EFFECTS OF COPYRIGHTS ON SCIENCE – EVIDENCE FROM THE 1942 BOOK REPUBLICATION PROGRAM*

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JUNE 8, 2016

This paper investigates how copyright – through its effects on price – can influence follow-on science. In 1942, the US Book Republication Program (BRP) issued temporary copyright licenses for enemy-owned science books to US publishers, enabling them to sell exact copies at an average price decline of 25 percent. We investigate the effects of this change on US science, using citations to BRP books from new scientific publications as a proxy for new "follow-on" science that builds on BRP books. Comparisons of citations to BRP books and Swiss books (which were not available for licensing) reveal a significant differential increase in citations to BRP books after 1942. Intensity estimates imply that a 10-percent reduction in price initiated a 38 percent increase in citations. A simple model of knowledge creation predicts that the effects of price will be greater for disciplines, such as math, that depend primarily on human capital, compared with other disciplines, such as chemistry, that depend more on physical capital. Confirming this prediction, citations data indicate a 3.5-fold additional increase in follow-on science for math. An analysis of variation in library holdings and loans indicates that reductions in price increased follow-on science by making BRP books available to a new group of scientists.

KEYWORDS: SCIENCE, COPYRIGHT, MEDIA, AND ECONOMIC HISTORY

JEL CODES: J24, N32, O14, O31, O34

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Intended to encourage creativity, copyrights grant intellectual property rights to the authors of creative works, including music, films, news, software, and books. With the growth of digitization, understanding the effects of intellectual property on the production and use of creative content has become critical, but economic analyses continue to be rare.[1] Recent empirical analyses have found that basic levels of copyright protection can increase both the quantity and the quality of creative output (Giorcelli and Moser 2015), possibly by increasing the profitability of authorship (MacGarvie and Moser 2013).

Yet, the design of intellectual property rights must consider tradeoffs between incentives for authors and losses in consumer welfare. For example, Heald (2014) and Reimers (2014) have shown that books that are off copyright today (because they were first published more than 95 years ago) are more likely to be available for sale compared with more recent books that are still on copyright. Similarly, historical analyses of book prices have found that extensions in copyright length led to a significant increase in the price of books (Li et al. 2015), possibly creating substantial losses in consumer surplus.

The welfare effects of copyrights may be particularly large for science because new "cumulative" or "follow-on" science (Scotchmer 1991) depends critically on access to existing scientific knowledge.[2] In fact, major funding agencies increasingly require grant recipients to make scientific articles available for free, essentially ignoring copyrights.[3] Although there is no direct evidence on the effects of copyrights, related research on follow-on science suggests that the welfare gains from reducing access costs may be significant. Furman and Stern (2011), for example, show that the creation of biological research centers that facilitate access to cancer cells has encouraged medical research. Murray et al. (2016) find that research contracts that improve access to genetically engineered mice have

[1] A well-developed literature in legal studies reflects the importance of copyrights (e.g., Landes and Posner 1989, DiCola 2013, and Heald 2014). Economic analyses of copyrights face two major empirical challenges. First, the extreme length of modern copyrights (95 years in the United States) makes it difficult to observe all but extremely old cultural goods on and off copyrights. Second, experimental policy variation is rare, because modern laws are heavily influenced by lobbying from the owners of profitable and durable goods, which is reflected in nicknames such as the 1998 "Mickey Mouse Protection Act" and the 2011 UK "Cliff (Richard's) Law." For notable recent research in economics see Reimer's (2014) and Nagaraj (2015). Earlier analyses of piracy in popular music have explored quasi-experimental variation in copyright enforcement. Waldfogel (2012) shows that the quality of recorded music increased after the creation of Napster. Oberholzer-Gee and Strumpf (2007) find that an increase in file sharing had no statistically significant effects on record sales.

[2] Scotchmer (1991) formalized the concept of "cumulative" science, in which the creation of new knowledge and innovation depends on access on existing knowledge. Recent analyses use the term interchangeably with "follow-on" science and innovation (e.g., Furman and Stern 2011; Galasso and Schankerman 2015).

[3] E.g., Howard Hughes Medical Institute Public Access Publishing (http://www.hhmi.org/about/policies#papp) and Bill & Melinda Gates Foundation Open Access Policy (http://www.gatesfoundation.org/how-we-work/general-information/open-access-policy, accessed December 3, 2015).

increased not only the number but also the diversity of new scientific articles.[4] A broader literature on open access suggests that scientific articles that are available for free are cited more (e.g., Eysenbach 2006, Evans and Reimer 2009). These findings are, however, compromised by selection, because authors are more likely to pay for open access if they expect an article to be of general interest.[5]

This paper examines the effects of copyrights on science by exploiting an important but understudied historical event: In 1942 the US Book Republication Program (BRP) issued temporary (6-month) copyright licenses to US publishers, allowing them to print exact copies of German-owned science books. At a time when German universities, such as Göttingen, continued to be leaders in math and science and most US scientists read German (e.g., Ammon 2001), US publishers simply republished the content of these books, without translations. We examine the effects of this program on follow-on science, using new data on more than 10,000 citations by new articles and books in chemistry and math.

A key effect of the BRP was a large reduction in the price of German-owned science books. Until 1942, the average BRP book sold for $43, equivalent to $1,310 in 2014 (using real wage conversions, Williamson 2016). After 1942, US publishers sold exact copies of these books with an average price decline of 25 percent. We use these data to examine the link between book prices and the use of existing knowledge in follow-on research.

To control for variation in the productivity of research fields that build on German-language science, we compare changes in citations to BRP books with changes in citations to Swiss books in the same disciplines. Similar to chemists and mathematicians in Germany, scientists at Zurich, Basel, and other Swiss universities were leaders in their fields, and they also wrote primarily in German. Due to Switzerland's neutrality, however, books with Swiss-owned copyrights could not be licensed to US publishers under the BRP.

Difference-in-differences comparisons indicate that citations to BRP books increased by an additional 149 percent compared with citations to Swiss books after 1941.[6] Confirming previous results on the role of German-Jewish émigrés (Moser, Voena, and Waldinger 2014),

[4] At the same time, the incentive effects of stronger copyrights for scientists are likely to be limited. Stern (2004), for example, finds that scientists forego wages to pursue scientific discoveries. By comparison, authors of popular fiction may be more responsive to profits. Contracts for Romantic period novelists list payments equivalent to millions of dollars for the most successful authors (MacGarvie and Moser 2012).

[5] McCabe and Snyder (2015) have shown that even basic controls for scientific quality reduce the correlation between open access and citations. To mitigate selection, Mueller-Langer and Watt (2014) examine hybrid open agreements, which assign open access based on authors, rather than articles.

[6] To be conservative, baseline specifications focus on Swiss and German books that were relevant to the US market, and therefore available in US libraries. Robustness checks that examine changes for all books yield slightly larger estimates (e.g., Appendix Table A1).

we also find that books by émigrés to the United States experienced a larger increase in citations. The overall increase in follow-on science for BRP books, however, is robust to excluding books by émigrés.

A purposefully simple model of follow-on science examines the mechanism by which the costs of accessing existing knowledge influence the production of new knowledge. This model predicts (under a broad set of alternative production functions) that a decline in price encourages the creation of new scientific knowledge. Intensity regressions indicate that a 10-percent decline in price is associated with a 38 percent increase in citations.

The model also predicts that the effects of price vary across disciplines. Intuitively, effects should be larger for disciplines that depend primarily on human capital (such as mathematics), and smaller for disciplines that are also heavily dependent on physical capital (e.g., in the form of laboratory space for chemistry). Confirming this prediction, triple-difference regressions indicate a large differential effect for math compared with chemistry: A 10-percent decline in price is associated with an additional 103 percent increase in citations.

An empirical challenge for identifying the effects of the BRP is that US publishers selected books for the program, so that the changes in citations after 1941 may reflect pre-existing characteristics of BRP books. In the main specifications, book fixed effects mitigate this issue by controlling for pre-existing differences in levels of citations. In addition, we estimate regressions with linear and flexible pre-trends to control for pre-existing differences in the time trends of citations. We also re-estimate the baseline with a matched sample of comparable BRP and Swiss books, using research subjects and non-English pre-BRP citations as matching variables. These estimates indicate a 136 percent increase in citations.

We also estimate alternative regressions that compare changes in citations *to the same book* by English-language publications with citations by publications in other languages that did not benefit directly from the BRP. These regressions indicate that English-language citations to BRP books increased by an additional 80 percent after 1941 compared with citations in other languages to the same books.

What was the mechanism by which lower book prices encouraged follow-on science? At the time, access to physical copies of library books was an important input in the production of new science. For example, one major objection against Los Alamos as the site of the Manhattan Project was that "in the wilds of New Mexico" there was no access to books "except the library of Horatio Alger books or whatever it was that those boys in the Ranch

School read."[7] Archival sources indicate that research libraries were a major purchaser of BRP books (e.g. Bokas and Edwards 2011, p. 25), and we find that books with a larger price decline in 1942 had become more diffused across US libraries by 1956. Moreover, an analysis of lending cards indicates a substantial increase in the first use of BRP books by research scientists around 1946, only four years after the BRP. Geographic data on the location of citing authors show that the expansion in library holdings and loans was followed by a westward expansion of citing publications.

As a final test, we link BRP books with US patents as a proxy for the creation of privately valuable, economically useful knowledge. This analysis indicates a substantial expansion in the number and geographic scope of patents that build on BRP books after 1942.

The remainder of this paper is structured as follows. Section I provides a brief overview of the BRP, and Section II introduces the data. Section III presents differences-in-differences results for BRP and Swiss books. Section IV introduces our model of follow-on science and tests predictions about price effects across disciplines. Section V investigates selection into the BRP, and presents alternative estimates that compare citations from English-language publications to BRP books with citations from publications in other languages to the same set of BRP books. Section VI investigates the mechanism by which lower access costs encouraged follow-on science, and Section VII concludes.

I. The World War II Book Republication Program

Until World War II, German publishers enjoyed "national treatment" - equal copyright protection as US publishers – as a result of a 1892 bilateral treaty between Germany and the United States.[8] This meant that German copyright owners held exclusive rights to sell German-owned science books in the United States; exclusivity was for 56 years, as specified by the 1909 US Copyright Act.[9]

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[7] John Manley, an experimental physicist, cited in Bird and Shirwin (2005, p. 207). Also see Hargittai (2006, pp. 89-131). The Custodian (1944) list 187 BRP books in physics. Our analysis focuses on math and chemistry because follow-on science in these disciplines was more readily observable. By comparison, many physicists at the time sought isolation to avoid knowledge leaks. Robert Oppenheimer and General Grove, for example, chose Los Alamos as a site for the Manhattan Project because it was a "site so isolated there was only a winding gravel road and one phone line into the place" (Bird and Sherwin 2006, p. 206).

[8] April 15, 1892, United States Copyright Office, Circular 38A; Kawohl 2008, pp. 436-439. 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).

[9] 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 increased copyrights to 50 years after the author's death and 75 years for corporate owners. The 1998 Copyright Term Extension Act further extended terms to 70 years after death and 95 years for corporate owners. See Goldstein (2003) for an accessible history of copyright law.

In 1939, the United States spent $1.5 million on foreign books and journals; the large majority of these publications originated from German scientists, who continued to be at the forefront of research (Richards 1981, p. 253). Representatives of US libraries, such as the president of the American Library Association (ALA) Ralph Munn, feared that war-time disruptions would harm US science by restricting access to German science. In 1939, Munn wrote to Secretary of State Cordell Hull

> ”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).

Initially, US libraries sourced books directly from Germany or 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).

By mid 1941, however, the US Department of State prohibited money transfers to Germany, and the Nazis forbade German publishers to ship book orders unless they had already been paid. Now two independent organizations kept the United States supplied with European publications: the Federal Government’s Interdepartmental Committee for the Acquisition of Foreign Publications (IDC, operated by the Office of Strategic Services), and Thomas Fleming’s library-sponsored Joint Committee (which Fleming had chaired since August 1941). These organizations transferred German journals onto microfilm and distributed copies in the United States (Richards 1981, p. 255).

On July 6, 1942, President Roosevelt issued Executive Order No. 9193, which authorized the US Alien Property Custodian to “direct, manage, supervise, control or vest the following classes of property: […] Patents, patent applications, copyrights, copyright applications, trademarks, or trademark applications or rights” (Myron 1945, p. 76). In late 1942, a group of prominent librarians and professors urged the Alien Property Custodian to exploit this directive to seize German-owned copyrights and reprint and distribute them, both to reduce the amount of money spent on acquiring these publications abroad and to ensure that books and journals would be widely disseminated (Richards 1981, p. 255).

Between 1942 and 1944, the Custodian appropriated more than 100,000 books with enemy-owned copyrights (*Forty-sixth Annual Record of the Register of Copyrights* 1944, p. 8), and offered licenses for a non-extendable period of 6 months to US publishers (Myron 1945, p. 85). US publishers then submitted bids for these licenses (Bokas and Edwards 2011, p. 22). We know little about the bidding process, but we know who won the licenses. Along

with Dover, J.W. Edwards Publisher, Inc. won the largest number of licensing bid, for a total of 650 titles (Bokas and Edwards 2011, p. 23). The Custodian collected licensing revenues on behalf of German copyright owners:

> "According to the terms of the licenses…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."[10]

Importantly, the BRP granted *temporary* 6-month licenses to US publishers, so that publishers who charged too much for a republication risked competition with another entrant after the initial 6-month contract. Without online publishing, menu costs were also high enough to prevent publishers from adjusting prices dynamically, so that BRP publishers charged a single price for each BRP book.

BRP books were reprinted as exact copies in editions between 200 and 500 copies (Bokas and Edwards 2011, p. 25). In 1943 J.W. Edwards published 700 titles of scientific books and 140 journals, "most of which have been published under license by the Alien Property Custodian Office."[11] Among Edwards' publications was Frederick Konrad Beilstein's (1918) *Handbuch der Organischen Chemie*, "a critical tool for every organic chemist working in a lab until the early 1970s." Until 1942, the German publisher Springer had sold the set for $2,000 (equivalent to a labor value of $54,200 in 2015, using the unskilled wage, Williamson 2015). Under the BRP, Edwards Brothers offered exact reproductions of Beilstein "for $400 a set, and the company sold more than 600 sets to laboratories, researchers, and academicians" (Bokas and Edwards, 2011 p. 25; equivalent to $10,800 in 2015, using the same labor value conversions).

II. DATA

The main data cover 11,143 citations to 777 BRP and Swiss science books by new scientific publications between 1920 and 1970. A unique feature of our data is that they include the price of BRP books under two copyright regimes (pre- and post BRP). To distinguish variation in follow-on science by English-language scientists (who were more directly affected by the US-based BRP) from variation in scientific output by other scientists, we assign all citing publications to a publication language. To identify books that are relevant to the US market, we match books with historical records of US library holdings. We also collect geographic information on citing authors and assign all books to research fields.

[10] Bill Edwards, cited in Bokas and Edwards 2011, p. 25.
[11] Ernest Rynearson writing in the *Edwards Brother Newsletter,* cited in Bokas and Edwards (2011, p. 23).

