 45 percent increase in citations.[33] Estimates are robust to controlling flexibly for differences in citations across research fields and over time (through interactions between research fields and citation year fixed effects, Table 4, column 2, significant at 1 percent) and for a book's age (through interactions between publication year and citation year fixed effects, Table 4, column 3, significant at 1 percent). Estimates are also robust to using the natural logarithm of citations as the dependent variable (Appendix Table A14, column 1).

TABLE 4 – OLS, EFFECTS OF PRICE DECLINE ON CITATIONS – ENGLISH VS. OTHER LANGUAGE

	(1)	(2)	(3)	(4)
English	-0.036	-0.034	-0.034	-0.034
	(0.042)	(0.039)	(0.039)	(0.042)
English x post	-0.077	-0.058	-0.054	-0.070
	(0.091)	(0.120)	(0.116)	(0.091)
English x Δp x post	1.192***	1.188***	1.170***	1.235***
	(0.344)	(0.431)	(0.447)	(0.342)
Δp				0.241
				(0.176)
Citation Year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation year FE	No	No	Yes	No
Publication year FE	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.366	0.411	0.393	0.138
N	18,986	18,524	18,524	18,524
Pre-1942 Mean	0.264	0.269	0.269	0.269

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same book from authors in other languages. The variable *post* indicates years after 1941. The variable Δp measures the difference between the original price and the BRP price for book *i*, divided by the original price.

To investigate the timing of changes in citations, we estimate $BRP * \Delta p_i * post$ separately for two-year intervals between 1930 and 1970:

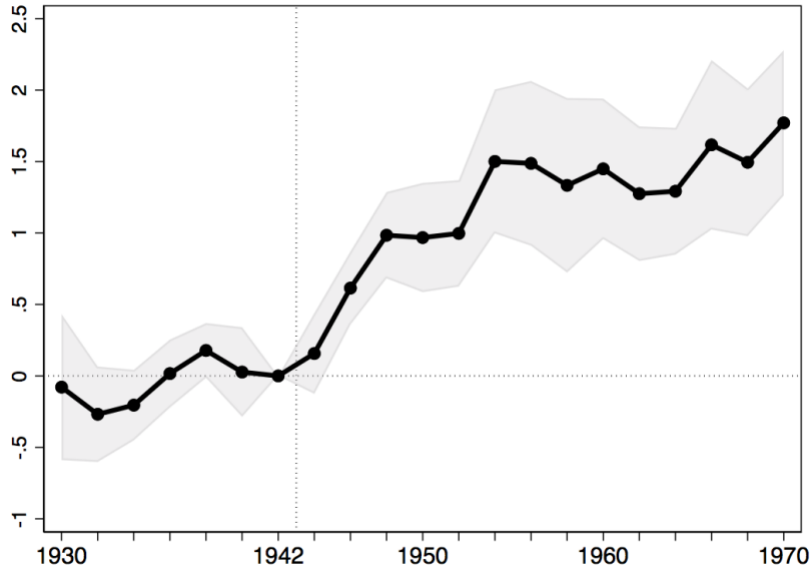
$$cites_{ilt} = \alpha\, English_l + \beta\, English_l \times post_t + \Sigma_s\, \theta_s\, \Delta p_i * English_l * \tau_s + book_i + \tau_t + \varepsilon_{ilt} \quad (6)$$

[33] Estimates are also robust to controlling for a separate linear pre-trend for English-language citations, with an estimate of 0.119, significant at 1 percent (Appendix Table A7, column 2).

where the indicator variable τ_t denotes two-year intervals 1930-31, 1932-1933,…to 1969-70, and years between 1920 and 1929 are the excluded period.

Time-varying estimates indicate no significant differences in citations before the BRP and show a large increase in citations afterwards (Figure 6). Until 1941, estimates range from -0.025 in 1931-32 (p-value 0.20) to 0.041 in 1941-42 (p-value 0.04). After 1945, estimates increase to 0.102 in 1947-48 (p-value 0.00) and 0.153 in 1953-54 (p-value 0.00). Estimates remain large and significant until 1969-70, with 0.180 additional citations (p-value 0.00). Compared with a pre-BRP mean of 0.263, this implies a 68 percent increase in citations.

FIGURE 6– TIME-VARYING EFFECTS OF CHANGES IN PRICE
ENGLISH VS. OTHER LANGUAGE CITATIONS TO BPR BOOKS



Notes: Estimates of θ_s with a 95-percent confidence interval in the OLS regression $cites_{ilt} = \alpha\ English_l + \beta\ English_l * post_t + \Sigma_s\ \theta_s\ \Delta p_i * English_l * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{ilt}$ for two-year intervals 1920-21,…,1969-70, with years 1941-42 as the excluded period. The dependent variable $cite_{ilt}$ counts citations to BRP book *i* in language *l* and year *t*. The indicator *English* equals 1 for citations from English-language authors. $Book_i$ is a vector of book fixed effects; μ_{ft} are field-by-year fixed effects, and τ_t indicates year fixed effects. The variable Δp measures the difference between the original price and the BRP price for book *i*, divided by the original price. Standard errors are clustered at the book level.

B. Comparing Citations to BRP and Swiss Books

As above, our second, complementary identification strategy compares changes after 1942 in English-language citations to BRP books with changes in English-language citations to Swiss books. This strategy addresses the potential issue that English-language citations may have increased mechanically after World War II, if English-language authors published more than other authors after the war. BRP books are matched with Swiss books in the same

research fields and similar levels of pre-BRP citations (using propensity score matching, as described in section III.C above).

OLS estimates imply that a 10-percent decline in price yields 0.112 additional English-language citations per year (Table 5, column 1, significant at 1 percent). Compared with an average of 0.284 citations until 1942, this implies 39 percent increase.[34] Although less precise, estimates are also robust to using the natural logarithm of citations as the dependent variable (Appendix Table A14, column 4). Year-specific estimates reveal no differences in citations by English-language and other authors before the BRP, but they show a large increase in English-language citations afterwards (Figure 7).

TABLE 5 – OLS, EFFECT OF PRICE DECLINE ON ENGLISH-LANGUAGE CITATIONS
BRP VS. SWISS BOOKS (MATCHED SAMPLE)

	(1)	(2)	(3)	(4)
BRP				0.022
				(0.141)
BRP x post	0.056	0.086	-0.126	0.085
	(0.089)	(0.143)	(0.164)	(0.101)
BRP x Δp x post	1.116***	1.060*	1.035	1.201***
	(0.376)	(0.527)	(0.621)	(0.361)
Δp				0.307
				(0.302)
Citation Year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation year FE	No	No	Yes	No
Publication year FE	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.562	0.624	0.583	0.205
N	9,302	9,302	9,048	9,302
Pre-1942 Mean	.284	.284	0.242	.284

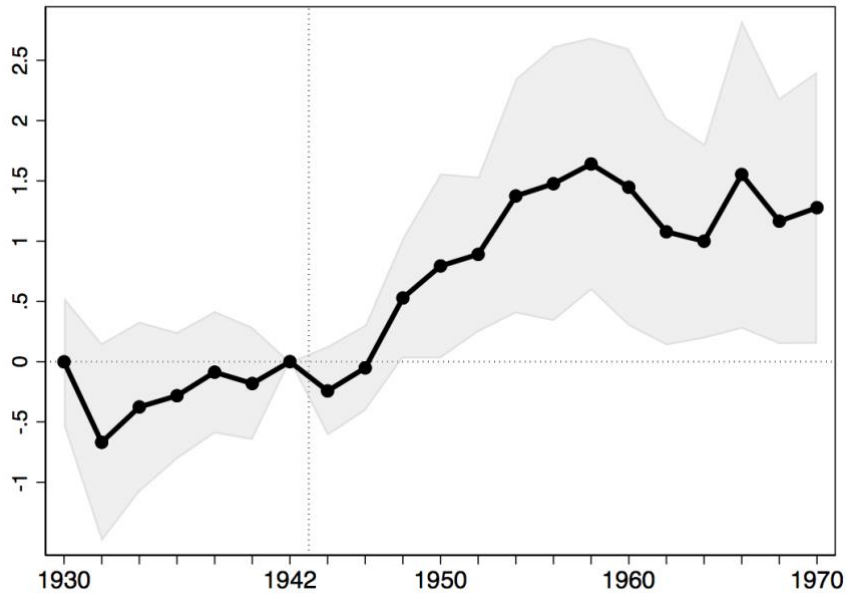
Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: BRP and Swiss books are matched using the Mahalanobis propensity score algorithm with fields and pre-1942 average non-English language citations per year as matching variables. The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

[34] Results on the full sample of BRP and Swiss books indicate that a 10 percent decline in price is associated with 0.101 additional citations per year, or 38 percent (Appendix Table A10, column 1, significant at 1 percent).

Triple differences estimates, which combine the two identification strategies, indicate that the same decline in price is associated with 0.128 additional English-language citations relative to other-language citations for BRP books relative to Swiss books (Table 6, column 1, significant at 1 percent), with no evidence for differential pre-trends in citations (Appendix Figure A4).

FIGURE 7 – TIME-VARYING EFFECTS OF CHANGES IN PRICE CITATIONS TO BRP VS. SWISS BOOKS - MATCHED SAMPLE



Notes: Estimates of θ_s with a 95-percent confidence interval in the OLS regression $cites_{it} = \beta\ BRP_i * post_t + \Sigma_s\ \theta_s\ \Delta p_i * BRP_i * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{it}$ for two-year intervals 1921-1922,…,1969-70, with years 1941-42 as the excluded period. The dependent variable $cite_{it}$ counts citations to a matched sample of 214 BRP and 39 Swiss book *i* in year *t*. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. $Book_i$ is a vector of book fixed effects μ_{ft} are field-by-year fixed effects, and τ_t indicates year fixed effects. The variable Δp measures the difference between the original price and the BRP price, divided by the original price. Standard errors are clustered at the book level.

C. Complementarities with Physical Capital

Next, we extend the knowledge production function to allow for heterogeneous effects across disciplines. Let ym,t = g(ym,t-1,kt) represent a discipline in which knowledge creation depends primarily on human capital, such as mathematics. Let yc,t = z(yc,t-1,kt) be a discipline in which knowledge production requires physical capital (such as laboratory space for chemical research). The elasticity of knowledge production with respect to physical capital is ec(yc,t-1,kt) =zk(yc,t-1,kt) kt /z(yc,t-1,kt) for chemistry and em(yc,t-1,kt) = gk(ym,t-1,kt) kt /g(ym,t-1,kt) for mathematics. This elasticity is smaller for mathematics than

for chemistry, so that $e^m(y_{m,t-1},k_t) < e^c(y_{c,t-1},k_t)$ for every $\{y_{m,t-1}, y_{c,t-1}, k_t\}$. Then, the threshold prices for existing knowledge (above which scientists choose not to invest in follow-on research) become

$$p_c' = z(y_{c,t-1},k_c^*) - z_k(y_{c,t-1}, k_c^*)\, k_c^* = z(y_{c,t-1},k_c^*)(1 - e^c(y_{c,t-1},k_c^*))$$
$$p_m' = g(y_{m,t-1}\, k_m^*) - g_k(y_{m,t-1},k_m^*)k_m^* = g(y_{m,t-1}\, k_m^*)(1 - e^m(y_{m,t-1}, k_m^*))$$

TABLE 6 – OLS, EFFECT OF PRICE DECLINE ON ENGLISH-LANGUAGE VS. OTHER CITATIONS – BRP VS. SWISS BOOKS (MATCHED SAMPLE)

	(1)	(2)	(3)	(4)
English	-0.035**	-0.035**	-0.035**	-0.035**
	(0.014)	(0.015)	(0.015)	(0.014)
BRP				0.111
				(0.103)
English x BRP	0.002	0.002	0.002	0.002
	(0.048)	(0.046)	(0.045)	(0.048)
BRP x post	0.071	0.103	-0.048	0.089
	(0.047)	(0.075)	(0.082)	(0.057)
English x post	0.115**	0.115**	0.115**	0.115**
	(0.045)	(0.048)	(0.047)	(0.045)
English x BRP x post	-0.140	-0.140	-0.139	-0.140
	(0.109)	(0.107)	(0.105)	(0.108)
BRP x Δp x post	0.101	0.077	-0.030	0.170
	(0.193)	(0.235)	(0.242)	(0.189)
English x BRP x Δp x post	1.276***	1.276**	1.276**	1.276***
	(0.402)	(0.468)	(0.462)	(0.400)
Δp				0.181
				(0.246)
Citation Year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No
Publ. year * Citation Year FE	No	No	Yes	No
Publication year	No	No	No	Yes
Field FE	No	No	No	Yes
R-squared	0.383	0.424	0.410	0.155
N	18,604	18,604	18,604	18,604
Pre-1942 Mean	.300	.300	.300	.300

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: BRP and Swiss books are matched using the Mahalanobis propensity score algorithm with fields and pre-1942 average non-English language citations per year as matching variables. The dependent variable measures citations to book *i* per year *t* and language *c* (English vs. other) between 1920 and 1970. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

If existing knowledge is equally valuable across disciplines, so that $y_{c,t-1}=y_{m,t-1,}$ then $p'_m \geq p'_c$. More generally, p' is weakly decreasing in the elasticity of cumulative knowledge with respect to physical capital:

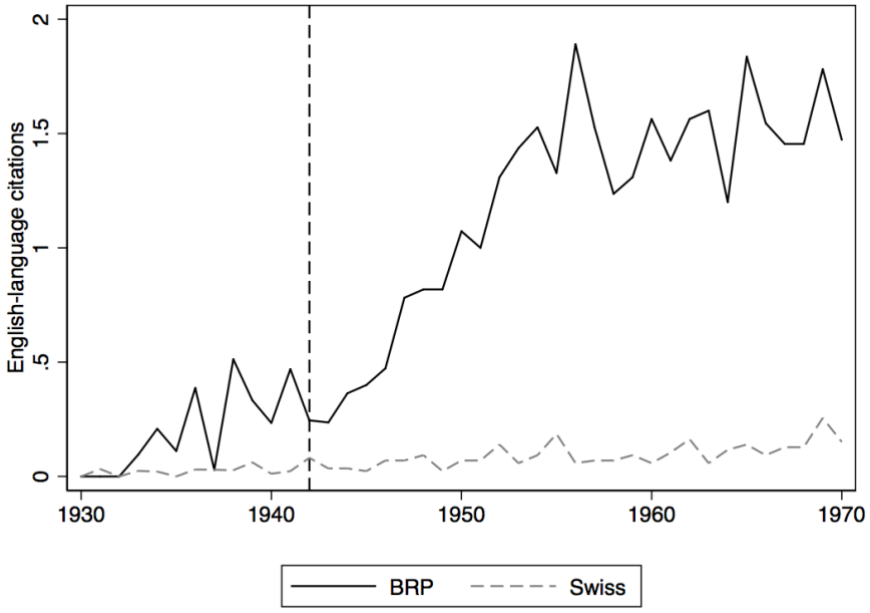
$$\frac{dp'}{de(y_{t-1},k^*)} = -f(y_{t-1},k^*) \leq 0 \quad \text{if} \quad f(y_{t-1},k^*) \geq 0 \qquad (7)$$

For a Cobb-Douglas production function $y_t = y_{t-1}^{\,1-\alpha} k_t^{\alpha}$, where α is the elasticity of knowledge production with respect to physical capital,

$$\frac{dp'}{d\alpha} = \alpha^{\frac{\alpha}{1-\alpha}} y\, r^{\frac{\alpha}{\alpha-1}} \frac{1}{1-\alpha} \log(\alpha/r) \leq 0 \quad \text{if} \quad \alpha \leq r$$

which implies that the threshold price of existing knowledge at which scientists invest in new knowledge is (weakly) decreasing in the elasticity of knowledge with respect to capital.