A. BRP Books and Changes in Price

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

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

The median BRP book was published in 1932, and all except two books were published between 1920 and 1940.[13] The Custodian lists the BRP price (charged by US publishers) for all 334 BRP books. For 319 of these books (96 percent), the Custodian also lists the original price that German publishers charged in the United States *before* the BRP.[14]

Under the original pre-BRP copyright regime, German publishers offered these books for an average of $41.40 (equivalent to $1,121 in 2015).[15] Before the BRP, German-owned chemistry books sold for an average of $48.57 ($1,316 in 2015, Appendix Figure A1), roughly four times the price of German math books, which sold for $10.47 ($284 in 2015).[16]

Under the BRP, book prices declined by an average of 24.97 percent ($\Delta p_i = 1 - BRP\ price/\ original\ price$, Appendix Table A1).[17] The book with the largest price decline,

[12] Three hundred and twenty-three of these 334 books are published in German. Five BRP books are English-language translations. These books experienced a smaller decline in price (16.9 compared with 25.0 percent for the remaining 278 BRP books), and a larger increase in citations (from 0.388 to 0.838). Titles include Lehmann and Floury (1943) *Toxicology and hygiene of industrial solvents*, Dreher (1943) *The chemistry of synthetic substances*, Peter (1942) *Seven-place values of trigonometric functions for every thousandth of a degree*, Seiffert (1943) *Virus diseases in man, animal and plant*, and Skaupy's *Principles of powder metallurgy* (1944).

[13] Pier Andrea Saccardo's (1881) *Sylloge Fungorum* presents a system for classifying mushrooms by spore color and form; this system remained the standard until the field switched to analyzing DNA. The next oldest book is Hermann Emil Fischer's (1906) *Untersuchungen über Aminosauren, Polypeptide und Proteine.* Professor Fischer (1852-1919, Nobel 1902) discovered the Fischer process of esterification and the Fischer projection, a symbolic presentation of drawing asymmetric carbon atoms.

[14] Fourteen of the 15 BRP books without an original price were published after 1941, and may not have been available in the United States at the time of the BRP. These books received no citations until 1941, and they were cited by an average of 0.155 new publications per book and year after 1941. One of the 15 books, Strohecker's *Taschenbuch für die Lebensmittelchemie,* had been published in 1938.

[15] Using relative wage conversions, based on the amount that an unskilled worker would have needed to purchase the book. Conversions based on Williamson 2016.

[16] These price differences may already reflect differences in the capital-intensity of knowledge production between chemistry and mathematics, which we will examine in more detail below.

[17] Prices declined for 242 of 271 BRP books with an original BRP price. Another 20 books experienced no change in price; 15 of these books are in chemistry and 5 in mathematics (Appendix Table A1). Nine books in

Saccardo's *Sylloge fungorum,* sold for an original price of $2,000 ($54,177 in 2015) and for $200 ($5,418) under the BRP. Beilstein's (1918) *Handbuch der Organischen Chemie* sold for an original price of $2,000 and for $400 ($10,835) under the BRP. Across disciplines, price declines were slightly smaller in chemistry (24.34 percent) than mathematics (27.44 percent).

B. Swiss Books as a Control

Swiss books are a useful control for unobservable changes in citations to German-language science books because - similar to German chemists and mathematicians, Swiss scientists - such as Alexander Ostrowski (1893-1986) at the University of Basel and Eduard L. Stiefel (1909-1978) at the ETH Zurich - were leaders in their fields.[18] Swiss research at the time was also published primarily in German.[19] Due to Switzerland's neutrality during the war, however, Swiss-owned copyrights were not subject to the BRP.

We construct data on Swiss books by first extracting all math and chemistry books from the records of the Swiss National Library (Sektion 54 "Chemie," and Sektion 51 "Mathematik"). Founded in 1895, the Library's holdings include 1,683 books in chemistry that were published between 1921 and 1942, and 447 books in mathematics.

C. Citations by Scientific Publications, 1920-1970

To measure follow-on science, we follow the standard approach in the literature and collect data on new scientific publications that cite BRP books.[20] We construct these data by searching records on new books and articles on Google Scholar for a book title (such as *Die Chemie des Pyrrols*) and the book's author (such as "Fischer").[21] Google Scholar is currently the most complete source of citations to foreign language books (Meho and Yang 2007).[22] It

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chemistry (but none in mathematics) experienced an average price increase under the BRP (17.47 percent from an original base price of $36.46 to $39.56). These books experienced a smaller (64 percent) increase in citations.

[18] Stiefel's (1935) dissertation *Richtungsfelder und Fernparallelismus in n-dimensionalen Mannigfaltigkeiten* describes on n-dimensional manifolds (also known as 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 of the study of characteristic classes. He became a full professor at the ETH Zurich in 1948, and founded the Swiss Institute of Applied Mathematics, whose objective was to design and construct an electronic computer.

[19] In the main specifications, we control for variation in the publication language through book fixed effects (e.g. Table 2, column 1). Controlling for publication languages in specifications with controls for subjects and publication years leaves the estimate for *BRP * post* substantially unchanged (0.437, significant at 1 percent).

[20] Furman and Stern (2011) use citations to articles that are linked with biological resource centers (BRCs) to measure changes in new scientific knowledge that builds on materials in a BRC. Alexopoulos (2011) shows that book publications between 1955 and 1997 are correlated with changes in R&D and scientific knowledge.

[21] 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.

[22] 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 stands out in

searches "articles, theses, books, abstracts and court opinions from academic publishers, professional societies, online repositories, universities, and other web sites."[23] A potential shortcoming of the algorithm is that its effectiveness may vary across publication years. To address this issue, we control for the publication year of citing publications.

US publishers printed exact copies of German books, so that citations to the original German-language version most accurately capture the direct effects of the BRP. Focusing on citations to the original version is a lower bound estimate for the effects of the BRP if BPR books became more popular, and more likely to be translated, as a result of the program. For example, new citations to Courant and Hilbert's (1931) *Methoden der Mathematischen Physik* declined after the publication of the translation (*Methods of Mathematical Physics*, vol. II, 1966). By 2016, *Methods* had received more than 16,000 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.[24]

The most serious potential drawback of citations is that they may be influenced by unobservable changes in tastes.[25] 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. In our empirical setting, the most serious threat is that US scholars could have withheld citations to Germans during the war and resumed them afterwards. Although it is difficult to observe such changes in tastes, related data on ethnic preferences are available for the two World Wars. These data confirm an observation by cultural historians, that World War II had more limited effects on US attitudes towards Germans because Pearl Harbor focused ethnic distastes on Japan. For example, the share of German-language operas dropped dramatically from 50 to 7 percent at the eve of World War I, but experienced only a small decline in World War II (Appendix Figure A3). Alternative measures of ethnic preferences, including purchases of ethnic foods and changes in baby names, confirm these patterns (Moser 2012b). Moreover, Iaria and Waldinger (2015) show that a boycott of scientists from Central countries led to a decline in citations only during WWI but not WWII.

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its coverage of conference proceedings and international journals, but also requires a substantially greater effort of data collection (with a total of 3,000 hours compared with 1000 for the Web of Science and 200 for Scopus).

[23] 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.

[24] Another 54 books in the Swiss library with at least 1 citation were published in Germany; we use these books in intent-to-treat regressions below.

[25] More generally, citations may initially be biased against novel findings. For example, Wang, Veugelers and Stephan (2016) document that, among articles published in the Web of Science in 2001, articles that make more "first-time" ever combination across journals are published in journals with lower impact factors, and 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.

D. Books in the Holdings of US Libraries

To create a comparable sample of BRP and Swiss books that were relevant to the US market, we identify BRP and Swiss books that entered the holdings of at least one US library. Historical records of library holdings are available 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" (Mansell 1968-1981). Physical copies of the NUC are available at the Hoover Institution Library & Archive. We consulted these records 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 (97 percent) and all 55 books in mathematics (100 percent). Among 486 Swiss books with at least one citation, 247 Swiss books are in the NUC, including 161 of 373 Swiss chemistry books (43 percent), and 86 of 112 Swiss math books (77 percent). To work with a comparable sample of BRP and Swiss books, we restrict the main specifications to 283 BRP and 247 Swiss books in the NUC, and use the all 291 BRP books and 486 Swiss books in a robustness check (Appendix Table A2). BRP books in the NUC receive 0.263 citations per year until 1941 and 0.566 afterwards. By comparison, Swiss books in the NUC receive 0.024 citations until 1941, and 0.078 afterwards (Table 1).

The NUC data also allow us to examine variation in the diffusion of science books across U.S. libraries. We use these data to investigate the mechanism by which reductions in the price of books may facilitate the creation of new follow-on science.

E. Citations by New Publications in English Compared with Other Languages

To distinguish citations that were differentially affected by the US BRP, we assign all 10,141 citations to their publication language. Among 9,053 citations to 283 BRP books between 1920 and 1970, 5,141 originate from English-language publications. With 243 English-language citations, Courant and Hilbert's *Methoden der Mathematischen Physik* (1931) is the most cited book.

To check whether English-language citations are a useful proxy for citations from US scholars we collect data on publication cities for two highly cited BRP and Swiss books

each.[26] These data indicate that the large majority of English-language publications (70 percent for the four books in this test) originate from the United States.

F. Locations of Authors over Time

To investigate changes in the location of citing and cited authors, we collect detailed data on careers and employment histories for 283 authors of BRP books and 280 Swiss authors in the same disciplines. To identify BRP authors who were émigrés, we examine records in the *International Biographical Dictionary of Central European Émigrés* (Strauss et al. 1983) and the Mathematics Genealogy Project (MGP).[27]

We also use the MGP to capture variation in the geographic locations of 1,812 authors who cite BRP books and 237 authors who cite Swiss books. The MGP offers comprehensive coverage on advisors, advisees, and PhD-granting institutions for 196,303 mathematicians between 1666 and 2016.[28] We use information on PhD-granting institutions for professors and their advisees to pinpoint the location of academic mathematicians. Location data are available for all 2,008 citations by 1,812 authors to BRP books in mathematics and for all 252 citations by 237 authors of Swiss books.[29] 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 an advisor to Norman Meyers, who graduated from Indiana University in 1957.

G. Citations to BRP Books in US Patents

To investigate the effects of the BRP on economically useful knowledge, we examine changes in the number of patented inventions that cite BRP books as relevant scientific knowledge. Specifically, we search the full text of US patent documents between 1920 and 1970 for patented inventions that cite a BRP book as relevant scientific knowledge.[30] For

[26] We perform this test for two of the five most highly cited books in each sample: Alexandroff and Topf's *Topologie* (1935) and van der Warden's *Moderne Algebra* (1931) for the BRP and Stiefel's *Mannigfaltigkeiten* (1936) and Leser's *Invariantentheorie Algebraische Formen* (1939) for Swiss books.
[27] Five of six émigrés from Straus (1983) appear as an advisor of at least one American PhD student in the MGP after 1932. The only missing émigré, Max Herzberger, worked in the private sector, and did not advise students.
[28] http://www.genealogy.ams.org/index.php, accessed January 28 to March 25, 2016.
[29] Because the MPG focuses on mathematicians, it covers only a small number of (mathematical) chemists. Location data are available for 118 citations by 80 authors of BRP chemistry books (3 percent of all of 3,520 citations in chemistry), and 10 citations by 9 authors of Swiss books in chemistry (3 percent of all 387 citations).
[30] In practice, this means that we perform an automatic search of the full text of patent documents for the *USPTO Bulk Data Downloads: Patent OCR Text* (available at www.google.com/patents) for the author and title of each book, and then hand-check all potential matches.

example, US2701248A for "Esters of pseudothiohydantoin-5-acetic acid and method for their preparation" (issued to Ferdinand B. Zienty, Brentwood MO on February 1, 1955) cites Beilstein's *Handbuch der Organischen Chemie*. A total of 238 US patents between 1920 and 1970 cite a BRP book, including 35 patents until 1941, and 203 afterwards.[31] By comparison, only 3 US patents cite Swiss books overall, and the number of citing patents declines from 2 to 1 after 1941. We also construct geographic data on the location of inventors. For example, Ferdinand Zienty (of US2701248A above) is located in Brentwood, MO, in 1955. Such data are available for 219 of 238 citing patents.

H. Research Subjects of BRP and Swiss Books

Citations may also vary systematically across research fields. To control for such variation, we match subject codes in the reports of the US Alien Property Custodian (1944) with subject codes in the Swiss National Library. The Custodian (1944) assigns 228 chemistry books to 38 topics (such as "catalysis"), and 55 books in mathematics 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 topics to create 25 mutually exclusive subject fields within chemistry and 8 within mathematics.

For BRP books in chemistry, compounds are the most common subject (58 books, Appendix Table A3). Prices for books on compounds decline by an average of 24.7 percent from an average original price of $29.60 ($802 in 2015). English-language citations to these books increase from 0.191 per book and year until 1941 to 0.441 after 1941. Organic chemistry and metals are the next largest subjects, with 28 and 27 books respectively. For organic chemistry, the price of BRP books declines by an average of 34.7 percent from an original price of $200.30 ($5,426 in 2015), and citations increase from 0.367 to 0.508. For metals, price declines by an average of 18.6 percent from an original price of $16.27 ($441 in 2015), and citations increase from 0.427 to 0.696 per book and year. For BRP books in mathematics, general mathematics is the most common subject, with 14 books (Appendix Table A3). For these books, the average price decline is 38.8 percent, from an original price of $11.96 ($324 in 2015); citations increase from 0.520 until 1941 to 1.740 afterwards. Geometry is the next largest subject, with 12 books, a price decline of 29.3 percent from an original price of $7.75 ($210 in 2015), and an increase in citations from 0.054 to 0.330.

[31] Among 283 BRP books in the NUC, 50 are cited in at least one US patent, including 46 BRP books in chemistry and 4 in mathematics; 233 patents cite one BRP book, and 5 patents cite 2 BRP books.

III. Follow-on Science for BRP and Swiss Science Books

Data plots reveal a large increase in English-language citations to BRP books after 1942. For example, English-language citations to Hilbert's *Methoden der Mathematischen Physik* (1931) increase from 0.727 per year until 1941 to 8.103 afterwards (Appendix Figure A4). Across all 283 BRP books, English-language citations more than double from 0.263 per book and year until 1941 to 0.566 afterwards (Figure 1). By comparison, citations to BRP books from scientific publications in other languages (which did not benefit directly from the US-based BRP) increased by less than 27 percent from 0.300 to 0.392.[32]

Compared with Swiss books, citations to BRP books follow a similar trend until 1942 and begin to diverge significantly after World War II (Appendix Figure A5). In 1932, for example, the average BRP book is cited by 0.182 new publications, and the average Swiss books is cited by 0.016 new publications. Citations increase slightly until 1938 and decline to 0.285 for BRP books and 0.012 for Swiss books in 1940.[33] After the war, citations to BRP books grow to 0.746 in 1956, while citations to Swiss books increase only to 0.065. Citations to BRP books remain high around 0.700 per book year until 1970, while citations to Swiss books remain below 0.150 (Appendix Figure A5).[34]

To systematically investigate this differential change, we estimate OLS regressions with controls for book differences and citation years:

$$cite_{it} = \beta\, BRP_i * post_t + book_i + \tau_t + \varepsilon_{it} \quad (1)$$

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. The indicator variable *BRP* equals 1 for books that US publishers licensed under BRP; $post_t$ is an indicator for years after 1942. Under the assumption that changes in citations for BRP and Swiss books would have been comparable in the absence of the BRP, the coefficient β estimates the effect of the BRP on follow-on science. A vector of $book_i$ fixed effects controls for book-specific

[32] Expanding the data to include books not in the NUC, English-language citations increase by 118 percent from 0.256 to 0.567, whereas citations from other languages only increase by 31 percent from 0.295 to 0.387.
[33] Between 1941 and 1945, when the Allied bombing campaign destroyed research facilities in Germany, citations to BRP books declined more than citations to Swiss books. Bombings reached a peak of 130 tons per months at the beginning of 1945 (Webster and Frankland 1961, Annex). Waldinger (forthcoming) estimates that a 10 percent increase in the destruction of physical capital reduced research output by 0.05 standard deviations.
[34] Due to the low level of pre-existing citations for Swiss books, the percentage change in citations for Swiss books (225 percent) exceeds the percentage change for BRP books (115 percent), and Poisson estimates of the difference-in-difference coefficient are not consistently positive. Results, however, hold in percentage terms and as Poisson estimates in our secondary specification using *other language* citations to BRP books as a control for English-language citations (e.g., Figure 1 and Table 5). We focus the exposition on the Swiss control because it is intuitively appealing, but all results hold for the alternative control.

differences in levels of citations across BRP and Swiss books. Citation year fixed effects τ_t control for variation in scientific output over time.

OLS estimates with book fixed effects indicate that citations to BRP books increase by an additional 0.392 per year after 1941 compared with citations to Swiss books in the same disciplines (Table 2, column 1, significant at 1 percent). Relative to a pre-BRP mean of 0.263, this implies a 149 percent increase. Alternative specifications with controls for the publication year and the research subject of the cited book show that citations to BRP books increased by an additional 0.436 citations (Table 2, column 4, significant at 1 percent). Relative to a pre-BRP mean of 0.268, this implies a 163 percent increase.[35]

We also re-estimate the baseline specifications with the natural logarithm of citations as the dependent variable. Log regressions indicate an additional 1.75-fold increase in citations for BRP books (Table 2, column 5, significant at 1 percent).[36]

B. Controls for Pre-Trends and Time-Varying Estimates

One potential issue with the basic difference-in-difference specifications is that citations to BRP books may increase as a result of unobservable changes in citations that precede the BRP. In the baseline estimates, we include book fixed effects to control for unobservable variation in the level of citations. In this section, we include alternative controls for pre-trends to control for unobservable differences in the time trend of citations.

First, we re-estimate the baseline regressions allowing for a separate linear pre-trend for BRP books:

$$cite_{it} = \beta\, BRP_i * post_t + book_i + \mu(t - 1919) * 1(1920 \leq t \leq 1941) * BRP_i + \tau_t + \varepsilon_{it} \quad (2)$$

where $\mu(t - 1919)$ counts years, starting at one in 1920, and $1(1920 \leq t \leq 1941)$ indicates the pre-BRP period. These regressions yield a 0.599 increase in citations per year (Table 2, column 2, significant at 1 percent).

More flexible controls for the pre-trend allow for BRP-specific year fixed effects:

$$cite_{it} = \beta\, BRP_i \times post_t + book_i + BRP_i * \tau_t \times 1(1920 \leq t \leq 1941) + \tau_t + \varepsilon_{it} \quad (3)$$

where $BRP_i \times \tau_t \times 1(1920 \leq t \leq 1941)$ are 21 separate fixed effects for BRP books in years between 1920 and 1941. Including this flexible control reduces the size of the estimate, but it

[35] An additional robustness check restricts the sample to books in the Library of Congress, which - similarly to books in the NUC - should be most relevant to the US market. Although this restriction comes at the cost of a reduction in sample size to 293 BRP and 19 Swiss books, estimates are robust (Appendix Table A4).
[36] A downside of log regressions is that we have to add a constant to observations with zero citations. Among 20,191 year-book pairs, 17,594 (87 percent) have zero observations; we add 0.00005 to the count of citations.

remains large and statistically significant at 0.227 (Table 2, column 3, significant at 1 percent), which implies an 86 percent increase in follow-on science.

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

$$cite_{it} = \Sigma_t \beta_t BRP_i \times \tau_t + book_i + \mu(t - 1919) \times 1(1920 \leq t \leq 1941) \times BRP_i + \tau_t + \varepsilon_{it} \quad (4)$$

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 of β_t indicate no significant differences in citations to BRP books until 1941, and show a large differential increase for BRP books after 1946, two years after the last BRP book was licensed (Appendix Figure A6). Estimates range from -0.126 in 1935-36 (p-value of 0.27, Appendix Figure A6) to 0.080 in 1941-42 (p-value of 0.34), and 0.111 in 1943-44 (p-value of 0.18). After the war, estimates increase to 0.330 for 1947-48 (p-value of 0.00), 0.571 in 1953-54, and remain large until 1969-70, at 0.555 (p-value of 0.00).

C. Books by Émigrés

Previous research has shown that fields in which the United States received a German Jewish refugee chemist after 1932 experienced a 31 percent increase in patenting by US inventors compared with fields of other German chemists (Moser et al. 2014). Similarly, the arrival of émigré scientists may have amplified the effects of their books on follow-on science in the United States. Five authors of BRP math books moved to the United States (Appendix Table A5): Richard Courant (1888-1972), Max Herzberger (1899-1982), John von Neumann (1883-1953), George Pólya (1887-1985), and Gábor Szegő (1895-1985).[37]

Plots of citations show that books by émigrés experienced a substantially larger increase in citations after 1941. On average, an émigré book received 0.500 citations in 1934, and 0.750 citations in 1940 and 1941. After 1941, citations to the average émigré book increased to 3.250 in 1953 and 3.500 in 1970 (Figure 2).

[37] Courant moved to the United States in 1934 after his dismissal from the University of Göttingen in 1932. Herzberger (*Strahlenoptik* 1931, 2 citations), emigrated in 1935 after his dismissal from Zeiss in 1932. John von Neumann (*Mathematische Grundlagen der Quantenmechanik*, 1932, 56 citations) emigrated in 1939, after he left University of Berlin in 1933. Gábor Szegő (*Aufgaben der Lehrsätze aus der Analysis*, 1925, 39 citations). was born in Hungary, and taught in Berlin and Koenigsberg until 1935. He moved to Washington University in 1936 and Stanford in 1938. Szegő's collaborator Pólya was also born in Hungary; he became a professor at the ETH in Zurich in 1914, and at Stanford in 1940. Four books by émigrés sold for an original price of $28.24 (roughly $759 in 2014, using the labor value for an unskilled worker of the commodity, Williamson 2016), $7.75, $7.85, and $14.40, respectively, and experienced a price decline of 102, 19, 124, and 140 percent respectively. Two authors of BRP books moved to Switzerland. Stefan Cohn-Vossen (1902-1936, *Anschauliche Geometrie*, 1932) emigrated to Switzerland in 1933 and to the USSR in 1935. Rolf Nevanlinna (1895-1980, *Eindeutige Analytische Funktionen* 1936) moved to Switzerland in 1947. Their books receive 0 and 10 citations until 1941, and 42 and 283 citations afterwards.

Excluding émigré books, however, does not substantially change the patterns of citations. Excluding émigré books, citations per book and year to non-émigré BRP books increased 0.350 in 1934, 0.325 in 1940 and 0.689 in 1941, to 2 in 1953, and remained at this level until 1965 (Figure 2). We also re-estimate the baseline specification for mathematics with an additional interaction term for books by émigrés:

$$cites_{it} = \beta\, BRP_i * post_t + \varphi\, émigré_i * BRP_i * post_t + book_i + \tau_t + \varepsilon_{it} \quad (5)$$

where $emigre_i$ equals 1 for books whose authors moved to the United States, and the coefficient β on $BRP_i * post_t$ estimates the effect of the BRP, controlling for any additional impact of books by émigrés. The coefficient φ on $émigré_i * BRP_i * post_t$ estimates the additional impact of books by émigrés. These estimates confirm that the effect of the BRP was not driven by émigré books. Controlling for émigrés leaves the estimate for *BRP * post* at 0.935 (Appendix Table A6, column 1, significant at 1 percent). Estimates of φ are large (at 1.114, Appendix Table A6, column 1) but they are not statistically significant (with a p-value of 0.45).

IV. Effects of Price on Follow-on Science

A major benefit of the empirical setting is that prices for the same book are observable under two distinct copyright regimes. These data indicate that – under the BRP regime of compulsory copyright licensing - the average BRP book experienced a price decline of 25 percent. This decline confirms existing empirical analyses, which have found that stronger copyrights can increase the price of books (by improving publishers' ability to price discriminate, Li et al. 2015). In this section we examine the effects of this increase in price on follow-on science. To motivate the empirical analyses, we first construct a simple two-period model of knowledge production. This model allows us to predict the effects of a decline in price on follow-on science – both at the aggregate level and across disciplines.

A. Effects of Price on Follow-on Science – Predictions

Suppose two identical generations of scientists produce new scientific knowledge in periods *t-1* and *t*.[38] 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 first-

[38] For simplicity, we assume that knowledge transmission only occurs through impersonal mechanisms, such as books, research libraries or deposits of research materials). A more general model with overlapping generations could allows for knowledge transmission across individuals. Such a model would capture an empirical fact that we describe below: the effects of the price appear to be stronger for books by émigrés. In the case of émigré books, second-generation scientists benefit not only from improved access to codified knowledge (through lower book prices *p*) but also from interpersonal knowledge transmission (through émigré scientists).

generation scientists in period *t-1*. Normalizing the price of new knowledge y_t to equal 1, scientists receive a sure payoff y_t if they produce follow-on knowledge; this payoff can be in the form of a monetary reward, recognition by peers, or other types of rewards.

To access existing knowledge y_{t-1}, second-generation scientists pay a price p. Here p represents the price of a book, but it could represent a fee to access an online depository of scientific articles or a biological resource center (such as in Furman and Stern 2011). 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.

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, and scientists are price takers for p and r. Depending on input prices p and r, scientists either choose to invest in producing follow-on science (and receive $y_t = f(y_{t-1}, k_t)$) or pursue their outside option, which is to do nothing and receive a payoff of zero.

Second-generation scientists choose k_t^* to maximize net payoffs $y_t - p - rk_t^*$, and invest in follow-on knowledge if and only if p is below a threshold price p' such that

$$f(y_{t-1}, k_t^*) - p' - rk_t^* \geq 0 \text{ or}$$
$$p' = f(y_{t-1}, k_t^*) - rk_t^* \quad (6)$$

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

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

B. Effects of Price on Follow-on Science – Estimates

To examine whether and how changes in price influence follow-on science, we estimate changes in citations by new scientific publications per book and year as a function of changes in the price of existing knowledge:

$$cite_{it} = \beta BRP_i * post_t + \theta \Delta p_i * BRP_i * post_t + book_i + \tau_t + \varepsilon_{it} \quad (7)$$

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

OLS estimates of equation (7) indicate that a 10-percent decline in price is associated with 0.101 additional citations (Table 3, column 2, significant at 1 percent). Compared with a pre-BRP mean of 0.264 annual citations for BRP books, this implies a 38 percent increase. Controlling for BRP-specific linear pre-trends leaves the estimate at 0.100 (Table 3, column 3

significant at 1 percent). Regressions with BRP-specific year dummies reduce the estimated effect only slightly to 0.099 (Table 3, column 4, significant at 1 percent).

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 help address this issue we check whether books with a larger number of pre-BRP citations by non-English publications experienced a larger decline in price. This correlation is small and not statistically significant.[39] 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. Historical sources, however, indicate that there were no close substitutes for BRP books in the US market.[40] 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.

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

$$cite_{it} = \beta\, BRP_i \times post_t + \Sigma_t\, \theta_t\, \Delta p_i \times BRP_i \times \tau_t + book_i + \tau_t + \varepsilon_{it} \quad (8)$$

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 (as in equation 4 above).

Year-specific estimates indicate no significant differences in citations before the BRP, and they show a large increase in citations after the war (Figure 3). Until 1942, estimates range from -0.040 in 1931-32 (p-value 0.37) to -0.002 in 1941-42 (p-value 0.92). Then estimates decline to -0.030 in 1943-44 (p-value 0.26). After 1945, estimates increase to 0.046 in 1947-48 (p-value 0.04) and 0.136 in 1953-54 (p-value 0.00). Annual estimates remain large and significant until 1969-70, with 0.128 additional citations (p-value 0.00). Compared with a pre-BRP mean of 0.263, this implies a 49 percent increase in citations.

C. Differential Effects across Disciplines – Predictions

An interesting implication of our simple model is that the effects of price should vary across disciplines, depending on their degree of capital-intensity. To show this, we allow for differences in the capital intensity of knowledge production across disciplines. Suppose $y_{c,t} = z(y_{c,t-1},k_t)$ represents chemistry and $y_{m,t} = g(y_{m,t-1},k_t)$ represents mathematics. The basic idea is that knowledge production is more dependent on physical capital (in the form of laboratory

[39] One additional citation by a non-English publication before the BPR is associated with an additional 3.65 percentage point decline in price (not statistically significant, Appendix Figure A2).
[40] See for example, the 1939 letter of Ralph Mann, president of the American Library Association to Secretary of State Cordell Hull (cited in Richards 1981, p. 254).

space and specialized equipment) in chemistry than mathematics. This is captured through the elasticity of knowledge production with respect to physical capital $e^x(y_{x,t-1},k_t) = g_k(y_{x,t-1},k_t)\, k_t / g(y_{x,t-1},k_t)$. Suppose $e^m(y_{m,t-1},k_t) < e^c(y_{c,t-1},k_t)$ for every $\{y_{m,t-1}, y_{c,t-1}, k_t\}$. Then discipline-specific threshold prices are

$$p_c' = z(y_{c,t-1},k^*) - z_k(y_{c,t-1},k^*)\, k^* = z(y_{c,t-1},k^*)(1 - e^c(y_{c,t-1}, k^*))$$

$$p_m' = g(y_{m,t-1},k^*) - g_k(y_{m,t-1},k^*)\, k^* = g(y_{m,t-1},k^*)(1 - e^m(y_{m,t-1}, k^*))$$

If existing knowledge is equally valuable across disciplines, so that $y_{c,t-1} = y_{m,t-1}$, then $p_m' \geq p_c'$.[41] More generally, p' is weakly decreasing in the elasticity of knowledge with respect to physical capital

$$\frac{\mathrm{d}\, p'}{\mathrm{de}(y_{t-1},k*)} = -\mathrm{f}(y_{t-1}, k*) \leq 0 \text{ if } \mathrm{f}(y_{t-1}, k*) > 0 \quad (9)$$

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

$$\frac{\mathrm{d}\, p'}{\mathrm{d}\alpha} = (1-\alpha) - 2\log(\alpha/r) \leq 0 \;\; if \;\; \alpha \leq r$$

which implies that the threshold price for existing knowledge is (weakly) increasing in the elasticity of knowledge with respect to capital.