FIGURE 8 – CITATIONS PER BOOK AND YEAR FOR BRP BOOKS IN MATHEMATICS



Notes: *English* are citations by to BRP books by English-language authors. *Other* measures citations to the same books by other language authors. Citations to BRP books from Google Scholar (http://scholar.google.com, accessed July 1st-September 25th, 2014).

Plots of citations confirm this prediction. There is a stronger and clearer increase in English-language citations to BRP books in mathematics than in chemistry. English-language citations to BRP books in mathematics increased from 0.198 per book and year before 1942 to 0.472 in 1946 and 1.890 in 1956, while citations in other languages remained low (Figure 8). English-language citations to BRP books in chemistry increased from 0.244 per book and

year before 1942 to 0.469 in 1956, while other citations stay roughly constant (Appendix Figure A5).

To systematically examine these effects across disciplines, we estimate

$$cites_{ilt} = \alpha\ English_l + \beta\ English_l \times post_t + \varphi\ English_l * math_i * post_t + book_i + \tau_t + \varepsilon_{ilt} \quad (8)$$

where $math_i$ is an indicator for BRP books in mathematics.

TABLE 7 – OLS, DIFFERENTIAL EFFECTS OF PRICE ON CITATIONS, BY DISCIPLINE

	(1)	(2)	(3)	(4)	(5)	(6)
English	-0.036	-0.034	-0.034	-0.036	-0.034	-0.034
	(0.042)	(0.039)	(0.042)	(0.042)	(0.039)	(0.042)
English x post	0.079	0.115*	0.103**	-0.074	-0.058	-0.072
	(0.053)	(0.063)	(0.052)	(0.091)	(0.120)	(0.091)
English x Math x post	0.674**	0.565**	0.629**			
	(0.279)	(0.218)	(0.266)			
English x Δp x post				0.646**	0.706**	0.650**
				(0.288)	(0.266)	(0.294)
English x Math x Δp x post				2.383***	2.110**	2.588***
				(0.907)	(0.887)	(0.930)
Δp						0.286
						(0.178)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Field * Citation year FE	No	Yes	No	No	Yes	No
Publication year FE	No	No	Yes	No	No	Yes
Field FE	No	No	Yes	No	No	Yes
R-squared	0.367	0.407	0.126	0.382	0.422	0.160
N	19,680	19,162	19,162	18,986	18,524	18,524
Pre-1942 Mean	0.263	0.268	0.268	0.268	0.269	0.269

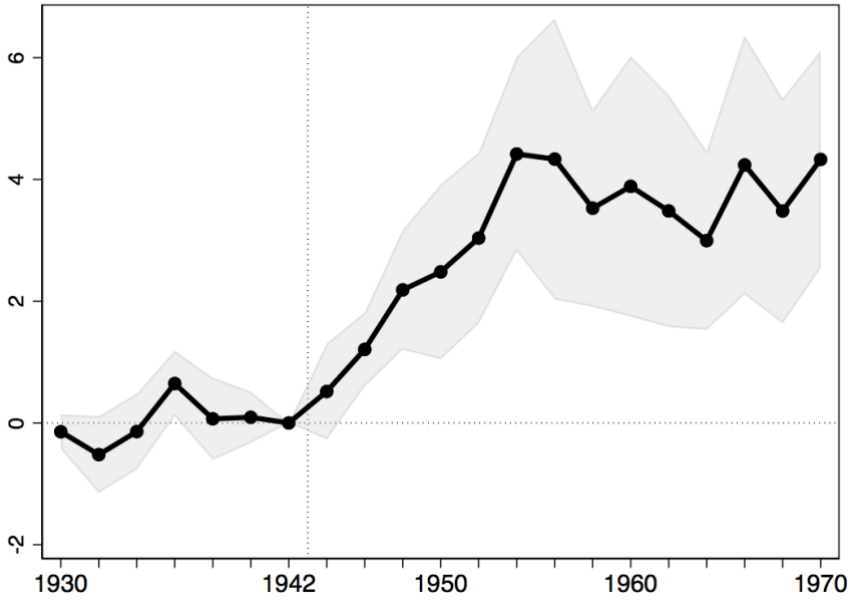
Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same book from authors in other languages. The variable *post* indicates years after 1941, and *Math* indicates 55 books in mathematics. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

Estimates for *English * math * post* indicate that English–language citations to BRP in mathematics increase by an additional 0.674 compared with chemistry and citations in other languages after 1941 (Table 7, column 1, significant at 5 percent). Relative to a pre-BRP mean of 0.263 citations, this implies an additional 2.6-fold increase. Estimates with flexible controls for idiosyncratic variation in research output over time and across fields yield 0.565 additional citations, which implies an additional 2.2-fold increase for mathematics (Table 7, column 2, significant at 5 percent, with interaction terms *fields **

citation years).[35] Intensity regressions imply that a 10 percent decline in price is associated with 0.238 additional English-language publications for mathematics (*English* * *math* * Δp * *post*, Table 7, column 4, significant at 1 percent).[36] Relative to a pre-BRP mean of 0.263 for BRP books, this implies a 90 percent increase.

FIGURE 9 – TIME-VARYING EFFECTS OF PRICE IN MATHEMATICS



Notes: Estimates of θ_s (with a 95-percent confidence interval) in the OLS regression $cites_{ilt} = \alpha\ English_l + \beta\ English_l * post_t + \Sigma_s\ \theta_s\ \Delta p_i * English_l * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{it}$ for two-year intervals 1921-1922,…,1969-70, with years 1941-42 as the excluded period. The dependent variable $cite_{it}$ counts citations to BRP math book i in year t. The indicator *English* equals 1 for citations by English-language authors. $Book_i$ is a vector of book fixed effects; μ_{ft} are field-by-year fixed effects, and τ_t indicates year fixed effects. The variable Δp measures the difference between the original price and the BRP price, divided by the original price. Standard errors are clustered at the book level.

Time-varying estimates of a decline in price indicate no significant differences in English-language citations to BRP math books compared with other citations before 1942. Until 1941 estimates range from -0.051 citations in 1931-32 (p-value 0.03, Figure 9) to 0.066 in 1935-36 (p-value 0.07). After the war, estimates increase to 0.309 for 1951-52 (p-value 0.05, Figure 9), and 0.447 in 1953-54 (p-value 0.00). Estimates remain large and significant until 1969-70, with 0.438 (p-value 0.00), implying a 166 percent increase.[37]

[35] Controlling for a linear pre-trend leaves the estimate for *English * math * post* unchanged at 0.674 (Appendix Table A7, column 3, significant at 5 percent), and increases *English * post* to 0.317 (p-value 0.18).
[36] For each 10 percent decline in price, BRP math books receive 0.303 additional English-language citations after 1941 ($English_l * \Delta p_i * post_t + English_l * math_i * \Delta p_i * post_t$, significant at 10 percent, Table 7, column 4).
[37] For chemistry, estimates of time-varying effects range from -0.019 in 1933-34 (with a p-value of 0.47) to 0.038 in 1941-42. After 1941, estimates reach 0.066 in 1947-48 (p-value of 0.02), 0.068 in 1953-54 (p-value of 0.04), and remain large and significant until 1969-1970 with an estimate of 0.104 (p-value of 0.19).

D. Substitution Effects

A potential concern for estimating the effect of a decline in price is that we cannot observe the process by which publishers set the price for BRP books. To investigate this issue, we check whether price declined more for books with more pre-BRP citations by non-English publications. This analysis shows that the correlation is small and not statistically significant (Appendix Figure A6). A related concern is that we cannot measure cross-price elasticities across books, and that US publishers may have lowered prices more for books with close substitutes. If there was unobservable variation in the price setting behavior of publishers, substitution effects would cause the estimate of θ to be downward biased, as long as books with close substitutes experienced a smaller increase in citations.

Historical records indicate that there were no good substitutes for BRP books, because these books were at the frontier of science. BRP books, such as Alexandroff and Hopf's *Topology*, Courant and Hilbert's *Methods of Mathematical Physics*, or Beilstein's *Handbook of Organic Chemistry*, were first to summarize the current state of science in new fields of mathematics and chemistry (Richards 1981, p. 254). Ideally, we would estimate cross price elasticities for BRP books and potential substitutes, but this is not possible due to data constraints.

Changes in citations suggests that English language translations were the closest substitute for a BRP book. Translations began to appear in the 1960s, when English replaced German as the *lingua franca* of science. With the publications of a translation, citations to the original BRP book declined. For example, citations to Courant and Hilbert's *Methoden der Mathematischen Physik* slowed dramatically when translations hit the market (Appendix Figure A3).

To further investigate whether substitutes for BRP books were available in 1942, we use Amazon's sales algorithm to identify books that customers who bought BRP books "also bought" or "frequently bought together."[38] We apply this algorithm to identify related books for the four most highly cited BRP books in mathematics, and then collect the year of the first edition of all of these related books to check whether they may have been available in the United States before 1942.

These data confirm that nearly all books that are thematically related to BRP books were first published *after 1942* (Appendix Figure A7). We also examine data on citations to these books in newly issued US patents per year (described in more detail below). This test

[38] Data collected from www.amazon.com, accessed September 19-30, 2016.

confirms that there were no good substitutes for BRP books before the BRP. None of the potential substitutes for BRP books was cited in a US patents until 1957.

V. Diffusion Across US Libraries

How did lower book prices increase citations? Our working hypothesis is that reductions in access costs enabled less affluent institutions to buy BRP books, enabling a new set of researchers to use BRP books in their work. Consistent with this mechanism, anecdotal evidence indicates that scientists considered access to a good library to be extremely important. For example, a major objection against Los Alamos as the site for the Manhattan Project was that "in the wilds of New Mexico" scientists lacked access to a decent library.[39] Sales records for JW Edwards also show that libraries bought many BRP books (Bokas and Edwards 2011, p. 25). We now examine this mechanism systematically, using data on library holdings, scientists' loans of library books, and changes in the locations of citing authors.

A. Variation in Library Holdings

Data on library holdings show that BRP books became diffused across a geographically and economically diverse set of libraries after the BRP (Figure 10).[40] By 1956, university libraries, like Ohio State, Oregon, and the University of Virginia held a substantial number of BRP books. By comparison, Swiss books remained concentrated in the holdings of two wealthy research libraries, the John Crerar Research Library at Chicago and Yale.

Library data also show that BRP books whose price declined more in 1942 had become more widely available across US libraries by 1956. BRP books in the top quartile of the price decline (ranging from 40 to 90 percent) had entered the holdings of 20 libraries and 11 US states by 1956 (Appendix Figure A8). For example, Beilstein's *Handbuch der Organischen Chemie* (1918), with a price decline of 90 percent, was available in 90 of 218 US libraries. By comparison, BRP book in the bottom quartile of the price decline (8 percent or less) were only accessible in 14 of 218 US libraries.[41]

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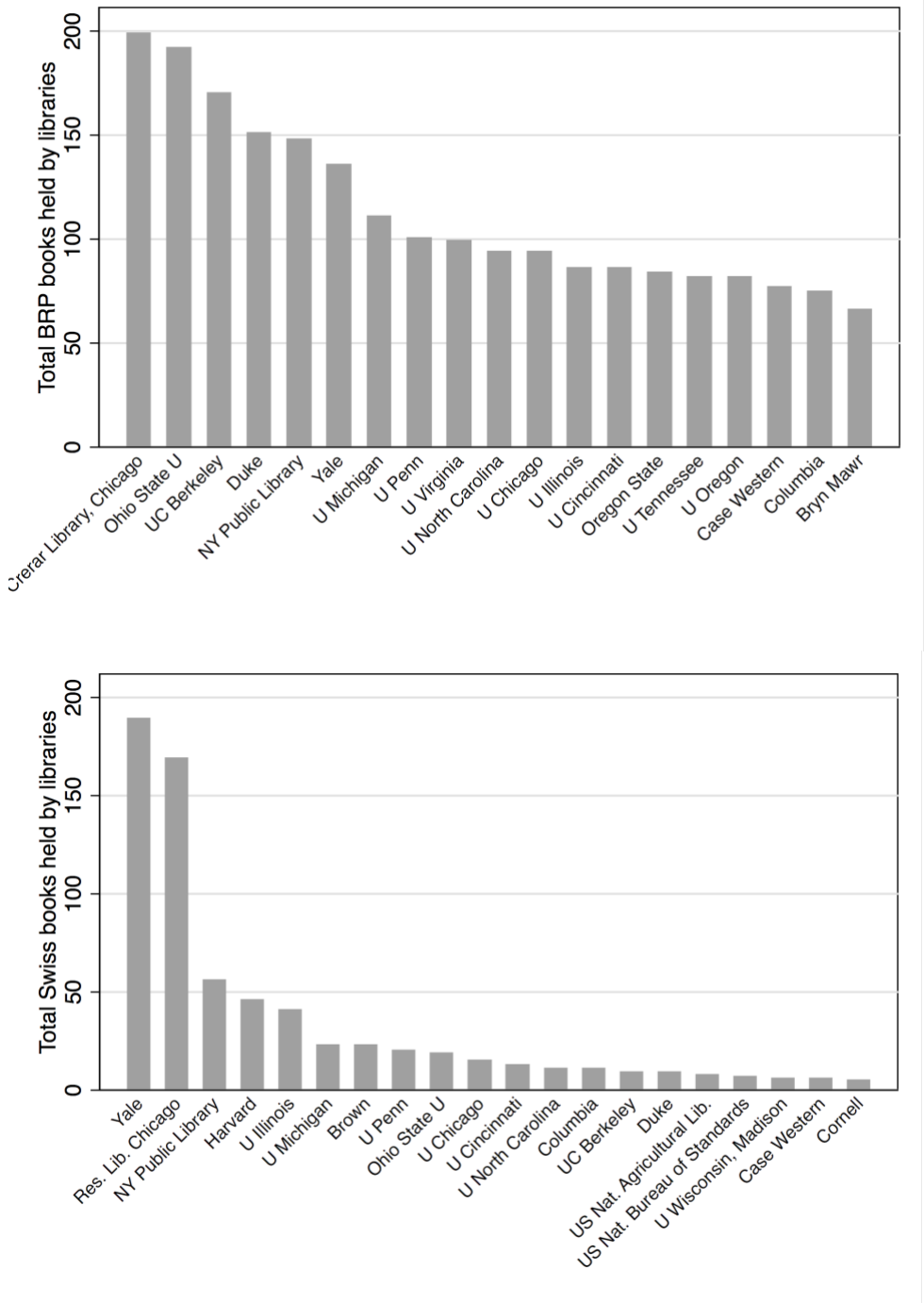
[39] John Manley, cited in Bird and Shirwin (2005, p. 207). Also Hargittai (2006, pp. 89-131).