C. Differential Effects across Disciplines – Estimates

Plots of citations confirm that the differential increase in citations after 1942 was significantly stronger for mathematics than for chemistry. Citations to BRP books in chemistry increase from 0.274 per book and year until 1941 to 0.132 in 1945 and 0.469 in 1956, while citations to Swiss chemistry books stay close to their low pre-BRP levels (Figure 4, bottom panel). By comparison, citations to BRP books in mathematics experience a more striking increase from 0.230 citations per book and year until 1941 to 0.400 in 1945 and 1.890 in 1956, while citations to Swiss books remain low (Figure 4, top panel). To evaluate the statistical significance of this difference, we estimate

$$cites_{it} = \beta\, BRP_i * post_t + \varphi\, BRP_i * math_i * post_t + book_i + \tau_t + \varepsilon_{it} \quad (10)$$

where $math_i$ is an indicator for BRP books in mathematics. OLS estimates indicate that 0.173 additional publications cite BRP chemistry books after 1941 compared with Swiss books (*BRP * post* to 0.173, Table 4, column 1, significant at 1 percent). Compared with a pre-BRP

[41] This prediction also holds if existing knowledge is more valuable in mathematics than chemistry ($y_{c,t-1} < y_{m,t-1}$). If existing knowledge is sufficiently more valuable in chemistry ($y_{c,t-1} > y_{m,t-1}$), then the threshold price of chemistry books can be higher than the threshold price of mathematics. Analogously, the threshold price increases more for chemistry when $r < 1 - \mu$ and r is sufficiently low.

mean of 0.263 citations for BRP books, this implies a 66 percent increase. Estimates for the triple differences estimator *BRP * math * post* indicate that, compared with citations in chemistry, citations to BRP in mathematics increase by an additional 0.917 after 1942 (Table 4, column 1, significant at 1 percent). Relative to a pre-BRP mean of 0.263 citations for BRP books, this implies an additional 349 percent increase.[42] Controlling for a BRP-specific linear pre-trend reduces the estimate for *BRP * math * post* to 0.914 (Table 4, column 2, significant at 1 percent), and increases the estimate for *BRP * post* to 0.334 (significant at 1 percent). Alternative specifications with BRP-specific year dummies for the pre-period (as in equation 3) increase *BRP * math * post* to 0.918 (Table 4 column 3, significant at 1 percent). Intensity estimates indicate that a 10-percent decline in price is associated with 0.271 additional citations for BRP math books ($BRP_i * math_i * \Delta p_i * post_t$, Table 4, column 5, significant at 1 percent).[43] Relative to a pre-BRP mean of 0.263 citations for BRP books, this implies a 106 percent increase. By comparison, a 10-percent decline in price is associated with only 0.035 additional citations for BRP chemistry books compared with Swiss chemistry books until 1941 ($BRP_i \times \Delta p_i \times post_t$, Table 4, column 5, significant at 10 percent).

Time-varying estimates indicate no significant differences before the BRP, and show a large differential increase in citations to BRP math books after 1946. Pre-BRP, estimates range from -0.213 citations in 1931-32 (p-value 0.09, Appendix Figure A7) to -0.157 in 1935-36 (p-value 0.08). After the war, the estimated effect of a 10-percent decline in price implies an increase by 0.114 additional citations per book and year for 1951-52 (p-value 0.05, Appendix Figure A7), and 0.270 in 1953-54 (p-value 0.00, Appendix Figure A7). Estimates remain large and significant, with 0.226 in 1969-1970 (p-value 0.00, Appendix Figure A7), which implies a 98 percent increase.[44]

V. Selection into the BRP

The main challenge for the baseline estimates is that some of the observed increase in citations may reflect pre-existing characteristics of books that were selected for the BRP rather than an effect of the BRP. Qualitative historical evidence cannot pin down the direction of selection. For example, archival records for J.W. Edwards only specify that

[42] BRP math books receive 1.090 additional citations compared with Swiss chemistry books until 1941 ($BRP_i \times post_t + BRP_i \times math_i \times post_t$, significant at 1 percent, Table 4, column 1).
[43] For each 10-percent decline in price, BRP math books receive 0.280 citations compared with Swiss chemistry books after 1941 ($BRP_i * \Delta p_i * post_t + BRP_i * math_i * \Delta p_i * post_t$, significant at 10 percent, Table 4, column 5).
[44] For chemistry, estimates of time-varying effects range from 0.020 in 1935-36 (with a p-value of 0.39) to 0.065 in 1937-38. After 1941, estimates reach 0.056 in 1947-48 (p-value of 0.02), 0.092 in 1953-54 (p-value of 0.00), and remain large and significant until 1969-1970 with an estimate of 0.100.

"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). BRP books may be positively selected if Uhlendorf chose to publish books with the highest expected demand. But BRP books could also be negatively selected because US publishers had not chosen to publish them at the market price for copyrights.

To help address these issues, the main specifications include book fixed effects to control for book-specific differences in the level of citations and separate BRP-specific pre-trends to control for pre-existing variation in the rate at which citations changed over time. This section presents three additional tests to address potential issues of selection.

A. Comparing Changes in Citations from Publications in English vs Other Languages

An alternative specification compares citations *to the same BRP book* by English-language and other scholars. This test is not affected by selection into treatment because it compares citations *to the same BRP book* by scholars that were differentially affected by the BRP. If the increase in citations after 1941 was driven by the unobservable characteristics of BRP books, citations from other-language scholars should increase at the same rate after 1942. If, however, improved access to BRP books drove the observed increase in citations, citations to BRP books should increase more from English-language scholars compared with citations from other-language scholars (who did not benefit from the US based BRP.)

Until 1941, both the level and the trend of English and other-language citations are roughly comparable (Figure 1). Citations by English-language publications remain close to an average of 0.26 per book and year, and citations in other languages vary around 0.29.

After 1941, however, English-language citations more than double to 0.557 per book and year, while other-language citations only increase by 34 percent to 0.391. This differential increase is particularly remarkable because many US scientists continued to publish in German-language journals until the late 1960s (e.g., Ammon 2001). Data on author locations indicate that US authors accounted for 55 percent of German-language citations to BRP books between 1920 and 1970 (448 of 821 citations), and 54 percent of German-language citations to Swiss books (78 of 145 German-language citations). The decline in other-language citations (Figure 1) coincides with the demise of German as a lingua franca of science in the 1960s (e.g. Ammon 2001, p. 465).

To examine this differential increase more systematically, we estimate

$$cites_{ilt} = \alpha\, English_l + \beta\, English_l \times post_t + book_i + \tau_t + \varepsilon_{it} \quad (11)$$

where the dependent variable $cites_{ilt}$ measures citations to book i in language l and year t, $English_l$ equals 1 for citations from English-language publications, and the control group are citations to the same BRP book by non-English language citations.

OLS estimates indicate that citations to BRP books increased by an additional 0.211 per book year after 1941 compared with citations to BRP books from other languages (Table 5, column 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. Results are robust across specifications (Table 5, columns 2-4). Estimates of a quasi-maximum likelihood Poisson model imply a differential increase of 0.771 in the growth rate of citations to BRP books from English-language publications compared with other languages (Table 5, column 5, significant at 1 percent).[45]

B. Mahalanobis Propensity Score Matching

As an additional test, we re-estimate the baseline specifications with a matched sample of 214 BRP books and 39 Swiss books with similar research subjects and comparable stocks of pre-BRP non-English-language citations (Appendix Table A7).[46] Confirming the baseline estimates, English-language citations to BRP books in this sample increase from 0.283 per book and year until 1941 to 0.661 afterwards. By comparison citations to Swiss books remain below 0.2 citations per book and year (Appendix Figure A8). OLS estimates indicate that BRP books receive 0.386 additional citations after 1941 (Appendix Table A8, column 1, significant at 1 percent). Relative to the pre-BRP mean of 0.283 citations per year for BRP books in the matched sample, this implies a 136 percent increase. Intensity regressions imply that a 10-percent decline in price is associated with 0.112 additional citations (Appendix Table A8, column 3, significant at 1 percent), which implies a 40 percent increase.

C. Intent-to-Treat for Books with German-Owned Copyrights

An additional (intent-to-treat, or ITT-type) test examines changes in citations to books *with German-owned copyrights*, which would have been available for the BRP but may not

[45] The differential increase in the growth rate of citations is captured by the estimate of the coefficient *BRP x post* of the QML Poisson estimate. A difference-in-differences Poisson model is specified as $cite_{it} = \exp(\beta_0 + \beta_1 BRP_i + \beta_2 post_t + \beta_3 BRP_i \, x \, post_t) + \varepsilon_{it}$. In this case $\Delta growth$ = [(log(citations BRP-post) – log(citations BRP-pre)) - (log(citations Swiss-post) – log(citations Swiss-pre))] $= [(\beta_2 + \beta_3) - \beta_2] = \beta_3$.

[46] Using the Mahalanobis propensity score algorithm (Abadie and Imbens 2002). We use pre-BRP citations from non-English language publications as a matching variable to minimize the risk of endogenous matching: these citations originate from countries other than the United States and years before the BRP.

have been selected. The records of the Swiss National Library include 41 books with German-owned copyrights; 6 of these 41 books were selected for the BRP.[47]

Plots of citations indicate a differential increase in citations for books with German-owned copyrights (Appendix Figure A9). Due to the small size of this sample, the estimate for *German-owned copyrights * post* is imprecisely estimated (with a p-value of 0.15) but it is large at 0.116.[48]

VI. Mechanism

In the final steps of the analysis we investigate the mechanisms by which reductions in access costs may have encouraged the creation of new follow-on science. Historical sources suggest that lower prices for BRP books encouraged the diffusion of BRP books across US libraries (e.g., Bokas and Edwards 2011, p. 25). Libraries provided access to a new group of scientists, who could then use BRP books in their own research. In this section we investigate this mechanism using data on library holdings, library loans to scientists, and changes in the location of citing authors. A final set of tests links BRP books with US patents.

A. Diffusion across Libraries

Data on historical library holdings, which we construct from the *National Union Catalog* (NUC, Mansell 1968-1981), make it possible to examine variation in the diffusion of books across US libraries. These data indicate a significant increase in the share of libraries that held at least one copy of a BRP book after 1942. Courant and Hilbert's *Methoden der Mathematischen Physik,* for example, had become available in 39 libraries across 16 states. The average BRP book had entered 16 libraries by 1956 and was available in 10 states. By comparison, Swiss books remained more concentrated in the holdings of a small number of exceptionally wealthy libraries (Appendix Figure A10). By 1956, Yale held 189 Swiss books, and the John Crerar Research Library at the University of Chicago held 169 Swiss books, while the average US library held only 4 Swiss books.

[47] Forty-one of 50 books with German-owned copyrights in the Swiss National Library are in the NUC (82 percent), compared with 283 of 291 BRP books (97 percent).

[48] If all books with German-owned copyrights had the same probability of being licensed, the intent-to-treat estimate for *German-owned copyright * post* would equal the OLS estimate for the treatment on the treated *BRP * post* divided by the probability that a book with German-owned copyright was selected for the BRP (0.15, Angrist and Imbens 1995, Wooldridge 2002, p. 636). This implies that the treatment on the treated equals 0.116/0.15 or 0.794. Compared with an OLS estimate of 0.523 for this sample, this estimate suggests that BRP books may have been negatively selected among German-owned books in the Swiss National Library.

BRP books that had experienced a larger price decline in 1942 were also available more widely across US libraries by 1956. On average, a BRP book with a price decline in the top quartile (40 to 90 percent) had become available in 20 libraries and 11 US states by 1956 (Figure 5). Beilstein's *Handbuch der Organischen Chemie* (1918) experienced a price decline of 90 percent, and had become available in 90 of 218 US libraries by 1956. By comparison, the average BRP book with a price decline in the bottom quartile (8 percent or less) had become available in 14 libraries and 9 states. A simple linear regression (shown in Figure 5) implies that each additional 10 percent decline in price was associated with a 13 percent increase in the share of libraries that held a BRP book.

B. Usage Data for BRP Books

Despite the richness of the data, the NUC alone cannot capture variation in the availability and the usage of BRP books over time, because libraries did not systematically record acquisition dates for science books.[49] To address this issue and capture variation in usage over time, we therefore examine physical copies of check-out sheets (typically attached to the inside back cover of a book). We have been able to collect these data for 127 BRP books, 45 percent of all BRP books in the holdings of Stanford's library in 2016.[50]

These data reveal a striking increase in the use of BRP books after 1942 (Figure 6). Until 1942, two BRP books had been borrowed from Stanford library at least once (*Stereochemie* by K. Freudenberg and *Die Mathematischen Hilfsmittel des Physikers* by E. Madelund). After 1942, three BRP books were borrowed for the first time in 1944, and two per year each in 1945, 1948, 1949, and 1952. Then five books were borrowed for the first time in 1955. The median book was first checked out in 1957.

C. Geographic Diffusion of Citing Authors

Next, we investigate whether the diffusion of BRP books across US libraries allowed authors in previously underserved locations to access and build on knowledge in BRP books. Data on the locations of citing authors over time suggest that the expansion of citing authors

[49] 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).
[50] BRP books in Stanford's library were sold at an average price of $68.16 until 1941, and experienced an average price decline of 34 percent under the BRP. Reference books, such as Beilstein, are excluded because they cannot be borrowed. We are less likely to observe original cards for popular books because check-out sheets were replaced once they had filled up; this will lead us to estimate usage with a delay. The library card for Courant and Hilbert's *Methoden der Mathematischen Physik* for example, lists it as first checked out in 1963.

tracked the expansion in library holdings, and indicate a westward shift in citations. Forty-nine of 50 citations to BRP books until 1941 originate from states where scientists could access the book in at least one library. After 1941, 813 of 815 citations to BRP books originate from states with at least one copy. Until 1941, citations to BRP books are concentrated in Chicago, Cambridge, Princeton, and Providence. After 1941, citations to BRP books expand to the Midwest and West (Figure 7). Sixty-three of 815 citations originate from Los Angeles in 1942; another 47 citations come from Stanford, 36 from Berkeley, and 36 from Madison.

D. Patents

Did the observed increase in scientific citations translate into an equivalent increase in invention? To investigate this issue, we examine changes in the number and in the locations of US patents that cite BRP books as relevant scientific knowledge. Patent data also allow us to investigate the BRP's impact on the commercial activity of private firms, above and beyond the impact on libraries and academics. Although these effects are excluded from the main estimates they may have been substantial. For example, the majority of J.W. Edwards's sales of Beilstein's *Handbuch der Organischen Chemie* targeted private sector firms. NUC libraries had acquired 158 copies of Beilstein by 1956, leaving 442 of a total of 600 copies reportedly sold by JW Edwards (Bokas and Edwards 2011, p. 25) for private sector firms.

Patent data reveal a large increase in patents that cite BRP books after 1942. Until 1941, a total of 34 US patents cite at least one BRP book in the description of their invention.[51] After 1941, 200 patents cite at least one BRP book. Beilstein, for example, receives 0.304 patent citations per year until 1941, and 1.345 afterwards. For the average BRP book, counts of citing patents increase by 15 percent, from 0.005 per book and year until 1941 to 0.024 afterwards (Figure 8).

Geographic data on the location of inventors indicate that the use of BRP knowledge diffused to inventors in a new group of states. Until 1941, 35 patents cite a BRP book, and 6 of 50 US states produce at least one patent that cites a BRP book. After 1941, 213 patents cite a BRP book, and 19 of 50 US states produce at least one citing patent, including California, Indiana, Missouri, Minnesota, and Wisconsin.[52] Taken together, these results suggest that the

[51] Thirty patents cite a BRP chemistry book and 4 cite a BRP math book until 1941; 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).
[52] Until 1942, 5 citing patents originate from New York, 3 from Pennsylvania, 2 from New Jersey, 2 from Ohio, and 1 from Maryland and Delaware each (Appendix Figure A11, top panel). After 1942, 9 citing patents

increase in follow-on science as a result of the BRP was associated with an increase in the number and in the geographic scope of patented inventions.

VII. Conclusions

In 1942, the US Book Republication Program made temporary copyright licenses for German science books available to US publishers. Rarely available price data for these books indicate that BPR books became available for a significantly lower price – with an average price decline of 25 percent. This paper has examined the effects of this change on citations by new scientific publications, as a measure for the creation of new scientific knowledge. Baseline estimates, which control for quality differences through book fixed effects, indicate that BRP books experienced a 1.5-fold increase in citations compared with Swiss science books in the same disciplines that were not available for licensing. Intensity estimates suggest that each additional 10 percent decline price was associated with nearly 0.4 additional new publications that build on an existing book.

These findings indicate that policies which facilitate access to existing knowledge can create dramatic benefits for the creation of new scientific knowledge. It is also notable that several of the books in our data, such as Beilstein's *Handbook of Organic Chemistry* (1918), were compilations of existing knowledge. A reduction in price for this books allowed a new group of scholars and firms to access that knowledge. Although the focus of this paper is on science, we also find that patenting increased in research fields that benefitted from the BRP.

Our simple model of knowledge production predicts substantive differences across disciplines in the effects of price on the creation of new knowledge: Disciplines in which knowledge production depends primarily on human capital (and less on physical capital) benefit most from lower access costs. Comparisons of changes in citations for chemistry and mathematics confirm these results. Chemistry, a discipline in which knowledge production depends heavily on access to physical capital in the form of research laboratories and equipment, experienced a 66 percent increase in citations after the BRP. By comparison, mathematics, which is primarily dependent on human capital, experienced a 4-fold increase.

The historical setting allows us to investigate the mechanism by which reductions in book prices have encouraged the creation of new knowledge. Geographic data on historical library holdings suggest that lower book prices helped to diffuse German-owned science

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originate from Indiana, 5 from Connecticut, 4 from California, 3 from Missouri, 2 each from Wisconsin and from Minnesota, and 1 each from Tennessee and Oklahoma (Appendix Figure A11, bottom panel). By comparison, patents that cite Swiss books remain more concentrated.

books across the United States. As more and more libraries acquired these books, a new set of authors gained access to the knowledge covered by the books, and was able to extend that knowledge.

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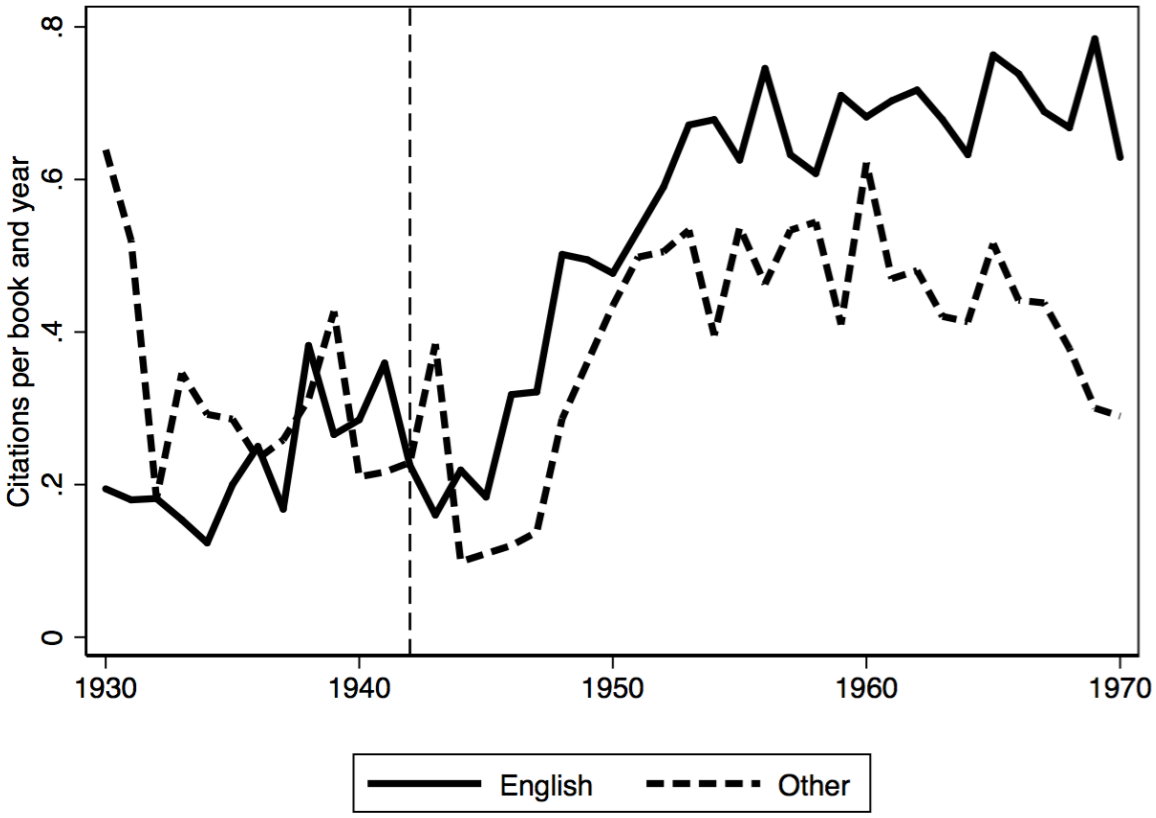
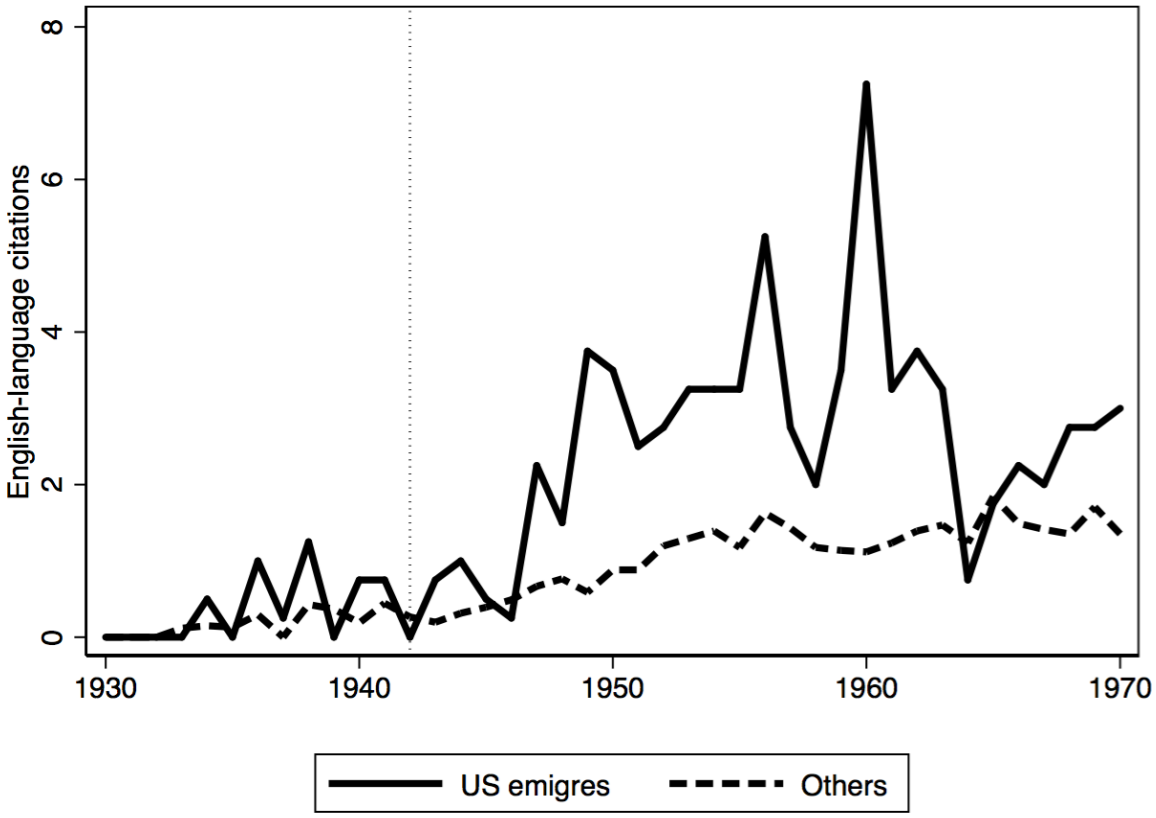
FIGURE 1 – CITATIONS TO BRP BOOKS
FROM PUBLICATIONS IN ENGLISH VERSUS OTHER LANGUAGES



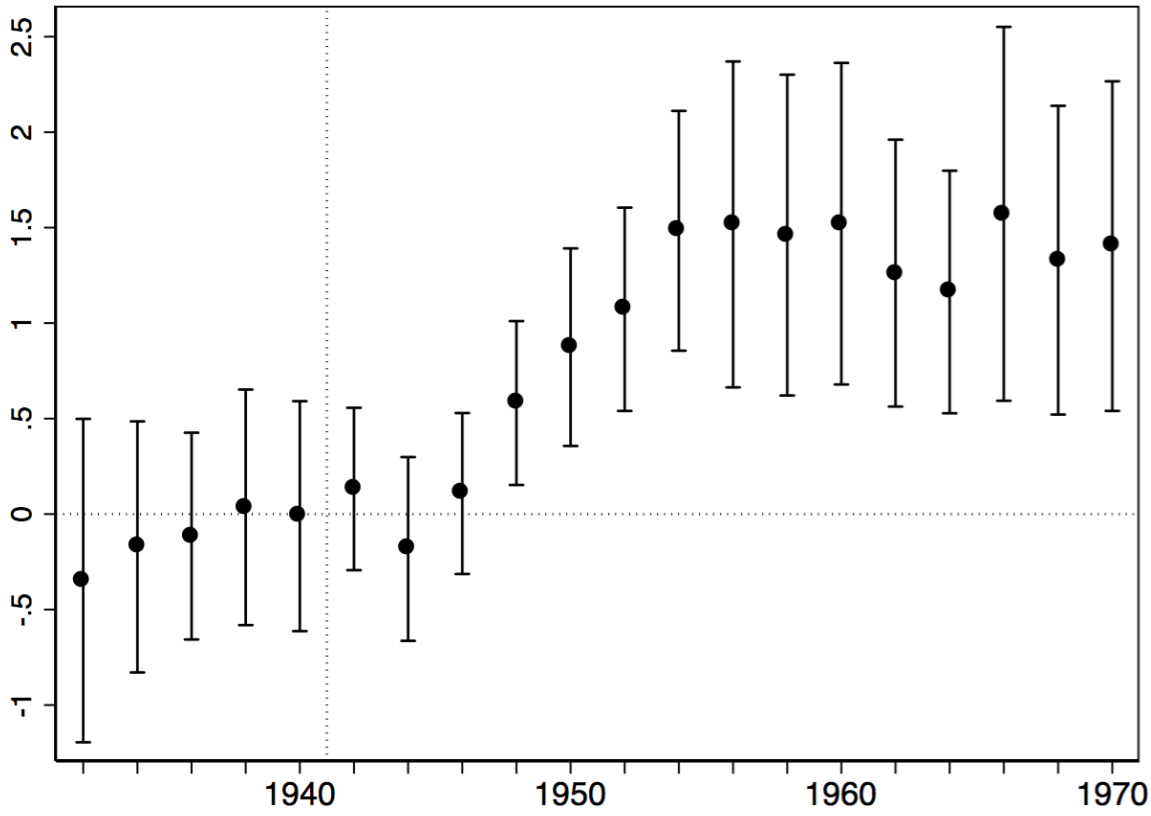
Notes: Citations per book and year for 283 BRP books by new scientific publications in English compared with citations to BRP books by new publications in other languages (which did not benefit directly from the BRP). Citations collected from Google Scholar (http://scholar.google.com, accessed July 1st-September 25th, 2014).

FIGURE 2 – CITATIONS PER BOOK AND YEAR
BRP BOOKS BY ÉMIGRÉS COMPARED WITH OTHER BRP BOOKS



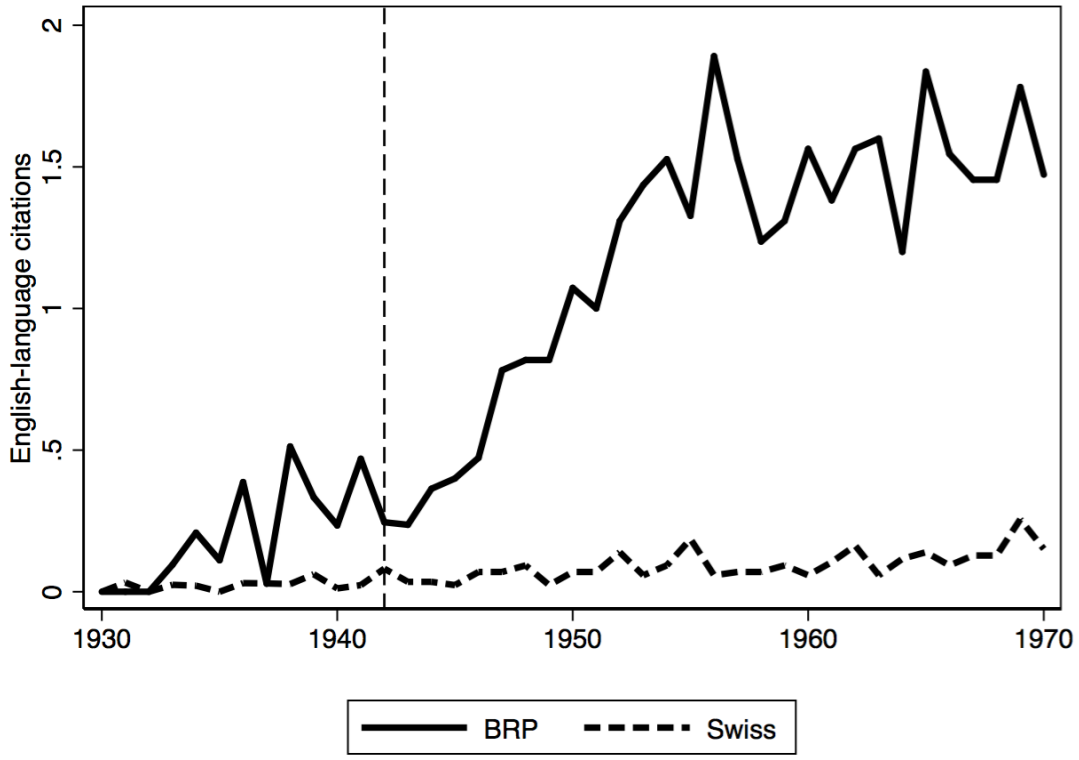
Notes: English-language citations per book and year for BRP books by seven mathematicians who emigrated to the United States after 1932 compared with other BRP books in mathematics. We identify émigrés using the *Dictionary of Central European Émigrés* (Straus et al. 1983) as well as information on PhD granting institutions for advisors and advisees in the Mathematics Genealogy Project (http://genealogy.math.ndsu.nodak.edu, accessed May 1-30, 2015).