[40] To construct these data, we accessed the records of the *National Union Catalog* (NUC, Mansell 1968-1981) in the archives of the Hoover Institution at Stanford. Printed between 1968 and 1981, the NUC records the libraries that held a copy of each book by 1956. It made interlibrary loans practical, by enabling researchers to find out which libraries held a book, allowing them to request it.

[41] Each additional 10 percent decline in price was associated with a 1.3 percent increase in the share of libraries that held a BRP book (with a p-value of 0.00, Appendix Figure A8). Excluding outliers (such as Beilstein), which can be found in more than 40 percent of US libraries, leaves the estimate at 0.8 (with a p-value of 0.00).

FIGURE 10 – BRP BOOKS (TOP) AND SWISS (BOTTOM) BOOKS IN US LIBRARIES

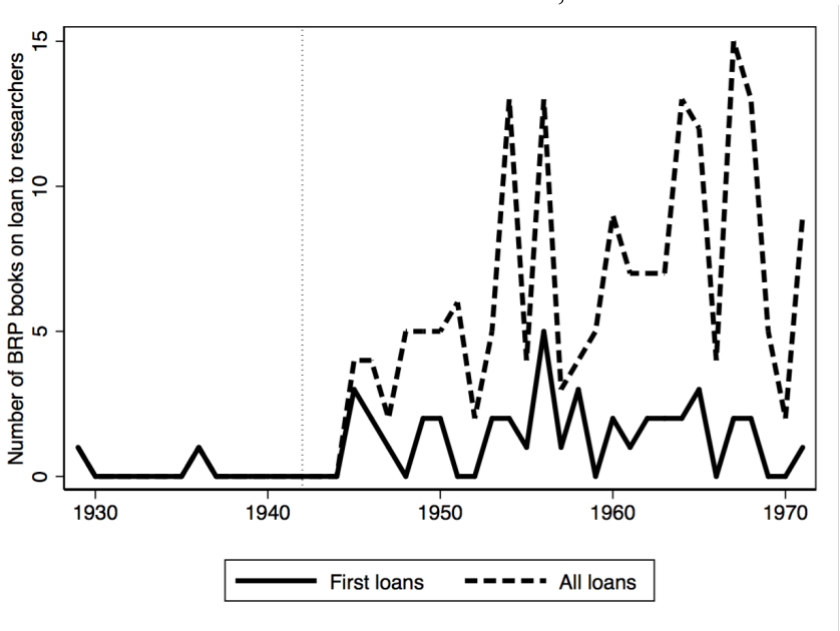


Notes: Counts of BRP books (top panel) and Swiss books (bottom panel) in the holding of a given library. For example, the Crerar Library owned 199 BRP books (top) and 15 Swiss books by 1956. Data on historical library holdings collected from the National Union Catalog (Mansell 1968-1981), accessed at the Hoover Institution Library and Archives.

B. Loans of BRP Books

Despite the richness of the data, the NUC alone cannot capture changes in the *usage* of BRP books over time.[42] To address this issue, we examine physical copies of check-out sheets that are attached to the inside back cover of each book (Appendix Figure A9). We were able to collect these data for 127 books, 45 percent of all BRP books in the Stanford University library in 2016.[43]

FIGURE 11 – BRP BOOKS ON LOAN, 1930-1970



Notes: BRP books on loan to researchers from Stanford's library in year *t*. The solid line (*First loans*) represents the number of BRP books that were first lent to a researcher in year *t*. The interrupted line (*All loans*) plots the total number of BRP books on loan in year *t*.

These data reveal a striking overlap between changes in the use and changes in citations (Figure 11). Until 1941, only two BRP books had been borrowed from the Stanford library at least once (*Stereochemie* by K. Freudenberg and *Die Mathematischen Hilfsmittel des Physikers* by E. Madelund). After 1941, three additional BRP books were borrowed for the first time in 1944, two in 1945, 1948, 1949, and 1952 each, and five in 1955. Data on the overall use of books (shown as the dashed line in Figure 11) further indicate that scientists used BRP books repeatedly in the 1940s and 50s.

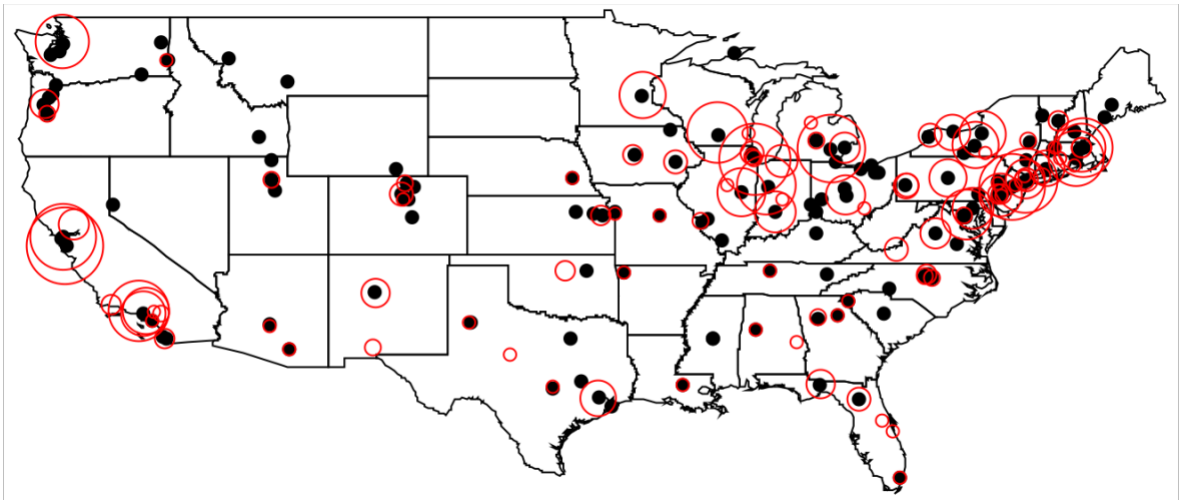
[42] Libraries did not systematically record acquisition dates for science books. For example, we received the following response from a Curator of Special Collections at Stanford's Library: "The library did not maintain any acquisition records before 1994 for this type of materials. I asked our acquisitions department if there is any way to capture this information, but it appears unlikely. This type of information simply was not considered useful for these books" (Kathleen M. Smith, Stanford, April 4, 2016).

[43] The average BRP book in Stanford's library sold for $68.16 until 1941, and became 34 percent cheaper under the BRP. Loan data exclude reference works, such as Beilstein, because they cannot be borrowed. We are less likely to observe the original cards for popular books because check-out sheets were replaced once they had filled up; this lead us to estimate usage with a delay for more popular books.

C. Citing Authors Near BRP Books

Next, we examine the geographic overlap between the locations of BRP books and the locations of citations. Ideally, we would like to know where each citing author worked when they cited a BRP book. Using information on the location of PhD granting institutions in the *Mathematics Genealogy Project* (MPG) we are able to capture the locations of 1,812 authors who cite BRP books.[44] Specifically, we use PhD-granting institutions for professors and their advisees to identify the location of citing authors. For example, David Gilbarg cites Courant and Hilbert's *Methoden der Mathematischen Physik* in his article on "Asymptotic Behavior and Uniqueness of Plane Subsonic Flows" in the *Journal of Pure and Applied Mathematics* in 1957. We assign this citation to Bloomington, Indiana because Gilbarg was

FIGURE 12 – LOCATIONS OF BRP MATH BOOK AND CITING MATHEMATICIANS



Notes: Black circles are libraries that had acquired BRP math books by 1956. Red circles show the locations of authors who cite BRP math book after the 1942; the size of the red circle represents the number of citations. To identify the locations of citing authors we use records of PhD granting institution of advisors and advisees in the Mathematics Genealogy Project (accessed January 28th-March 10, 2016).

an advisor to Norman Meyers, who graduated from Indiana University in 1957. Location data are available for all 1,995 citations by 1,812 authors to BRP books in mathematics.

Plots of location data already show that citations tracked the geographic diffusion of BRP books (Figure 12). Before 1942, 64 percent of citations to BRP books originate from the US Northeast (around Cambridge MA, Princeton, and Providence) and from Chicago. Afterwards, citations expand to the Western and Southern United States.

[44] The MGP offers includes advisors, advisees, and PhD-granting institutions for 196,303 mathematicians between 1666 and 2016. http://www.genealogy.ams.org/index.php, accessed January 28 to March 25, 2016.

To test whether authors near BRP books became more likely to use BRP books after 1942, we estimate:

$$cite_{kt} = \beta\ within\ 25\ miles_k \times post_t + \eta_k + \tau_t + \varepsilon_{kt} \quad (9)$$

where the dependent variable $cite_{kt}$ counts citations from authors at location k and year t. The explanatory variable $within\ 25\ miles_k$ indicates locations within a 25-mile radius of a BRP book; 87 of 101 locations are within a 25-miles of BRP books. To control for location-specific differences in citations (e.g., due to variation in research funding), the vector η_k includes location fixed effects.

OLS estimates confirm that locations near BRP books experienced a larger increase in citations. Authors within 25 miles of BRP books produce an additional 0.184 publications that cite BRP books per year after 1941 (Appendix Table A15, column 1, significant at 1 percent) compared with authors in more distant locations. Relative to a pre-BRP mean of 0.031, this implies a 5.9-fold increase.

Importantly, there is no evidence of differences in the trends of citations before 1941, even though levels of citations are lower in more distant locations (Appendix Figure A10). The estimated effects of nearness also attenuate with distance and eventually become negative. Locations within a 50-mile radius produce 0.138 additional citations (Appendix Table A15, column 2, significant at 1 percent), which implies a 4.5-fold increase. With a full set of distance dummies, coefficients for locations *within 25 miles* and *25-50 miles* are positive, large, and statistically significant (at the 1 percent level, Appendix Table A15, column 4), whereas estimates become negative or insignificant above 50 miles.

All estimates are robust to including additional controls for proximity to an émigré from Germany, who may have encouraged citations to BRP (and other German) books because they had read these books back home. OLS estimates for proximity to a BRP book remain large with controls for proximity to an émigré institution: Locations within a 50-mile radius from a BRP library generate 0.117 additional citations to BRP books per year after 1942 (Appendix Table A16, column 2, significant at 5 percent). By comparison, locations within a 50-mile radius from a university with émigrés receive only 0.093 additional citations, and this estimate is indistinguishable from zero (Appendix Table A16, column 2, p-value equal to 0.17).

VI. Alternative Measures: New PhDs and Patents

To complement our analyses of citations, this section examines two alternative measures for advances in science and innovation: new PhDs in math and new US patents that cite BRP books.

TABLE 8 – OLS, EFFECTS OF DISTANCE FROM LIBRARIES WITH BRP BOOKS ON NEW PHDS IN MATH

	(1)	(2)	(3)	(4)
Within 25 miles * post	0.798*			0.542
	(0.481)			(0.430)
Within 50 miles * post		0.792*		
		(0.464)		
Within 75 miles * post			0.808*	
			(0.467)	
25-50 miles * post				0.890
				(0.613)
50-75 miles * post				0.049
				(0.599)
75-100 miles * post				-0.778
				(0.553)
Year FE	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes
R-squared	0.504	0.504	0.504	0.507
N	9,180	9,180	9,180	9,180
Pre-1942 Mean	0.358	0.358	0.358	0.358

Standard errors in parentheses clustered at the location level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures the number of new PhDs in mathematics at location *k* in year *t.* The indicator within *x miles* equals 1 for locations that are within *x* miles of a library with at least one BRP math book. The indicator *x-y miles* equals 1 for locations that are further between *x* and *y* miles away from a library with BRP books. The variable *post* equals 1 for years after 1941.

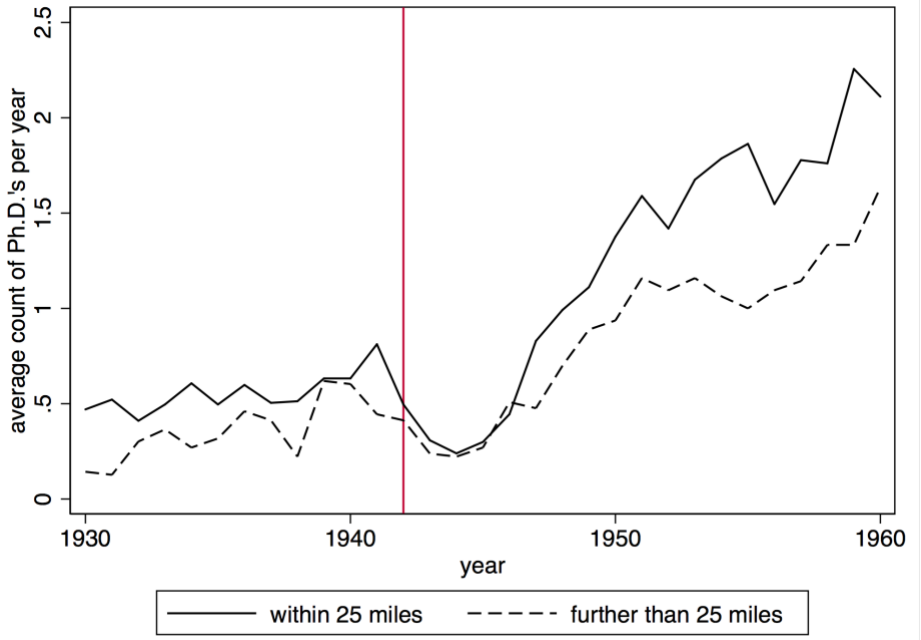
A. New PhDs in Mathematics

Changes in the number of new PhDs are a particularly useful complement to citations, because they capture variation in scientific output *above the level of BRP books*. To construct this measure, we examine data on 13,623 mathematicians who received their PhDs between 1920 and 1970 across 180 locations from the Mathematics Genealogy Project. We then re-estimate the distance regressions in equation (9) for PhDs:

$$PhD_{kt} = \beta \text{ within 25 miles}_k \times post_t + \eta_k + \tau_t + \varepsilon_{it} \quad (10)$$

where PhD_{kt} counts the number of PhDs theses in mathematics in location k and year t, and the variable within 25 miles_k indicates locations that are within 25 miles of at least one BRP book in mathematics.

FIGURE 13 – NEW PHDS PER YEAR, BY DISTANCE OF LOCATION FROM BRP LIBRARY



Notes: Citations by scientific publications per book and citation year for 55 BRP math books., by distance of the PhD-granting institution from a library holding at least one BRP book. We have collected data on the geographic locations of authors from records of PhD granting institution of advisors and advisees in the Mathematics Genealogy Project (http://www.genealogy.ams.org, accessed January 28th-March 10, 2016). Data on libraries holdings were constructed from the records of the National Union Catalog (Mansell 1968-1981) at the Hoover Institution Library and Archives.

OLS estimates indicate that locations within 25 miles of BRP books produce 0.798 additional PhDs per year after the BRP. Relative to a mean of 0.358 before 1942, this implies a 2.2-fold increase (Table 8, column 1, significant at 10 percent). Maps of new PhDs confirm that new PhD grants became more concentrated around locations with BRP books after the BRP (Appendix Figure A11). A potential concern with these tests is that universities that acquired BRP books may differ systematically from other universities.[45] Importantly, however, there are no significant differences in pre-trends across nearby and distant locations near (Figure 13), even though distant locations produce fewer PhDs on average.

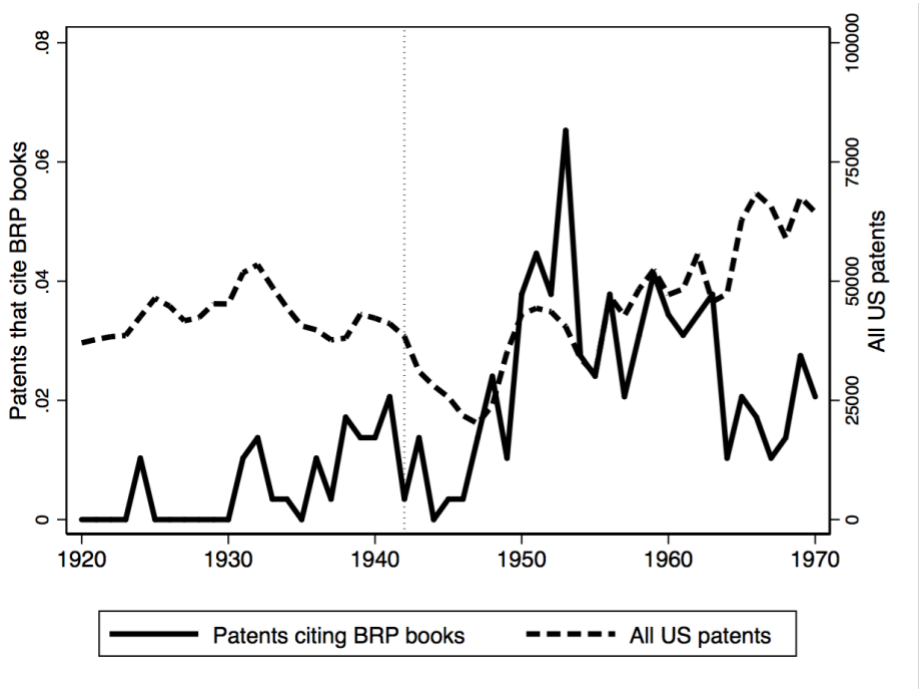
B. New US Patents

A final test examines the effects on private sector invention. Records from J.W Edwards show that many books were sold to private sector firms. For example, Edwards sold

[45] Universities that bought BRP books may have been able to attract better faculty, who then produced more students. Waldinger (2010) shows that the quality of PhD advisors mattered greatly for the career outcome of PhD students in mathematics. Peer effects among faculty were much more limited (Waldinger 2012).

600 copies of Beilstein's *Handbuch der Organischen Chemie* (Bokas and Edwards 2011, p. 25), but only 158 libraries held a copy in the NUC, leaving 442 copies for private sales. We can trace the potential effects of these books on firm inventions through their patents.

FIGURE 14 – PATENTS THAT CITE BRP BOOKS



Notes: Patents that cite BRP books as relevant scientific knowledge (per filing year, solid line), compared with the total number of US patent filings in the same year. Patents collected from Google Patents (http://patents.google.com, accessed January 1st-April 30th, 2016).

To measure inventions that used knowledge in BRP books, we search the full text of all US patent documents between 1920 and 1970 for citations to BRP books as relevant scientific knowledge.[46] For example, US Patent 3,210,370 for a "PROCESS FOR PREPARING 2,2'-METHYLENE- BISARENEIMIDAZOLES" (filed on June 22, 1964, issued to Joseph J. Ursprung, Portage, Michigan. and assigned to The Upjohn Company, in Kalamazoo, Michigan) uses Beilstein's *Handbuch der Organischen Chemie* to illustrate the products of its invention:

> "ETHYL 2- (5,G-DEIMEEFIHYL-ZBE'NZHHDAZOLYL) ACETATE A mixture of 6.8 g. (0.05 mole) of 4,5-dimethyl-1,2- phenylenediamine (Beilsteins Handbuch der Organischen Chemie, 13, 179 4th edition, 1930)" and
>
> "5,5,6-TRIMETHYL-2,2-METHYLENEBIS- BENZIMIDAZOLE A mixture of 4.64 g. (0.02 mole) of ethyl 2-(5,6-dimethyl-Z-benzimidazolylacetate (prepared as described above), 2.44 g. of 4-methyl-1,2-phenylenediamine (Beilsteins Handbuch der Organischen

[46] We perform an automatic search of the full text of patents in the *USPTO Bulk Data Downloads: Patent OCR Text* (available at www.google.com/patents) for authors and titles, and then hand-check all potential matches.

Chemie, 13, 148, 4th edition, 1930), and 50 ml. of 1,2,4-trichlorobenzene was stirred and heated to 180 C.

Notably, citations include page numbers and precise references to the context in which each book was used, indicating that these were real uses, rather than courtesy citations. Between 1920 and 1970, 238 US patents include at least one citation to a BRP book.

Confirming the main results, analyses of patent data suggest a large increase in cumulative invention in response to the BRP. Before 1942, a total of 34 US patents cite at least one BRP book in the description of their invention.[47] Afterwards, 200 patents cite BRP books. Beilstein, for example, is cited as relevant scientific knowledge in 0.304 patents per year before 1942, and 1.345 afterwards. For the average BRP book, patent references increase by 15 percent, from 0.005 per book and year to 0.024 (Figure 14).

VII. Conclusions

This paper has found that weaker copyright laws, which reduce the price of scientific materials, can encourage the creation of new cumulative science. When the US government broke the copyright monopoly for German-owned science book, prices for these books declined by an average of 28 percent. Our analysis suggests that each 10-percent decline in price triggered a 40 percent increase in new research that cites these books. These results are robust to a broad range of alternative specifications, including flexible controls for differential changes in citations across research fields and over time.

We show that BRP books became more evenly diffused across a geographically and economically diverse set of American universities, allowing a new group of researchers to use these books in their research. A geographic analysis of citations indicates that authors who were near BRP books began to use them disproportionately after 1942. Importantly, these results are not limited to citations, but they are confirmed by two alternative measures of cumulative science – new PhDs theses and new US patents that cite BRP books.

These results indicate that policies which facilitate access to existing knowledge - either through lower prices or targeted subsidies – can encourage the creation of new science. Our findings complement recent analyses of textbooks, which have shown that books are a powerful tool to shape attitudes and beliefs (Cantoni et al. 2017), and that access to existing

[47] Thirty patents cite a BRP chemistry book and 4 cite a BRP math book before 1942; 190 patents cite a BRP chemistry book and 10 cite a BRP math book after 1941 (530 and 150 percent more, respectively.) The larger number of chemical patents reflects the exceptional effectiveness of patents in chemicals (e.g. Moser 2012a).

knowledge may even boost economic growth by promoting innovation (Squicciarini and Voigtländer 2015).[48]

More generally, our findings illustrate an important tradeoff in the design of copyright laws. Analyses of music and literature suggest that basic copyrights encourage creativity by increasing payments to authors (e.g., Di Cola 2013, MacGarvie and Moser 2013, Giorcelli and Moser 2016. For online media, Cagé et al (2018) show that copying is rampant, which suggests that some level of copyright enforcement could help incentivize investments in high-quality news. Our findings illustrate the downside of stronger copyright laws. These downsides are especially severe for science and other fields in which new creativity and innovation depends on access to existing work.

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[48] Cantoni et al (2017) show that a change in China's textbook curriculum caused significant changes in attitudes, improving China's governance and increasing skepticism toward free markets. Squicciarini and Voigtländer (2017) show that the density of encyclopedias subscribers was a strong predictor of city growth after the onset of the French industrial revolution.

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APPENDIX –
FOR ONLINE PUBLICATION

TABLE A1 – SUMMARY STATISTICS, BRP BOOKS

	N	Mean	St. Dev.	Median
All BRP books				
Original *p*	271	42.79	179.57	11.15
BRP *p*	283	19.41	41.77	7.50
Δp	271	24.97	21.33	21.87
Chemistry				
Original p	216	51.18	200.34	11.70
BRP p	228	22.43	46.00	8.50
Δp	216	24.34	21.39	21.76
Mathematics				
Original p	55	9.84	5.77	8.00
BRP p	55	6.88	4.32	5.75
Δp	55	27.44	21.11	23.47

Notes: Means, standard deviations, and median prices for 283 books with German-owned US copyrights that were licensed to US publishers under the 1942 BRP. The variable *Δp* measures the percentage decline in price, calculated as the difference between the original price and the BRP price, divided by the original price. Price data collected from records of the Alien Property Custodian (1942).

TABLE A2 – MOST CITED BRP BOOKS

Author	Title	Publication Year	Pre-1942 Citations	Post-1942 Citations	Field
Courant, R. & D. Hilbert	*Methoden der Mathematischen Physik*	1931	8	235	Mathematics
Becker, R.	*Ferromagnetismus*	1939	10	232	Chemistry
Alexandroff, P. & H. Topf, H.	*Topologie*	1935	6	235	Mathematics
Nevanlinna, R.	*Eindeutige Analytische Funktionen*	1936	6	230	Mathematics
Waerden, B.	*Moderne Algebra*	1931	11	195	Mathematics
Saccardo, P.	*Sylloge Fungorum Omnium Hucusque Cognitorum... curante Alex*	1881	59	141	Chemistry
Hansen, M.	*Der Aufbau der Zweistofflegierungen*	1936	25	172	Chemistry
Doetsch, G.	*Theorie und Anwendung der Laplace-Transformation*	1937	7	169	Mathematics
Clar, E.	*Aromatische Kohlenwasserstoffe: Polycyclische Systeme*	1942	0	166	Chemistry
Speiser, A.	*Die Theorie der Gruppen von Endlicher Ordnung*	1937	2	112	Mathematics

Notes: Citations refer to citations to BRP books by English-language citations.

TABLE A3 – MOST CITED SWISS BOOKS

Author	Title	Publication Year	Pre-1942 Citations	Post-1942 Citations	Field
Leser, Conrad	*Invariantentheorie Algebraische Formen*	1939	0	41	Mathematics
Huber, Wilhelm	*Zur Kenntnis der Sulfuration Aromatischen Amine nach dem sogennanten "Backprozess"*	1932	0	34	Chemistry
Motzkin, Theodor	*Zur Theorie der Linearen Ungleichungen*	1936	0	34	Mathematics
Warschawski, Stefan	*Das Randverhalten der Ableitung der Abbildungsfunktion bei Konformer Abbildung*	1932	0	34	Chemistry
Stiefel, Edward	*Richtungsfelder und Fernparallelism in n-Dimensionalen Mannigfaltigkeiten*	1936	2	31	Chemistry
Hofmann, Albert	*Über den Enzymatischen Abbau des Chitins und Chitosans*	1929	3	17	Mathematics
Jungen, Reinwald	*Sur les series de Taylor n'ayant que des singularités algébrico-logarithmiques sur leur cercle de convergence*	1932	6	13	Chemistry
Muller, Hans.	*Zur Theorie der elektrischen Ladung und der Koagulation der Kolloide*	1928	0	19	Mathematics
Halpern, Ada	*Etude de certains potentiels logarithmiques*	1937	2	17	Chemistry
Gutzeit, Grégoire	*Sur une méthode d'analyse qualitative rapide des cations et anions les plus usuels*	1930	3	13	Mathematics

Notes: Citations refer to citations to Swiss books by English-language citations.

TABLE A4 – CHANGES IN PRICE AND IN CITATION FOR THE TOP FIVE RESEARCH FIELDS, BRP AND SWISS BOOKS IN MATHEMATICS (TOP) AND CHEMISTRY (BOTTOM)

	BRP Books					Swiss Books		
	Price		Citations		N	Citations		N
	Original	Δp	Pre-1941	Post-1941		Pre-1941	Post-1941	
Mathematics								
Mathematics	11.96	38.80	0.520	1.740	14	0.025	0.112	4
Geometry	7.75	29.27	0.054	0.330	12	0.028	0.112	17
Algebra	8.74	15.79	0.143	0.990	7	0.017	0.119	13
Set Theory	9.99	31.59	0.447	2.695	6	0.047	0.072	13
Analysis	9.52	18.14	0.337	1.952	5	0.009	0.162	16
Chemistry								
Compounds	29.60	24.68	0.191	0.441	58	0.016	0.059	74
Organic Chemistry	200.30	34.65	0.367	0.508	28	0.000	0.057	6
Metals	16.27	18.57	0.427	0.696	27	0.057	0.060	4
Electrochemistry	15.97	18.93	0.152	0.520	14	0.023	0.045	10
Analytical Chemistry	14.77	32.79	0.242	0.299	12	0.063	0.138	5
Physical Chemistry	22.01	26.09	0.249	0.276	10	0.000	0.000	1

Notes: Research fields for 283 BRP and 247 Swiss books in the US National Union Catalog. Research fields are constructed based on topic codes in Alien Property Custodian (1942) and the *Katalog* (vols. 1921-1939 and 1931-1940) of the Swiss National Library.