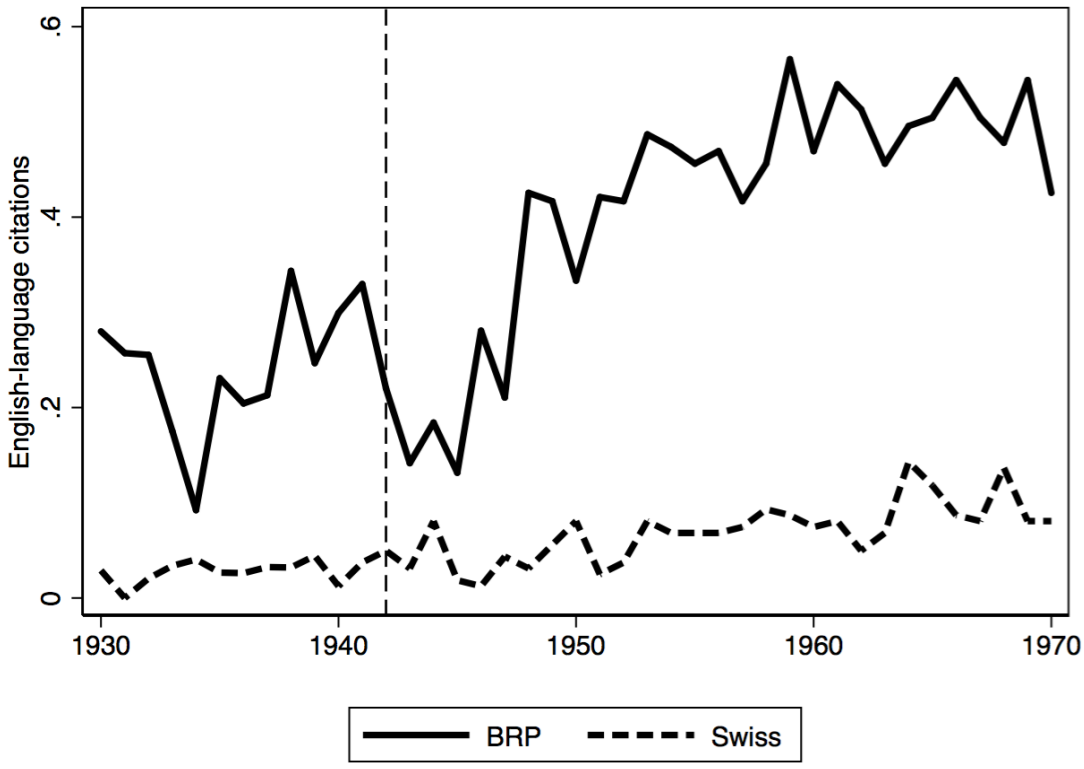
FIGURE 3– TIME-VARYING EFFECTS OF PRICE
ENGLISH-LANGUAGE CITATIONS FOR BRP COMPARED WITH SWISS BOOKS



Notes: Estimates of the coefficient β_s (with a 95-percent confidence interval) in the OLS regression $cite_{it} = \alpha\, BRP_i + \beta\, BRP_i \times post_t + \Sigma_s\, \theta_s\, \Delta p_i \times BRP_i \times \tau_s + book_i + \mu(t - 1919) \times 1(1920 \leq t \leq 1941) \times BRP_i + \tau_t + \varepsilon_{it}$ $_t$ for two-year intervals 1930-131,…,1969-70. Years before 1930 are the excluded period. The dependent variable $cite_{it}$ counts scientific articles and books that cite book i in year t. The variable BRP_i equals 1 for 283 books that were licensed to US publishers under the BRP; τ_t is an indicator for 2-years intervals 1930-31, 1932-33, ….1969-70. The variable Δp measures the difference between the original (pre-BRP) price for book i and the price that the US publisher charged under the BRP, divided by the original price. $Book_i$ is a vector of book fixed effects. The term $(t - 1919) \times 1(1920 \leq t \leq 1941) \times BRP_i$ controls for a linear pre-trend in citations that is specific to BRP books.

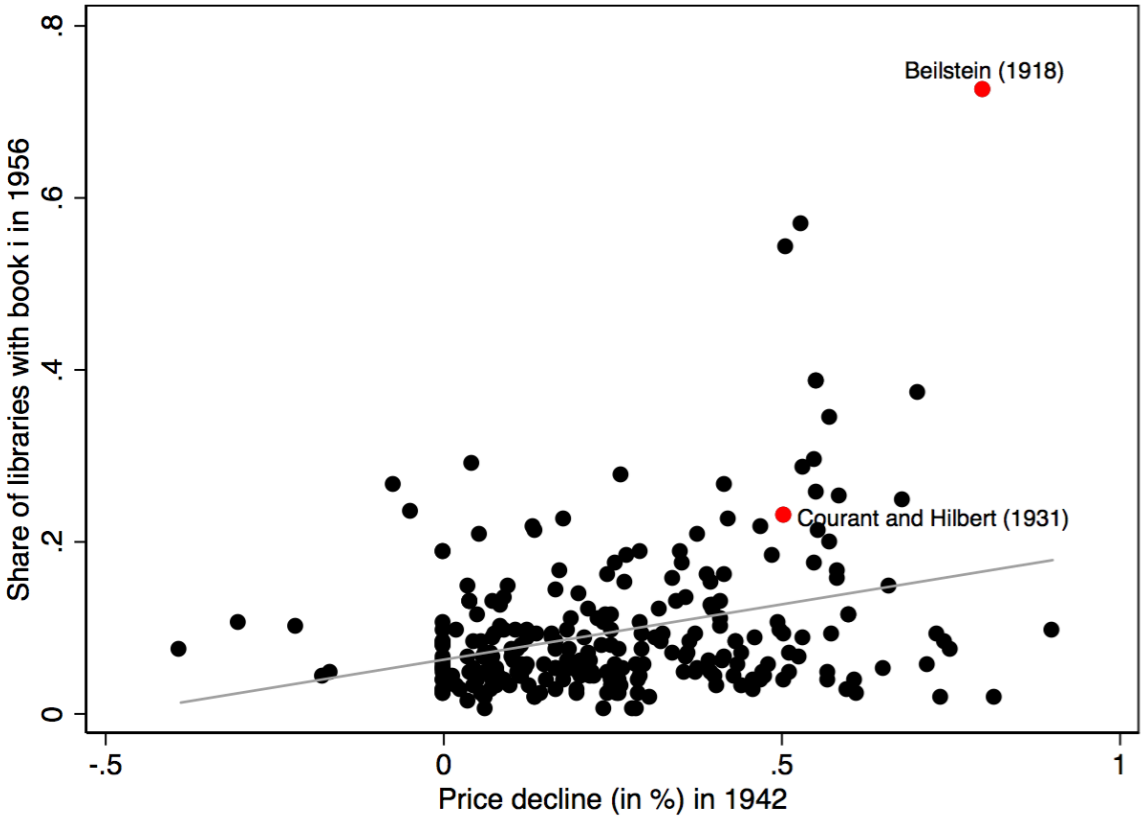
FIGURE 4 – CITATIONS BY NEW PUBLICATIONS PER BOOK AND YEAR
MATHEMATICS (TOP) AND CHEMISTRY (BOTTOM)





Notes: Citations per book and year for 55 BRP math books and 86 Swiss math books (top panel) and 228 BRP chemistry books and 161 Swiss chemistry books (bottom panel).

FIGURE 5 – SHARE OF LIBRARIES HOLDING A COPY VS PRICE DECLINE OF BRP BOOKS



Notes: The share of libraries that held at least one copy of BRP book *i* in 1956 against the decline in price for the same book in 1942. Data on libraries holdings were constructed from the records of the National Union Catalog (Mansell 1968-1981) at the Hoover Institution Library and Archives.

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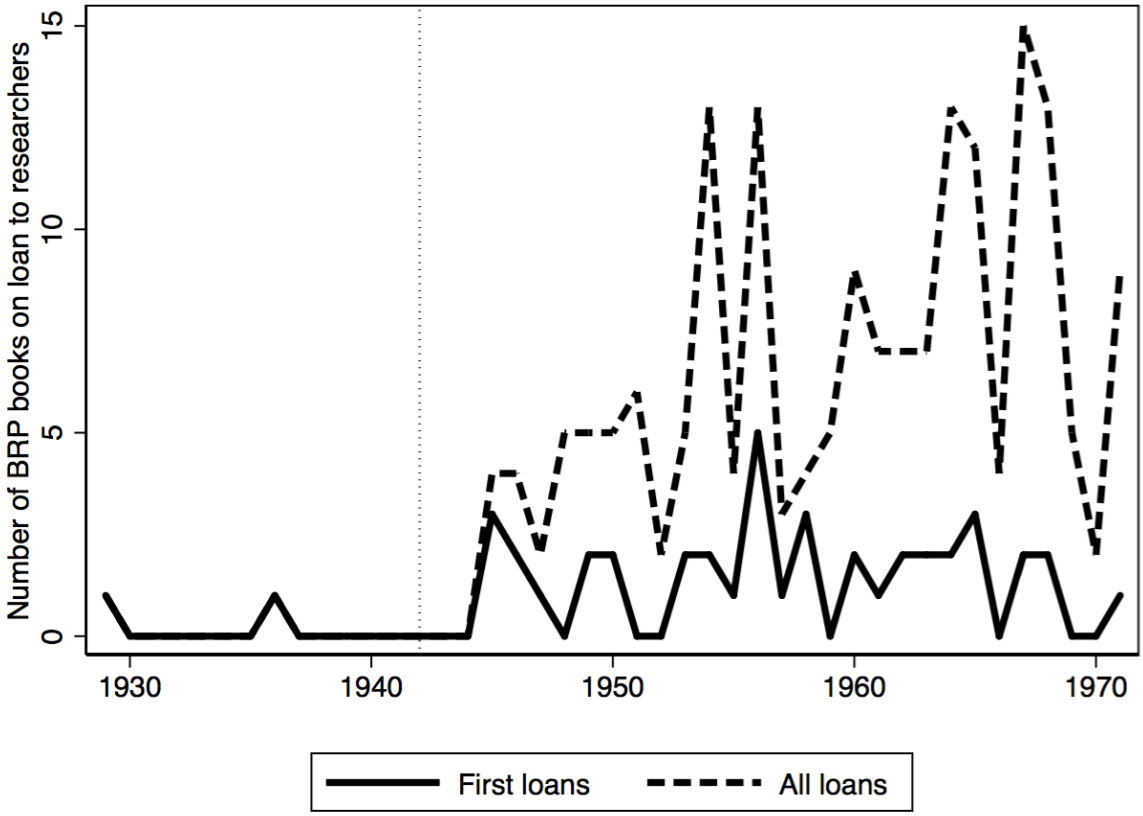
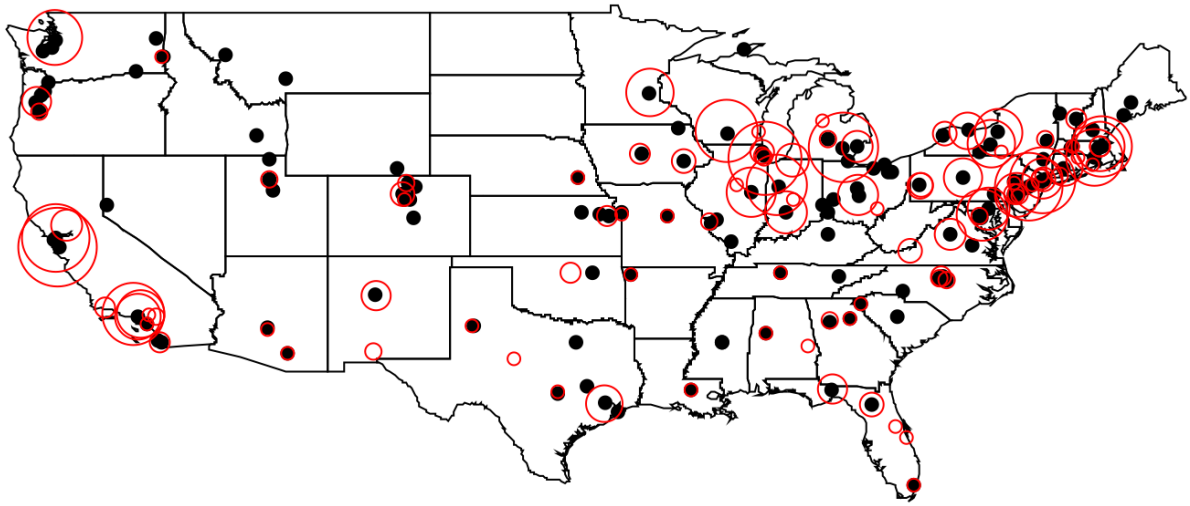
FIGURE 6 – BRP BOOKS ON LOAN, 1930-1970



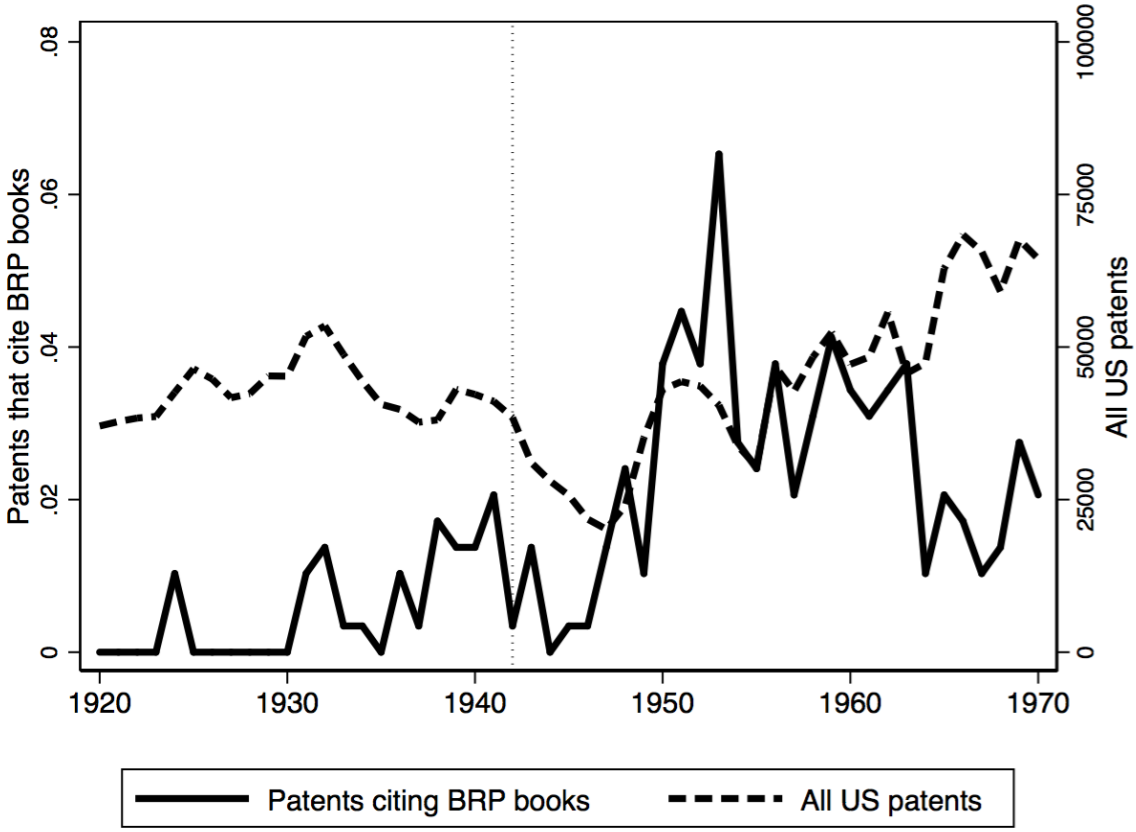
Notes: BRP books on loan to researchers from Stanford's library in year *t*. The solid line (*First loans*) plots first usage: the number of BRP books that were first lent to a library customer in year *t*. The interrupted line (*All loans*) plots all usage: the total number of BRP books on loan to researchers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

FIGURE 7 - LIBRARIES AND AUTHORS WHO CITE BRP MATH BOOKS, 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 authors who cite math BRP book after the 1942; 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).

FIGURE 8 – 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).

TABLE 1 – COMPARISON OF MEANS
CITATIONS BY NEW PUBLICATIONS PER BOOK AND YEAR

	1920-41	1942-1970	Difference
All Books (N=530)	0.105	0.338	0.232***
	(0.487)	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) of the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. *BRP* books include 283 books with German-owned copyrights 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). Data on citations to these books between 1920 and 1970 are constructed from Google Scholar (http://scholar.google.com), July 1st - September 25th, 2014.

TABLE 2 – OLS, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR AND LN(CITATIONS PER YEAR)

	Counts of citations (columns 1-4)				Ln(counts of citations) (columns 5-8)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BRP x post	0.392***	0.599***	0.227***	0.436***	1.011***	2.776***	0.448*	1.024***
	(0.086)	(0.158)	(0.071)	(0.096)	(0.179)	(0.622)	(0.257)	(0.192)
BRP				0.222**				1.116***
				(0.088)				(0.264)
Citation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Linear BRP pre-trend	No	Yes	No	No	No	Yes	No	No
Flexible BRP pre-trend	No	No	Yes	No	No	No	Yes	No
Publication year & subject FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.550	0.551	0.551	0.146	0.408	0.409	0.410	0.151
N	20,191	20,191	20,191	19,702	20,191	20,191	20,191	19,702
Pre-1942 mean	0.263	0.263	0.263	0.268				

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

Notes: The dependent variable is counts of the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970 (columns 1-4) and the natural logarithm of 0.00005 + counts of the number of new scientific articles and books that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 247 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 for years after 1941. Columns 2 and 6 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for the 1920 to 1941.

TABLE 3 – OLS, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR

	(1)	(2)	(3)	(4)	(5)
BRP x post	0.393***	0.097	0.253**	-0.042	0.127
	(0.086)	(0.077)	(0.113)	(0.079)	(0.087)
BRP					0.159*
					(0.086)
BRP x Δp x post		1.006***	0.998***	0.990***	1.066***
		(0.344)	(0.343)	(0.341)	(0.313)
Δp					0.282
					(0.230)
Citation year FE	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	Yes	No
Linear BRP pre-trend	No	No	Yes	Yes	No
Flexible BRP pre-trend	No	No	No	Yes	No
Publication year & subject FE	No	No	No	No	Yes
R-squared	0.551	0.554	0.554	0.554	0.167
N	19,844	19,844	19,844	19,844	19,383

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

Notes: The dependent variable counts the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 247 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 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. Columns 2 and 6 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for years between 1920 and 1941.

TABLE 4 – DIFFERENTIAL EFFECTS BY DISCIPLINE. OLS, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR

	All books (columns 1-4)				Books with price (columns 5-8)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BRP x post	0.173***	0.334**	0.032	0.254***	0.088	0.234**	0.955**	0.068
	(0.048)	(0.164)	(0.057)	(0.059)	(0.077)	(0.111)	(0.407)	(0.081)
BRP x Math x post	0.917***	0.914***	0.918***	0.699**				
	(0.308)	(0.309)	(0.307)	(0.280)				
BRP				0.154*				0.085
				(0.079)				(0.085)
BRP x Δp x post					0.346	0.339	0.328	0.465*
					(0.296)	(0.290)	(0.289)	(0.278)
BRP x Math x Δp x post					2.708***	2.707***	2.719***	2.984***
					(0.923)	(0.925)	(0.919)	(0.932)
Δp								0.263
								(0.246)
Citation year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Linear BRP pre-trend	No	Yes	No	No	No	Yes	No	No
Flexible BRP pre-trend	No	No	Yes	No	No	No	Yes	No
Publication year and subject FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.558	0.558	0.558	0.159	0.563	0.563	0.563	0.199
N	20,191	20,191	20,191	19,702	19,844	19,844	19,844	19,383
Pre-1942 Mean	0.263	0.263	0.263	0.268	0.264	0.264	0.264	0.269

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

Notes: The dependent variable counts articles and books that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 BRP. The control group covers 247 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 for years after 1941. The variable *Math* indicates 141 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. Columns 2 and 6 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for years between 1920 and 1941.

TABLE 5 –ENGLISH-LANGUAGE CITATIONS TO BRP BOOKS
COMPARED WITH CITATIONS FROM PUBLICATIONS IN OTHER LANGUAGES
OLS, DEPENDENT VARIABLE IS CITATIONS PER YEAR

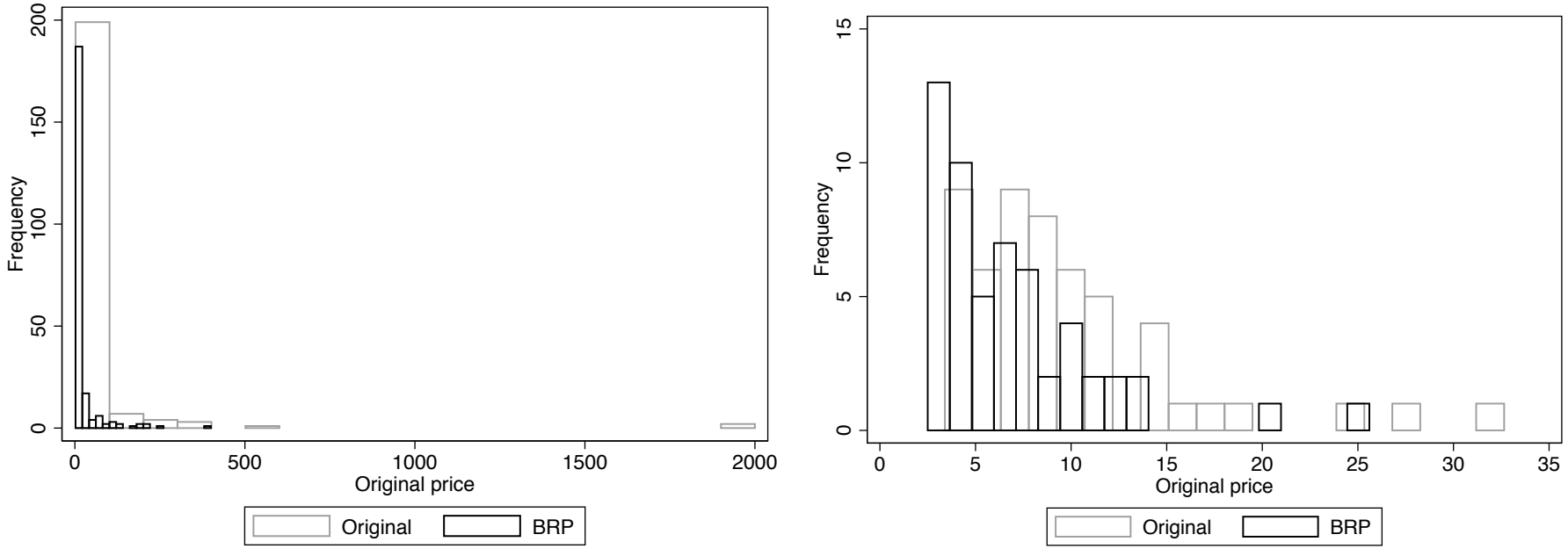
	All books (columns 1-2)		Books with price (columns 3-4)		QML Poisson
	(1)	(2)	(3)	(4)	(5)
English	-0.036	-0.034	-0.036	-0.034	-0.129
	(0.042)	(0.042)	(0.042)	(0.042)	(0.150)
English x post	0.211***	0.229***	-0.077	-0.070	0.497***
	(0.066)	(0.067)	(0.091)	(0.091)	(0.157)
English x Δp x post			1.192***	1.235***	
			(0.344)	(0.342)	
Δp				0.241	
				(0.176)	
Citation year FE	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	No	Yes	No	Yes
Publication year & subject FE	No	Yes	No	Yes	No
Linear BRP pre-trend	No	No	No	No	No
Flexible BRP pre-trend	No	No	No	No	No
R-squared	0.357	0.117	0.366	0.138	--
N	19,680	19,162	18,986	18,524	18,610
Pre-1942 mean	0.263	0.268	0.264	0.267	0.281

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

Notes: The dependent variable counts new *English-language* publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group are citations to BRP books by new scientific publications from other languages (which did not benefit from the BRP). The variable *post* equals 1 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.

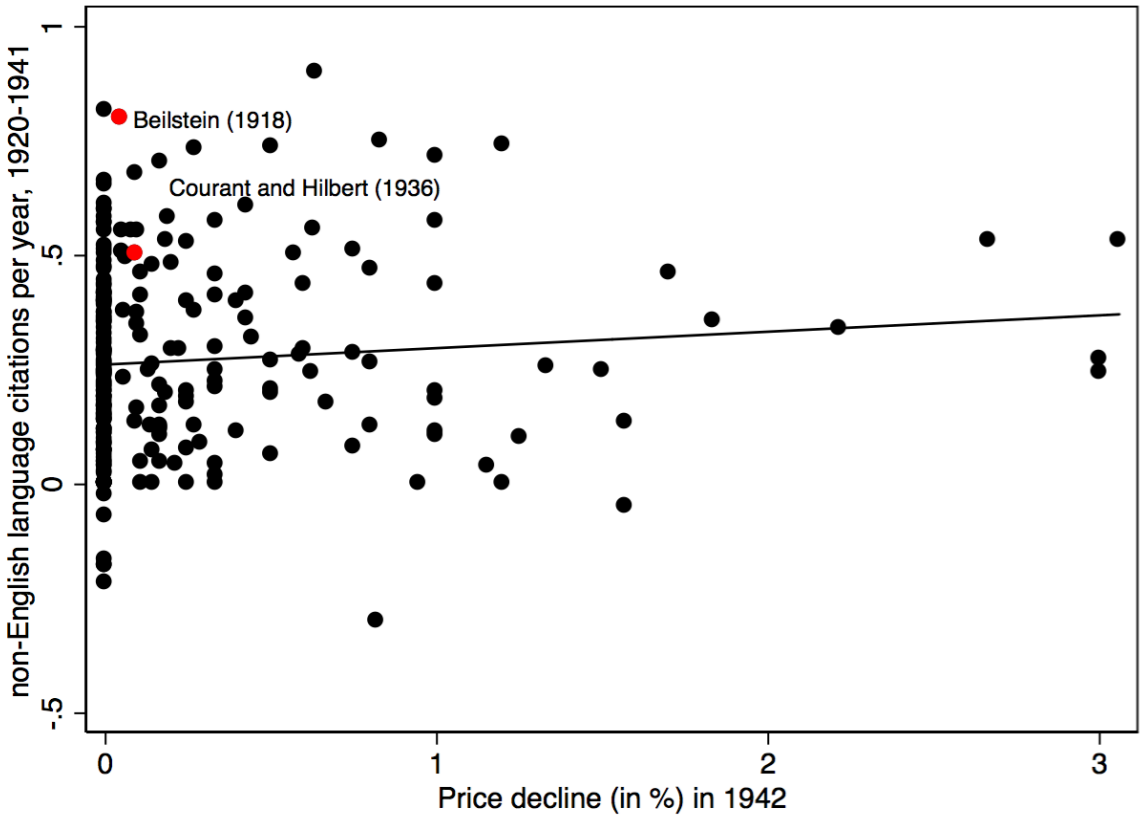
APPENDIX –
NOT FOR PUBLICATION

FIGURE A1 – ORIGINAL AND BRP PRICES FOR BRP BOOKS – CHEMISTRY (LEFT) AND MATHEMATICS (RIGHT)



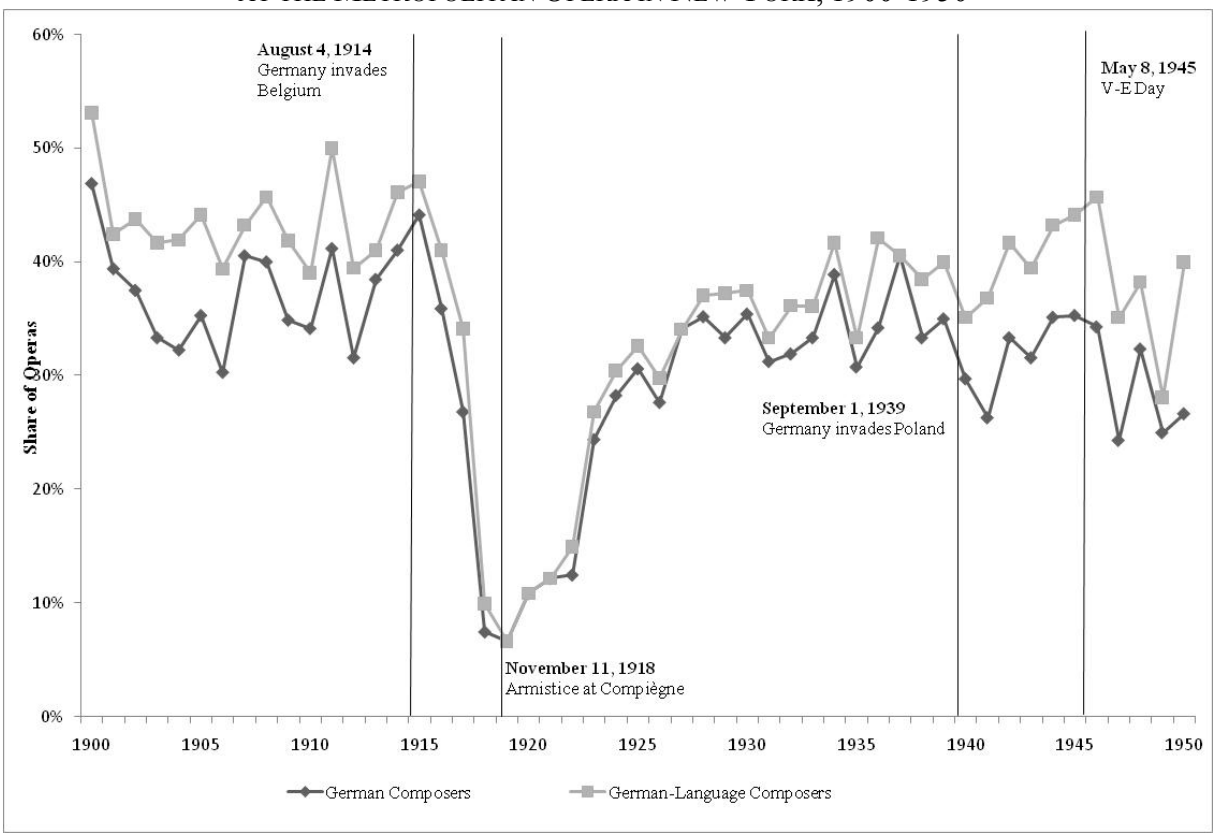
Left: BRP prices for 228 books in chemistry, with an average and median original price of $51.18 and $11.48. Two chemistry books sold for an original price of $2,000 each: Beilstein's *Handbuch der Organischen Chemie* (with a BRP price of $400) and Saccardo's *Silloge Fungorum* (with a BRP price of $200).
Right: BRP prices for 55 books in mathematics, with an average and median original price of $9.80 and $8.00. 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 – DECLINE IN PRICE VS PRE-BRP NON-ENGLISH CITATIONS PER YEAR