TABLE A5 – COMPARISON OF MEANS
NEW PUBLICATIONS THAT CITE BRP BOOKS PER BOOK AND YEAR

	1920-41	1942-1970	Difference
All (N=283)	0.281	0.479	0.197***
	(0.784)	(1.371)	(0.025)
English	0.263	0.566	0.303***
	(0.775)	(1.653)	(0.041)
Other languages	0.299	0. 391	0. 092***
	(0.793)	(1.006)	(0.026)
Difference	0.036	0.174***	0.211***
	(0.027)	(0.021)	(0. 049)
Chemistry (N=228)	0.306	0.384	0.078***
	(0.838)	(1.088)	(0.023)
English	0.274	0.414	0.140***
	(0.814)	(1.251)	(0.037)
Other languages	0.337	0.353	0.016
	(0.860)	(0.895)	(0.027)
Difference	0.063	0.060***	0.124***
	(0.033)	(0.019)	(0.046)
Mathematics (N=55)	0.204	0.872	0.667***
	(0.574)	(2.138)	(0.077)
English	0.230	1.195	0.965***
	(0.633)	(2.661)	(0.135)
Other languages	0.179	0.549	0.369***
	(0.509)	(1.363)	(0.070)
Difference	0.050	0.647***	0.596***
	(0.041)	(0.075)	(0.152)

Notes: Means and standard deviations (in parentheses) of the number of new scientific publications (including articles and books) that cite a BRP book *i* per year *t* between 1920 and 1970. *English* are citations by English-language authors; *other languages* are citations by authors in other languages that cite the same books. To construct data on citations from different languages, we first collected citations from Google Scholar (available at http://scholar.google.com, accessed July 1st - September 25th, 2014), and then manually assigned all citing publications to their publication language.

TABLE A6 – OLS, EFFECTS OF BRP ON CITATIONS BY ENGLISH VS. OTHER LANGUAGE AUTHORS AND TO BRP VS SWISS BOOKS
DEPENDENT VARIABLE IS LN(CITATIONS) PER BOOK AND YEAR

	(1)	(2)	(3)	(4)	(5)	(6)
English	-0.575**	-0.554*	-0.554**			
	(0.275)	(0.303)	(0.277)			
English x post	0.786***	0.851***	0.851***			
	(0.284)	(0.286)	(0.287)			
BRP						1.163*
						(0.637)
BRP x post				1.405***	1.140*	1.379***
				(0.456)	(0.576)	(0.507)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Subject * year FE	No	Yes	No	No	Yes	No
Publication year & subject FE	No	No	Yes	No	No	Yes
R-squared	0.310	0.360	0.098	0.427	0.500	0.160
N	19,680	19,162	19,162	9,365	9,365	9,365
Pre-1942 Mean	.263	.268	.268	.282	.283	. 283
Standard errors in parentheses are clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1						

Notes: The dependent variable is the natural logarithm of citations to book *i* per year *t* between 1920 and 1970. We add a small number (0.0000001) to the number of citations to account for the fact that several observations in our data have zero citations. In columns 1-3, the indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same books from authors in other languages. In columns 4-6, the dependent variable is the log of English-language citations, the indicator *BRP* equals 1 for 283 books that were licensed to US publishers under the 1942 Book Republication Program (BRP), and the control group covers 247 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals one for years after 1941.

TABLE A7 – OLS, EFFECTS OF BRP AND PRICE DECLINE ON ENGLISH-LANGUAGE CITATIONS. CONTROLLING FOR LINEAR PRE-TRENDS

	(1)	(2)	(3)	(4)
English	-0.036	-0.036	-0.036	-0.036
	(0.042)	(0.042)	(0.042)	(0.042)
English x post	0.211***	-0.077	0.079	-0.074
	(0.066)	(0.091)	(0.053)	(0.091)
English x Δp x post		1.192***		0.646**
		(0.344)		(0.288)
English x Math x post			0.674**	
			(0.279)	
English x Math x Δp x post				2.383***
				(0.907)
Citation Year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	Yes
R-squared	0.357	0.366	0.368	0.382
N	19,680	18,986	19,680	18,986
Pre-1942 Mean	0.263	0.264	0.263	0.264

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The depended variable is de-trended by estimating separate linear pre-trends for English-language citations and for citations by authors publishing in other languages, and then controlling for these different trends in the post-period. The indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same books from authors in other languages. The variable *post* equals one for years after 1941. The variable *Math* indicates 55 books in mathematics. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

TABLE A8 – COMPARISON OF MEANS:
NEW PUBLICATIONS THAT CITE BRP VS. SWISS BOOKS

	1920-41	1942-1970	Difference
All Books (N=530)	0.105	0.338	0.232***
	(0.487)	(0.255)	(0.018)
BRP (N=283)	0.263	0.566	0.303***
	(0.775)	(1.653)	(0.041)
Swiss (N=247)	0.024	0.078	0. 054***
	(0.171)	(0.353)	(0.007)
Difference	0.239***	0.488***	0.249***
	(0.014)	(0.020)	(0. 038)
Chemistry (N=389)	0.111	0.271	0.160***
	(0.514)	(0.993)	(0.017)
BRP (N=228)	0.274	0.413	0.140***
	(0.814)	(1.251)	(0.037)
Swiss (N=161)	0.025	0.069	0.044***
	(0.176)	(0.311)	(0.007)
Difference	0.249***	0.345***	0.096***
	(0.013)	(0.019)	(0.035)
Mathematics (N=141)	0.089	0.523	0.434***
	(0.395)	(1.776)	(0.051)
BRP (N=55)	0.230	1.195	0.965***
	(0.633)	(2.661)	(0.135)
Swiss (N=86)	0.021	0.094	0.073***
	(0.152)	(0.420)	(0.015)
Difference	0.209***	1.101***	0.892***
	(0.023)	(0.054)	(0.104)

Notes: Means and standard deviations (in parentheses) for English-language citations to BRP and Swiss books *i* per year *t* between 1920 and 1970. *BRP* books include 283 books with German-owned copyrights in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). Swiss books cover 247 books with Swiss-owned copyrights that were not available for copyright licensing due to Switzerland's neutrality during the war. To construct data on citations from different languages, we first collect citations from Google Scholar (available at http://scholar.google.com, accessed July 1st - September 25th, 2014), and then manually assigned all citing publications to their publication language.

TABLE A9 – COMPARISON OF MEANS:
CITATIONS TO BRP VS. SWISS BOOKS, MATCHED SAMPLE

	1920-41	1942-1970	Difference
All Books (N = 255)	0.218	0.581	0.362***
	(0.710)	(1.667)	(0.038)
BRP (N = 214)	0.283	0.661	0.378***
	(0.804)	(1.787)	(0.047)
Swiss (N = 39)	0.027	0.141	0.113***
	(0.196)	(0.531)	(0.024)
Difference	0.256***	0.520***	0.264***
	(0.036)	(0.054)	(0.091)
Chemistry (N = 193)	0.229	0.405	0.175***
	(0.751)	(1.207)	(0.033)
BRP (N = 165)	0.302	0.462	0.160***
	(1.420)	(1.767)	(0.041)
Swiss (N = 29)	0.023	0.068	0.045***
	(0.352)	(0.460)	(0.016)
Difference	0.280***	0.394***	0.114*
	(0.043)	(0.045)	(0.078)
Mathematics (N = 60)	0.186	1.147	0.961***
	(0.572)	(2.572)	(0.114)
BRP (N = 49)	0.230	1.331	1.102***
	(0.633)	(2.785)	(0.141)
Swiss (N = 11)	0.042	0.326	0.284
	(0.240)	(0.854)	(0.079)
Difference	0.188***	1.005 ***	0.818***
	(0.059)	(0.158)	(0.274)

Notes: Means and standard deviations (in parentheses) of the number of new scientific publications that cite book *i* per year *t* between 1920 and 1970. *BRP* books include 214 books with German-owned copyrights in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). Swiss books cover 39 books with Swiss-owned copyrights that were not available for copyright licensing due to Switzerland's neutrality during the war. To construct data on citations from different languages, we first collect citations from Google Scholar (available at http://scholar.google.com, accessed July 1st - September 25th, 2014), and then manually assigned all citing publications to their publication language.

TABLE A10– OLS, EFFECT OF CHANGE IN PRICE ON ENGLISH-LANGUAGE CITATIONS
BRP VS. SWISS BOOKS (FULL SAMPLE)

	(1)	(2)	(3)
BRP			0.159*
			(0.086)
BRP x post	0.097	0.170*	0.127
	(0.077)	(0.100)	(0.087)
BRP x Δp x post	1.006***	0.961**	1.066***
	(0.344)	(0.433)	(0.313)
Δp			0.282
			0.159*
Citation Year FE	Yes	Yes	Yes
Book FE	Yes	Yes	No
Field FE * Citation year FE	No	Yes	No
Publication year FE	No	No	Yes
Field FE	No	No	Yes
R-squared	0.554	0.587	0.167
N	19,844	19,383	19,383
Pre-1942 Mean	.264	.269	.269

Standard errors in parentheses clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The the dependent variable measures citations to book *i* per year *t* between 1920 and 1970 The indicator *BRP* equals 1 for 283 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 247 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

TABLE A11 – OLS, EFFECT OF PRICE DECLINE ON ENGLISH-LANGUAGE CITATION
BRP VS. SWISS. BOOKS IN THE LIBRARY OF CONGRESS.

	(1)	(2)	(3)	(4)	(5)	(6)
BRP			0.742***			0.613**
			(0.259)			(0.264)
BRP x post	0.361***	0.361***	0.439***	0.070	0.070	0.148
	(0.089)	(0.089)	(0.151)	(0.083)	(0.083)	(0.155)
BRP x Δp x post				0.992***	0.992***	1.000***
				(0.342)	(0.342)	(0.316)
Δp						0.378
						(0.287)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Publication Year FE	No	No	Yes	No	No	Yes
Field FE	No	No	Yes	No	No	Yes
Linear pre-trend	No	Yes	No	No	Yes	No
R-squared	0.551	0.545	0.156	0.554	0.548	0.178
N	10,567	10,567	10,308	10,220	10,220	9,989
Pre-1942 Mean	0.263	0.263	0.268	0.264	0.264	0.269

Standard errors in parentheses are clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: OLS regressions for BRP and Swiss books that are listed among the entries of the US Library of Congress. The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 BRP books that are listed in the Library of Congress and that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 19 Swiss books in the Library of Congress that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price. In columns 2 and 5 the dependent variable is de-trended by estimating separate linear pre-trends for BRP and Swiss books for pre-BRP years and controlling for trends in the post-period.

TABLE A12 – DIFFERENTIAL EFFECTS FOR BOOKS BY ÉMIGRÉS. CITATIONS TO BRP BOOKS BY ENGLISH VS. OTHER LANGUAGE AUTHORS

	(1) Baseline (math)	(2) Excl. BRP books and citations by émigrés	(3) Excl. citations from institutions with an émigré BRP author	(4) Excl. citations from students of émigré authors of BRP books	(5) Excluding citations from institutions with any émigrés from Germany	(6) Baseline estimates for math
English	0.051	0.012	0.053	0.053	0.053	0.051
	(0.065)	(0.069)	(0.069)	(0.069)	(0.069)	(0.066)
English x post	0.596**	0.508**	0.606**	0.606**	0.606**	0.479*
	(0.253)	(0.242)	(0.257)	(0.257)	(0.257)	(0.244)
US émigré x English x post						1.614
						(1.589)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.389	0.405	0.388	0.388	0.388	0.400
N	3,978	3,648	3,884	3,884	3,884	3,978
Pre-1942 Mean	.210	.210	.241	.241	.241	.230

Standard errors in parentheses are clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same books from authors in other languages. The variable *post* equals one for years after 1941. The variable *US émigré* indicates books by mathematicians who emigrated to the United States after the Nazi government took power in 1933. Columns 1 and 6 includes all math books. Column 2 excludes books by BRP authors émigrés. Column 3 excludes citations from institutions of BRP authors émigrés. Column 4 excludes citations by BRP authors émigrés' students of students. Column 5 excludes citations from all institutions with at least one German émigré (as listed by Cottrell 1956).

TABLE A13 – BOOKS BY ÉMIGRÉS TO THE UNITED STATES

Title	Author	Publication year	English- language Citations		Price	
			1920-41	1942-70	Original	Δp
Methoden der mathematischen Physik	R. Courant and D. Hilbert	1931	8	235	28.24	0.504
Strahlenoptik	M. Herzberger	1931	0	2	7.75	0.161
Mathematische Grundlagen der Quantenmechanik	J. v. Neumann	1932	6	28	7.85	0.554
Aufgaben und Lehrsätze aus der Analysis	G. Pólya and G. Szegő	1925	4	34	14.40	0.583

Notes: Emigrés are identified using entries in the *International Biographical Dictionary of Central European Émigrés 1933-1945* (Strauss et al. 1983), as well as based on affiliations with US universities, which we collect from the *Mathematics Genealogy Project* (available at http://genealogy.math.ndsu.nodak.edu, accessed February 1-18, 2015).

TABLE A14 – OLS, EFFECTS OF PRICE ON CITATIONS BY ENGLISH VS. OTHER LANGUAGE AUTHORS AND TO BRP VS SWISS BOOKS
DEPENDENT VARIABLE IS LN(CITATIONS) PER BOOK AND YEAR

	(1)	(2)	(3)	(4)	(5)	(6)
English	-0.576**	-0.556*	-0.556**			
	(0.275)	(0.304)	(0.278)			
English x post	-0.065	0.009	-0.483			
	(0.381)	(0.507)	(0.417)			
English x Δp x post	3.600***	3.577***	5.541***			
	(1.001)	(1.225)	(1.191)			
BRP						1.157*
						(0.615)
BRP x post				0.935*	0.799	-0.106
				(0.521)	(0.731)	(0.628)
BRP x Δp x post				1.583	1.241	5.038***
				(1.292)	(1.636)	(1.454)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Subject * year FE	No	Yes	No	No	Yes	No
Publication year & subject FE	No	No	Yes	No	No	Yes
R-squared	0.314	0.366	0.114	0.429	0.501	0.176
N	18,986	18,524	18,524	9,302	9,302	9,302
Pre-1942 Mean	.264	.269	.269	.284	.284	.284

Standard errors in parentheses are clustered at the book level. *** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is the natural logarithm of citations to book *i* per year *t* between 1920 and 1970. We add a small number (0.0000001) to the number of citations to account for the fact that several observations in our data have zero citations. In columns 1-3, the indicator *English* equals 1 for citations by *English-language* authors; the control group are citations to the same books from authors in other languages. In columns 4-6, the dependent variable is the log of English-language citations, the indicator *BRP* equals 1 for 283 books that were licensed to US publishers under the 1942 Book Republication Program (BRP), and the control group covers 247 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals one for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price.

TABLE A15 – OLS,
EFFECT OF BRP ON ENGLISH-LANGUAGE CITATIONS, BY DISTANCE FROM LIBRARY WITH BRP BOOKS

	(1)	(2)	(3)	(4)
25 miles * post	0.184***			0.145***
	(0.047)			(0.046)
50 miles * post		0.138***		
		(0.050)		
75 miles * post			0.170***	
			(0.040)	
25-50 miles * post				0.205***
				(0.073)
50-75 miles * post				-0.126**
				(0.060)
75-100 miles * post				-0.039
				(0.057)
Year FE	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes
R-squared	0.272	0.269	0.269	0.279
N	4,752	4,752	4,752	4,752
Pre-1942 Mean	0.031	0.031	0.031	0.031

Standard errors in parentheses clustered at the location level.
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable counts new citations by English-language publications to BRP books in mathematics from location *k* in year *t.* The indicator *x miles* equals 1 for locations that are within *x* miles from a library that acquired at least one BRP book by 1956. The indicator *x-y miles* equals 1 for locations that are between *x* and *y* miles away from a library with BRP books. The variable *post* equals 1 for years after 1941.

TABLE A16 – OLS,
EFFECT OF BRP ON ENGLISH-LANGUAGE CITATIONS, BY DISTANCE FROM LIBRARY WITH BRP BOOKS AND/OR ÉMIGRÉ INSTITUTION

	(1)	(2)	(3)	(4)
Emigre at 25 miles * post	0.087			0.073
	(0.067)			(0.087)
Library at 25 miles * post	0.177***			0.152***
	(0.045)			(0.053)
Emigre at 50 miles * post		0.093		
		(0.067)		
Library at 50 miles * post		0.117**		
		(0.048)		
Emigre at 75 miles * post			0.090	
			(0.063)	
Library at 75 miles * post			0.133***	
			(0.044)	
Emigre at 25-50 miles * post				-0.001
				(0.094)
Library at 25-50 miles * post				0.196**
				(0.083)
Emigre at 50-75 miles * post				0.063
				(0.075)
Library at 50-75 miles * post				-0.130*
				(0.066)
Emigre at 75-100 miles * post				-0.109
				(0.090)
Library at 75-100 miles * post				0.002
				(0.068)
Year FE	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes
R-squared	0.271	0.269	0.268	0.279
N	4,752	4,752	4,752	4,752
Pre-1942 Mean	.031	.031	.031	.031

Standard errors in parentheses clustered at the location level.
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable counts new citations by English-language publications to BRP books in mathematics from location *k* in year *t.* The indicator *Emigré x miles* equals 1 for locations that are within *x* miles from an institution with an émigré that acquired at least one BRP book by 1956. The indicator *Library x-y miles* equals 1 for locations that are between *x* and *y* miles away from a library with BRP books. The variable *post* equals 1 for years after 1941.

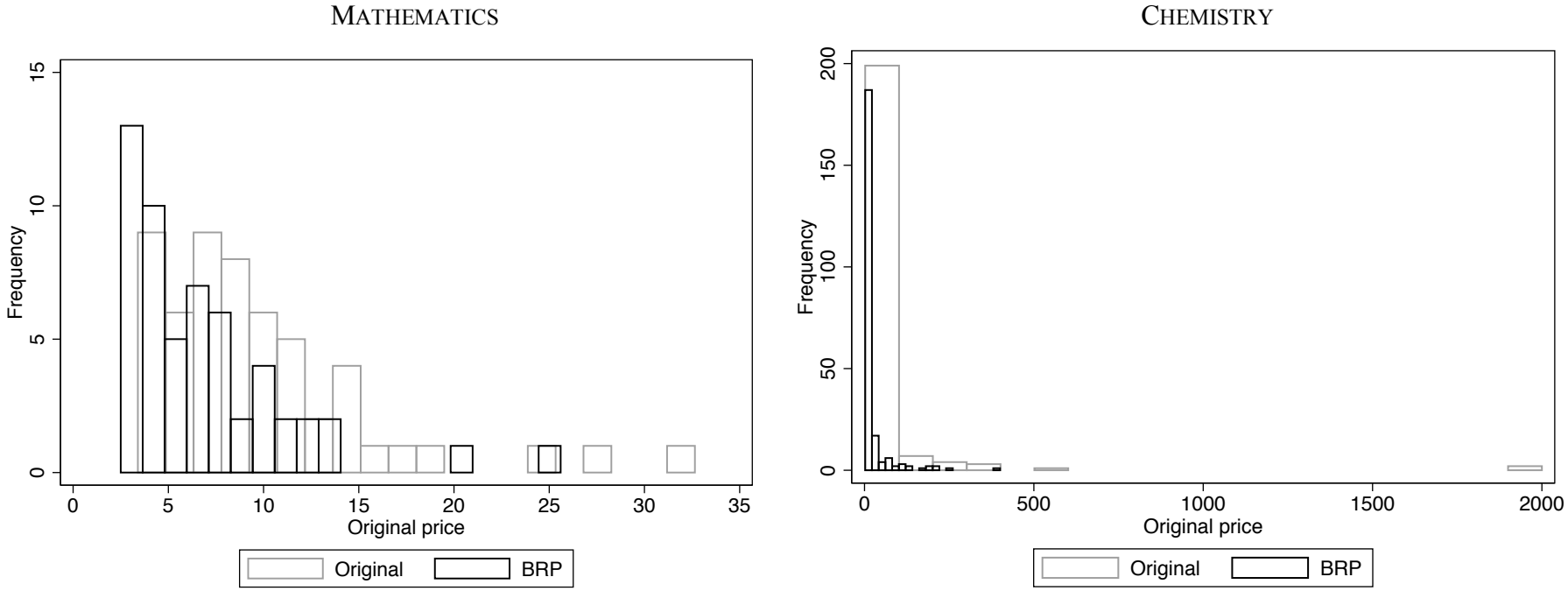
TABLE A17 – OLS, EFFECT OF BRP ON ENGLISH-LANGUAGE CITATIONS. INCLUDING BOOKS THAT ARE NOT IN THE NUC

	(1)	(2)	(3)	(4)	(5)	(6)
BRP			0.220***			0.141**
			(0.057)			(0.059)
BRP x post	0.393***	0.393***	0.420***	0.107	0.107	0.116
	(0.083)	(0.083)	(0.085)	(0.076)	(0.076)	(0.078)
BRP x Δp x post				0.971***	0.971***	1.068***
				(0.338)	(0.338)	(0.305)
R-squared	0.549	0.544	0.142	0.552	0.547	0.164
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Linear pre-trend	No	Yes	No	No	Yes	No
Publication Year FE	No	No	Yes	No	No	Yes
Subject FE	No	No	Yes	No	No	Yes
R-squared	0.549	0.544	0.142	0.552	0.547	0.164
N	29,879	29,879	29,241	29,504	29,504	28,894
Pre-1942 Mean	0.263	0.263	0.268	0.264	0.264	0.269

Standard errors in parentheses are clustered at the book level.
*** p<0.01, ** p<0.05, * p<0.1

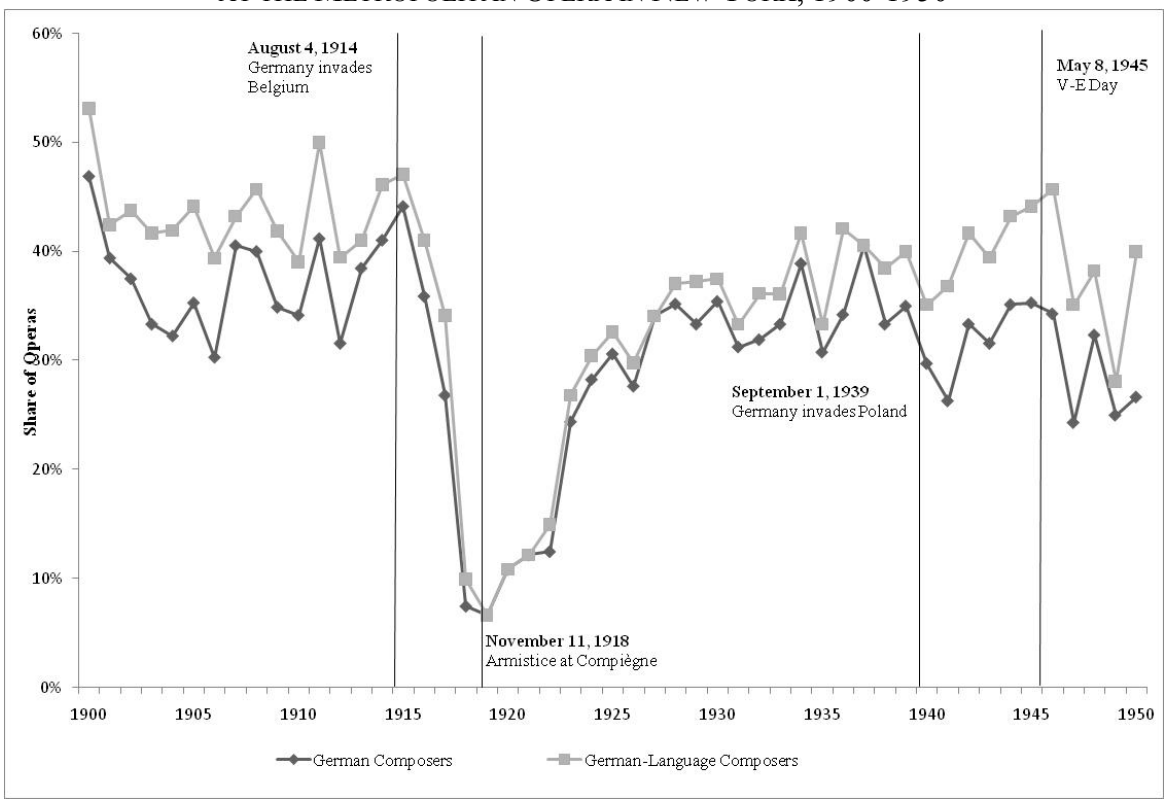
Notes: OLS regressions for the full sample of BRP and Swiss books, including books that are not listed in the National Union Catalog (which captures the holdings of US libraries.) The dependent variable measures citations to book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 291 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 486 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. The variable *post* equals for years after 1941. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price. In columns 2 and 6 the dependent variable is de-trended by estimating separate linear pre-trends for BRP and Swiss books for pre-BRP years and controlling for trends in the post-period.

FIGURE A1 – ORIGINAL AND BRP PRICES FOR BRP BOOKS



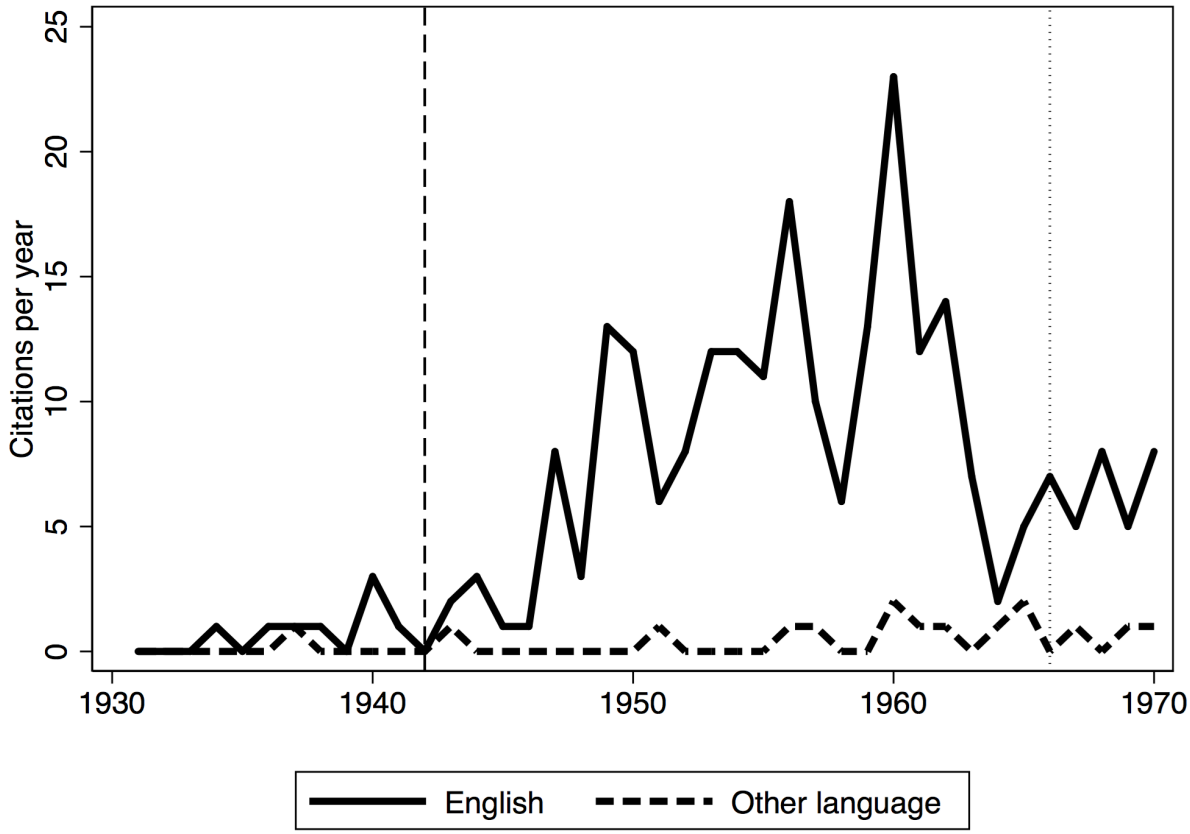
Notes: Original (pre-BRP) and BRP prices for 55 books in mathematics (left) and 228 books in chemistry (right). Two chemistry books sold for an original price of $2,000 each: Beilstein's *Handbuch der Organischen Chemie* (with a BRP price of $400) and Saccardo's *Silloge Fungorum* (with a BRP price of $200). The most expensive math books are Courant's *Grundlagen der Mathematik* (with an original price of $32.6 and a BRP price of $25.6) and Courant and Hilbert's *Methoden der Mathematischen Physik* (with an original price of $28.2 and a BRP price of $14).

FIGURE A2 – SHARE OF GERMAN-LANGUAGE OPERAS
AT THE METROPOLITAN OPERA IN NEW YORK, 1900-1950



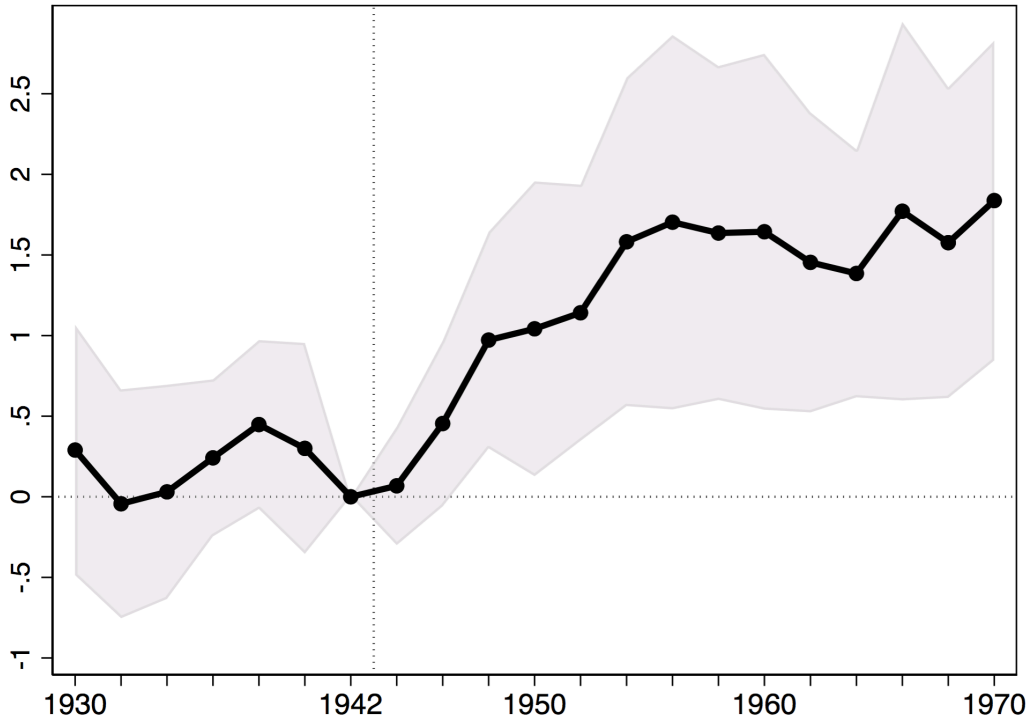
Notes: Data on the share of German-language operas collected from historical schedules of performances in the online archives of the Metropolitan Opera in New York (Moser 2012). *German composers* include Carl Maria von Weber, Engelbert Humperdinck, Friedrich Handel, Friedrich von Flotow, Giacomo Meyerbeer, Hermann Goetz, Jacques Offenbach, Ludwig van Beethoven, Max von Schillings, Peter Cornelius, Richard Strauss, and Richard Wagner. *German-language composers* further include Austrian composers Wolfgang Amadeus Mozart, Ernst Krenek, Franz von Suppé, Johann Strauss Jr. and Franz Schubert and the Bohemian Christoph von Gluck. Composers are assigned to ethnicities based on their country of birth, which means that Beethoven and Handel are counted as German, even though Beethoven was also active in Vienna and Handel in London.

FIGURE A3 – CITATIONS BY NEW PUBLICATIONS PER YEAR –
METHODEN DER MATHEMATISCHEN PHYSIK (1931) BY R. COURANT AND D. HILBERT



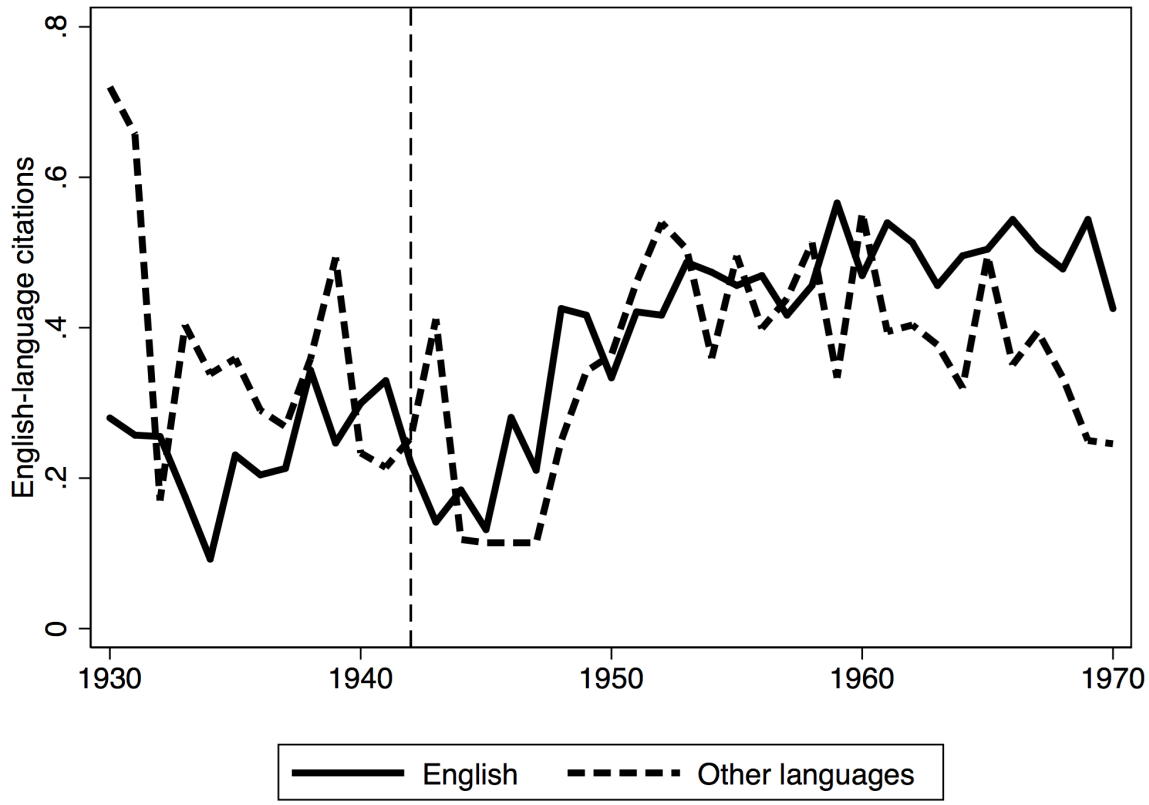
Notes: Citations *Methoden der Mathematischen Physik* (1931) by new scientific publications (book and articles) per year. Citations data from Google Scholar (http://scholar.google.com) between July 1st and September 25th, 2014. We restrict the data to new publications that cite the original German language versions of BRP books, and exclude citations to English translations (here, *Methods of Mathematical Physics*, 1966).

FIGURE A4 – TIME-VARYING EFFECTS OF CHANGES IN PRICE
ENGLISH VS. NON-ENGLISH CITATIONS TO BRP VS. SWISS BOOKS



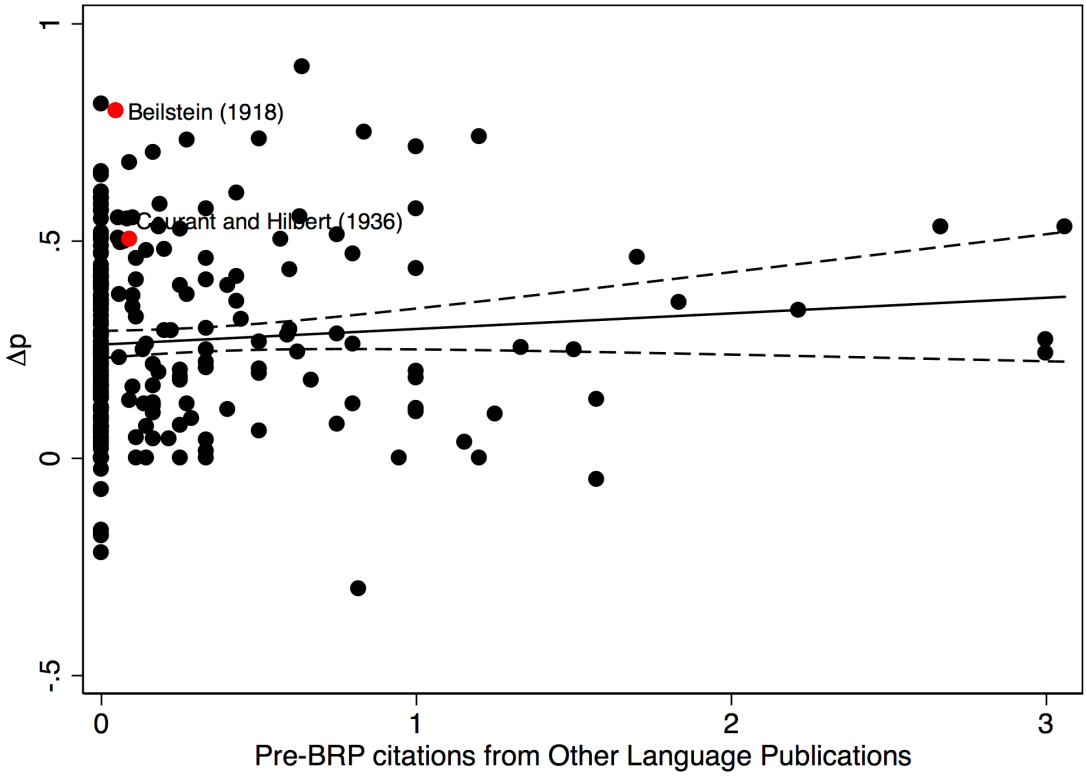
Notes: Estimates of θ_s with a 95-percent confidence interval in the OLS regression $cites_{ilt} = \alpha_1 English_l + \alpha_2 English_l * post_t + \beta_1 BRP_i * English_l + \beta_2 English_l * post_t + \beta_3 BRP_i * English_l * post_t + \beta_4 BRP_i * post_t * + \Delta p_i + \Sigma_s \theta_s \Delta p_i * English_l * BRP_i * \tau_s + book_i + \mu_{ft} + \tau_t + \varepsilon_{ilt}$ for two-year intervals 1920-21,…,1969-70, with years 1941-42 as the excluded period. The dependent variable $cite_{ilt}$ counts citations to book i in language l and year t. The indicator *English* equals 1 for citations from English-language authors. The indicator *BRP* equals 1 for 214 books that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books that were not available for licensing due to Switzerland's neutrality during the war. $Book_i$ is a vector of book fixed effects; μ_{ft} are field-by-year fixed effects, and τ_t indicates year fixed effects. The variable Δp measures the difference between the original price and the BRP price for book i, divided by the original price. Standard errors are clustered at the book level.

FIGURE A5 – CITATIONS TO BRP BOOKS IN CHEMISTRY
BY ENGLISH-LANGUAGE AUTHORS PER BOOK AND YEAR



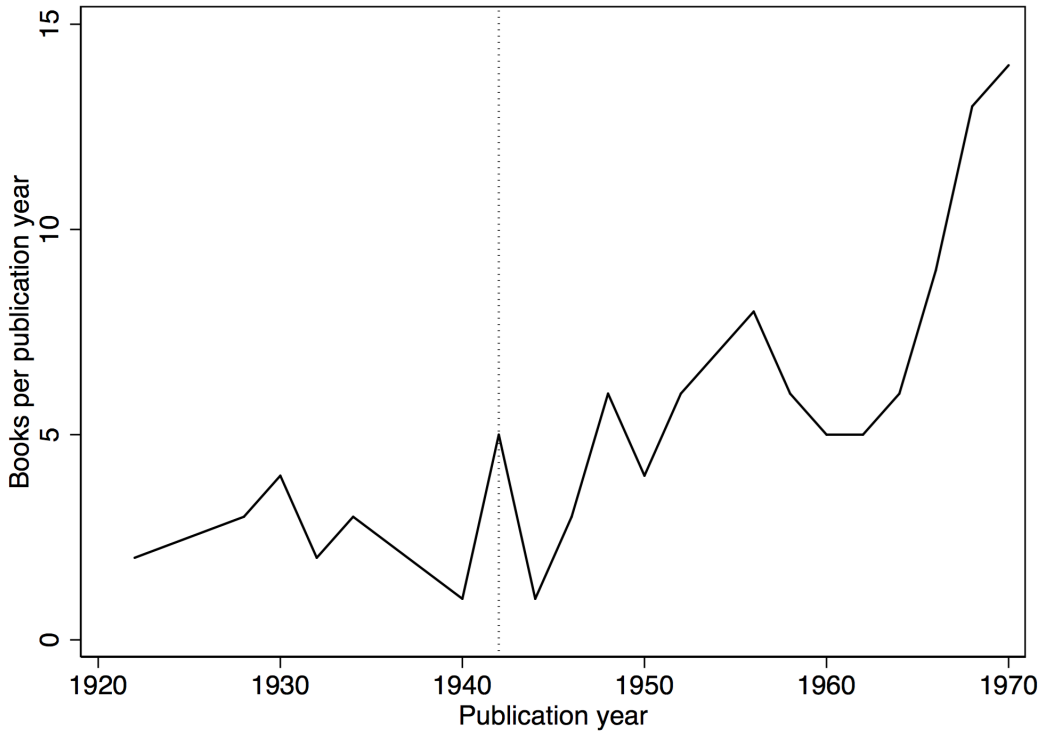
Notes: Citations per book and year for 228 BRP chemistry books by new scientific publications in English compared with citations to BRP books by new publications in other languages (which did not benefit directly from the BRP). Citations collected from Google Scholar (http://scholar.google.com, accessed July 1st-September 25th, 2014).

FIGURE A6 – DECLINE IN PRICE FOR BRP BOOKS
WITH FEW AND MANY PRE-BRP CITATIONS BY AUTHORS PUBLISHING IN OTHER LANGUAGES



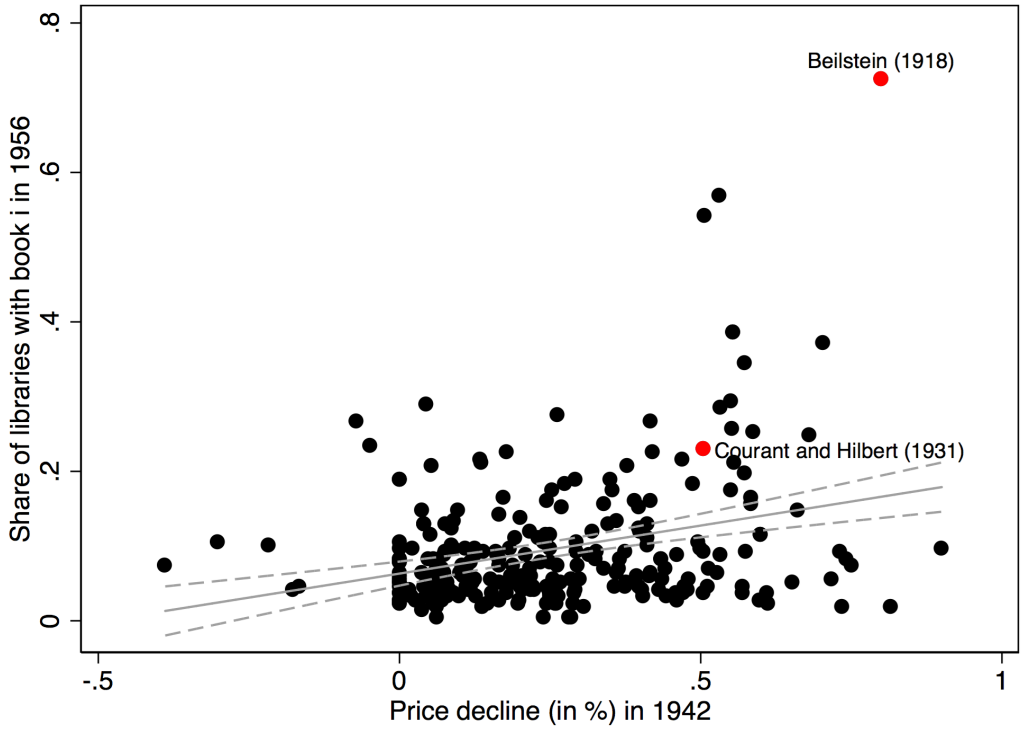
Notes: The vertical axis shows the percentage decline in price Δp (calculated as the difference between the original price and the BRP price divided by the original pre-BRP price). The horizontal axis shows the pre-BRP counts of citations per year to the same BRP book by publications in other languages. The solid line plots the linear relationship between Δp and pre-BRP citations; the dashed lines denote 5 percent confidence intervals. One additional citation by a non-English publication before the BPR is associated with an additional 3.6 percentage point decline in price (with a p-value of 0.18).

FIGURE A7– PUBLICATION YEARS FOR POTENTIAL SUBSTITUTES FOR BRP BOOKS



Notes: Books that customers on Amazon who bought BRP books "also bought" or "frequently bought together" with BRP books by the publication year of their first edition. For the four most highly cited BRP books in mathematics: Courant and Hilbert (1931) *Methoden der Mathematischen Physik,* Alexandroff and Hopf (1935), van der Waerden (1931), *Moderne Algebra*, Nevanlinna (1936), *Eindeutige analytische Funktionen* (R. Nevanlinna, 1936). Data collected from www.amazon.com, accessed September 21-30, 2016).

FIGURE A8 – SHARE OF LIBRARIES THAT HAD ACQUIRED A BRP BOOK BY 1956 VS ITS PRICE DECLINE IN 1942



Notes: The share of libraries that had acquired a BRP book *i* by 1956 against the decline in price for the same book in 1942. Each additional 10 percent decline in price was associated with a 1.3 percent increase in the share of libraries that held a BRP book (with a p-value of 0.00). Excluding outliers (such as Beilstein), which can be found in more than 40 percent of US libraries, leaves the estimate at 0.8 (with a p-value of 0.00). We constructed data on libraries holdings of BRP books a physical copy of the National Union Catalog (Mansell 1968-1981), which is available in the Hoover Institution Library and Archives.

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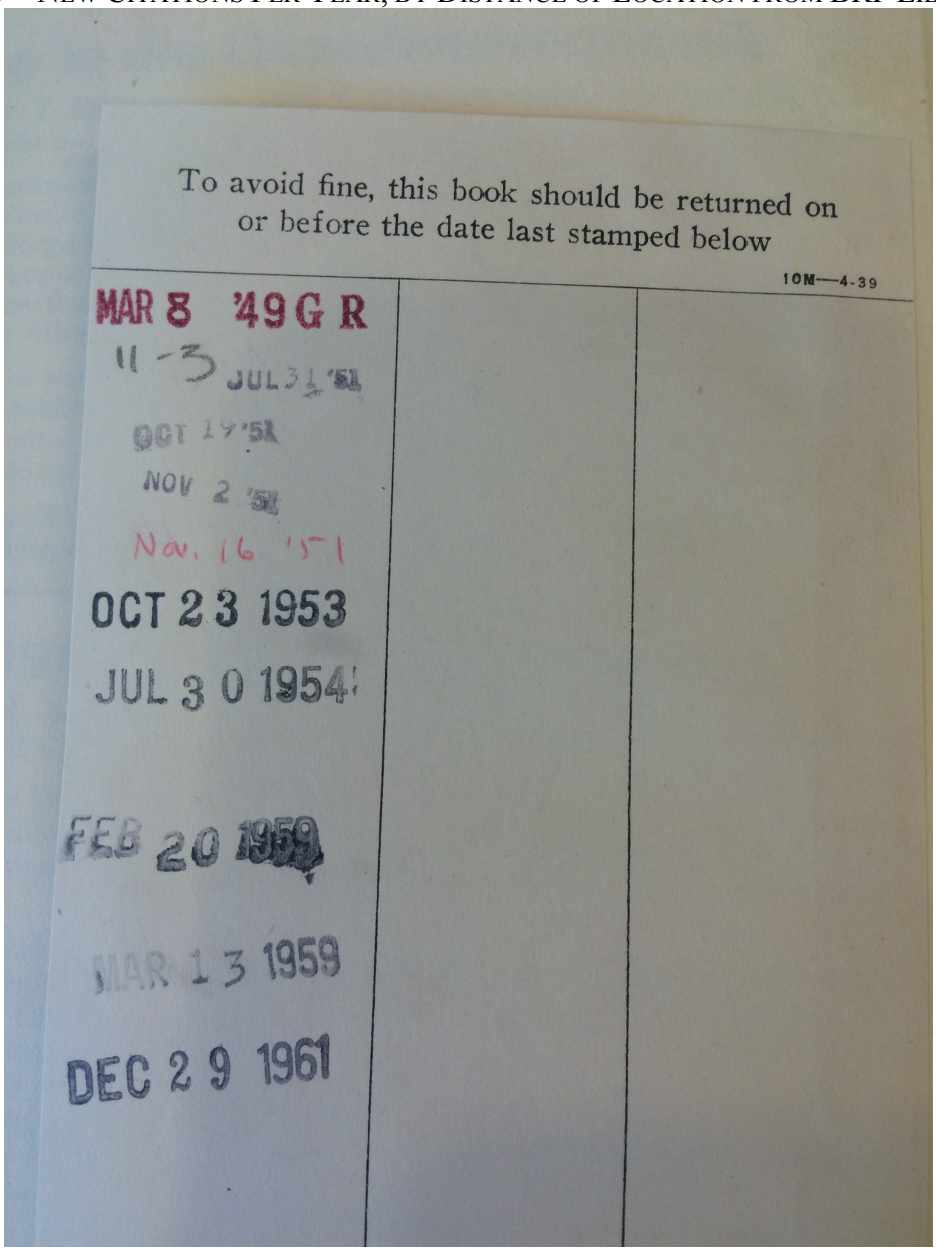
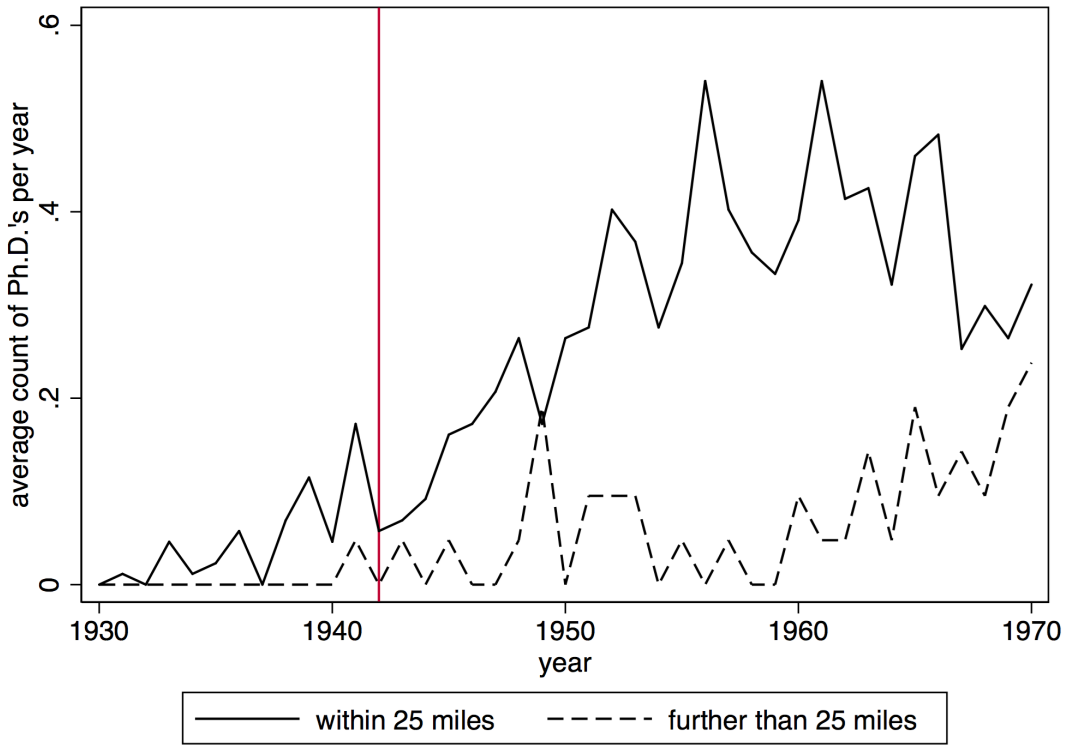
FIGURE A9 – NEW CITATIONS PER YEAR, BY DISTANCE OF LOCATION FROM BRP LIBRARY



Notes: Check-out sheets included in the back of the BRP book "Grundlagen Und Anwendungen Ihrer Theorie" by H.C.F von Weizsäcker. Stanford University Library, June 2016.

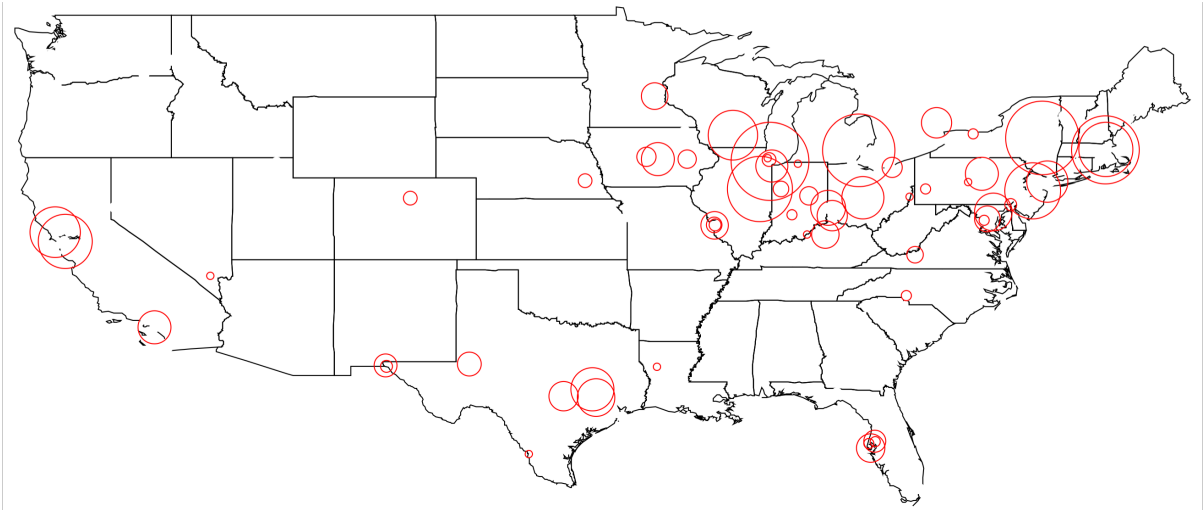
FIGURE A10 – NEW CITATIONS PER YEAR, BY DISTANCE OF LOCATION FROM BRP LIBRARY



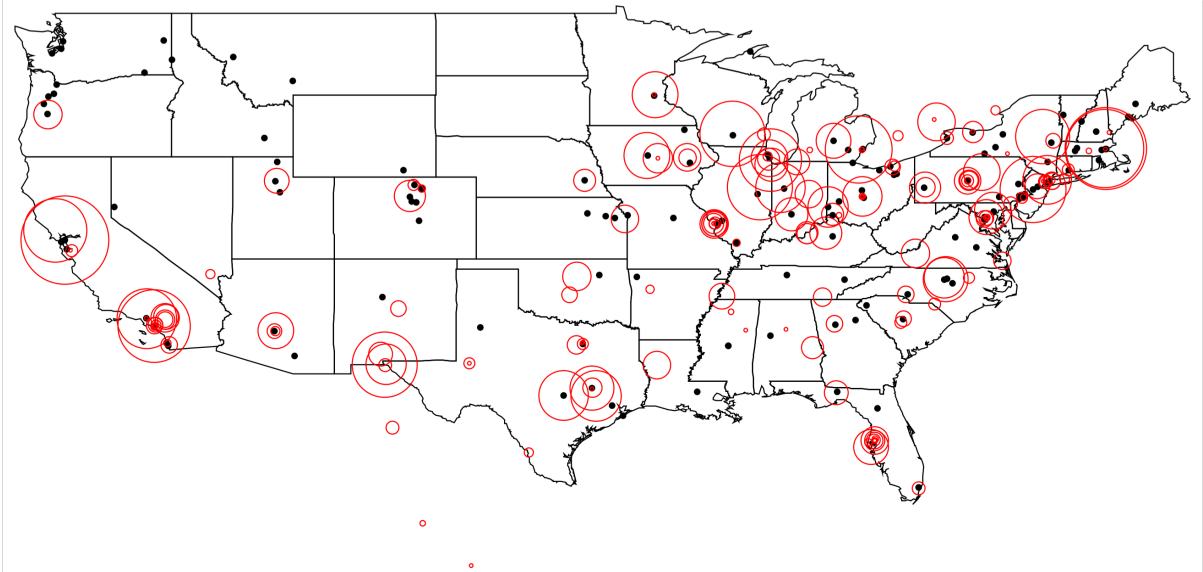
Notes: Citations by scientific publications per book and citation year for 55 BRP math books., by distance of the author from a library holding at least one BRP book. We have collected data on the geographic locations of authors from records of PhD granting institution of advisors and advisees in the Mathematics Genealogy Project (available at http://www.genealogy.ams.org, accessed January 28th-March 10, 2016). Data on libraries holdings were constructed from the records of the National Union Catalog (Mansell 1968-1981) at the Hoover Institution Library and Archives.

FIGURE A11 – LOCATIONS OF NEW PHDS AND BRP BOOKS IN MATH

1920-1941



1942-1970



Notes: Black circles map the locations of US libraries where BRP math books had become available by 1956. Red circles show the locations of PhD-granting institutions; the size of the red circle represents the number of citations from a location. We have collected data on the geographic locations of authors from records of PhD granting institution of advisors and advisees in the Mathematics Genealogy Project (http://www.genealogy.ams.org, accessed January 28th-March 10, 2016).