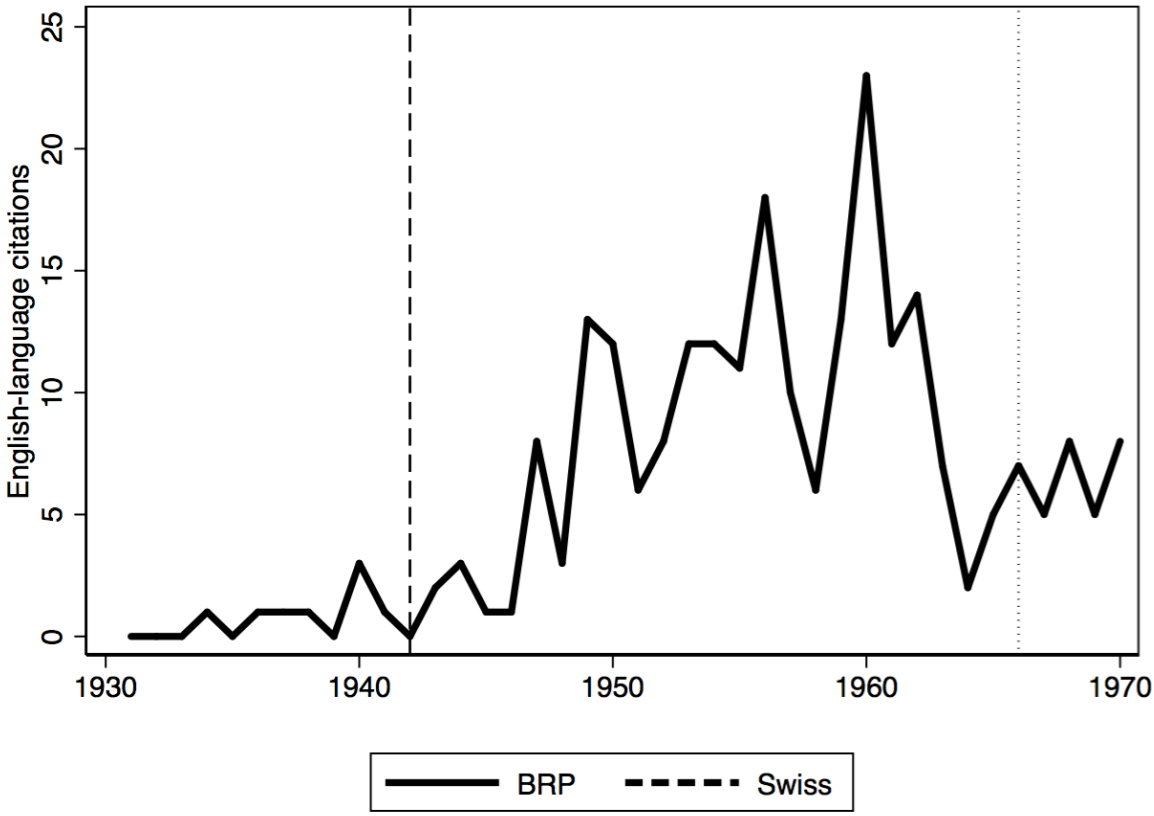
Notes: Decline in price for 283 BRP books against pre-1942 non-English citations per year to the same books.

FIGURE A3 – SHARE OF GERMAN-LANGUAGE OPERAS
AT THE METROPOLITAN OPERA IN NEW YORK, 1900-1950



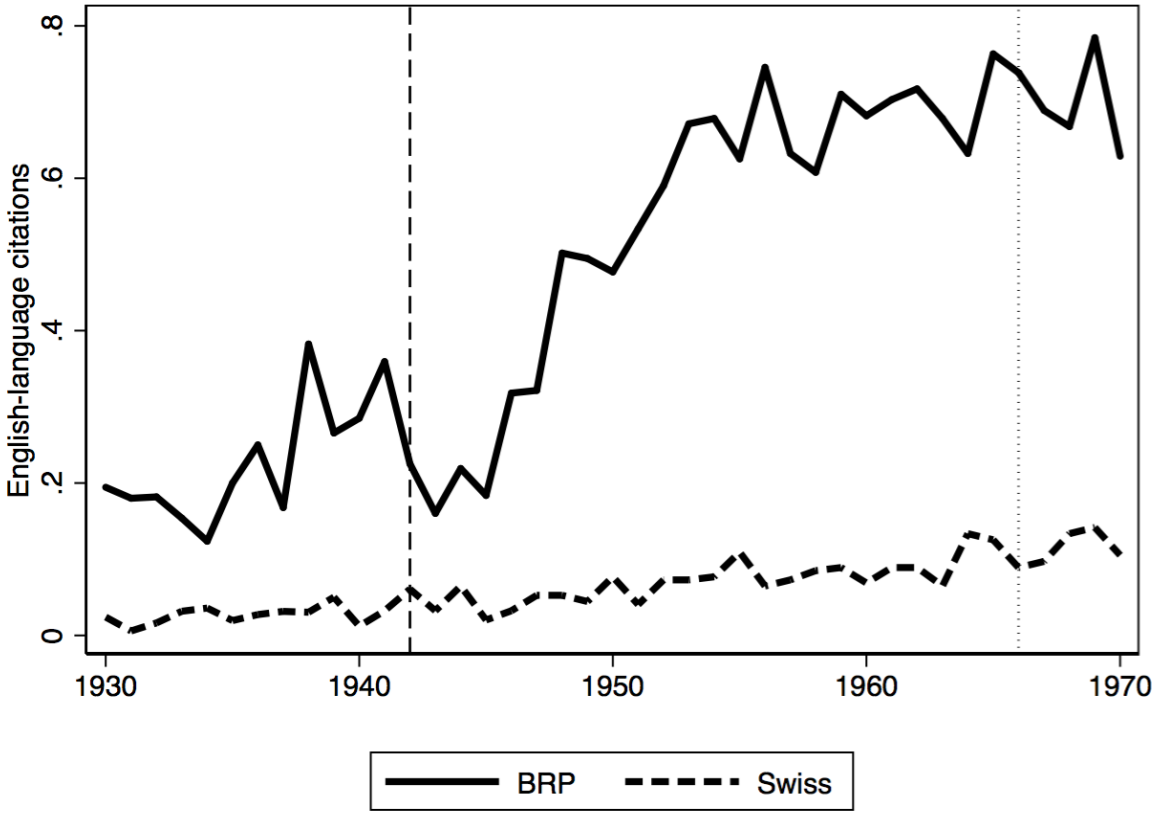
Notes: Data on the share of German-language operas collected from historical schedules of performances in the online archives of the Metropolitan Opera in New York (Moser 2012). *German composers* include Carl Maria von Weber, Engelbert Humperdinck, Friedrich Handel, Friedrich von Flotow, Giacomo Meyerbeer, 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 A4 – CITATIONS BY NEW PUBLICATIONS PER YEAR –
"METHODEN DER MATHEMATISCHEN PHYSIK" (1931) BY R. COURANT AND D. HILBERT



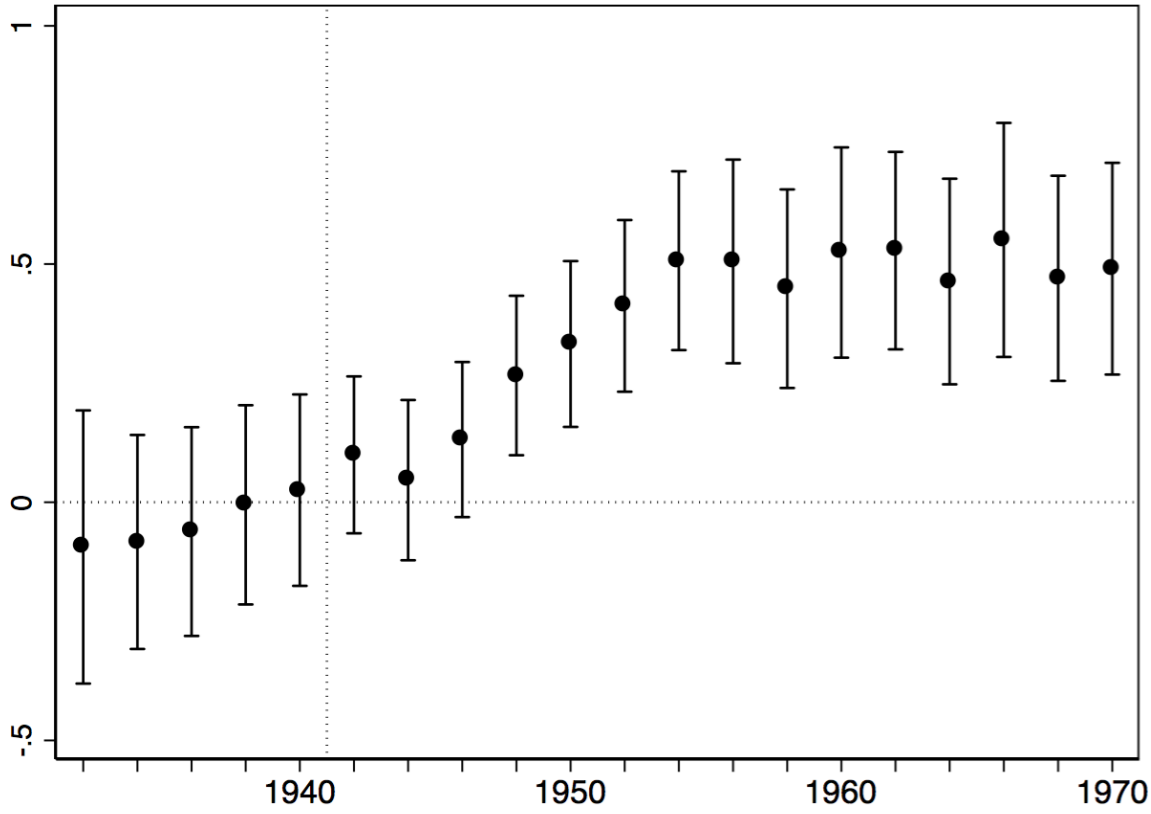
Notes: Citations *Methoden der Mathematischen Physik* (1931) by new scientific publications (book and articles) per year. Citations data from Google Scholar (http://scholar.google.com) between July 1st and September 25th, 2014.

FIGURE A5 – ENGLISH-LANGUAGE CITATIONS TO BRP AND SWISS BOOKS



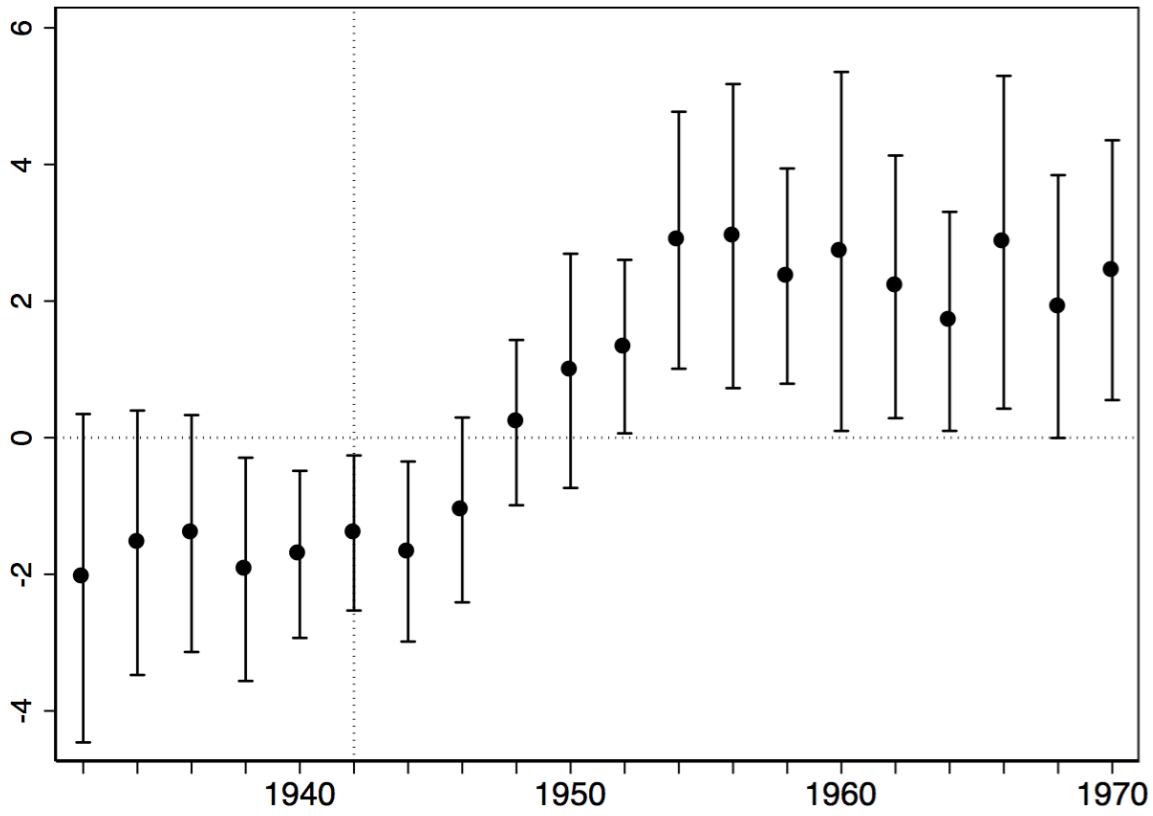
Notes: Citations by new English-language publications to BRP and Swiss books in the National Union Catalog (NUC). Data include 5,141 English-language citations to 283 BRP books and 247 Swiss by new publications between 1930 and 1970 collected from Google Scholar (http://scholar.google.com, accessed July1st to September 25th, 2014).

FIGURE A6 – TIME-VARYING EFFECTS OF THE BRP ON FOLLOW-ON SCIENCE



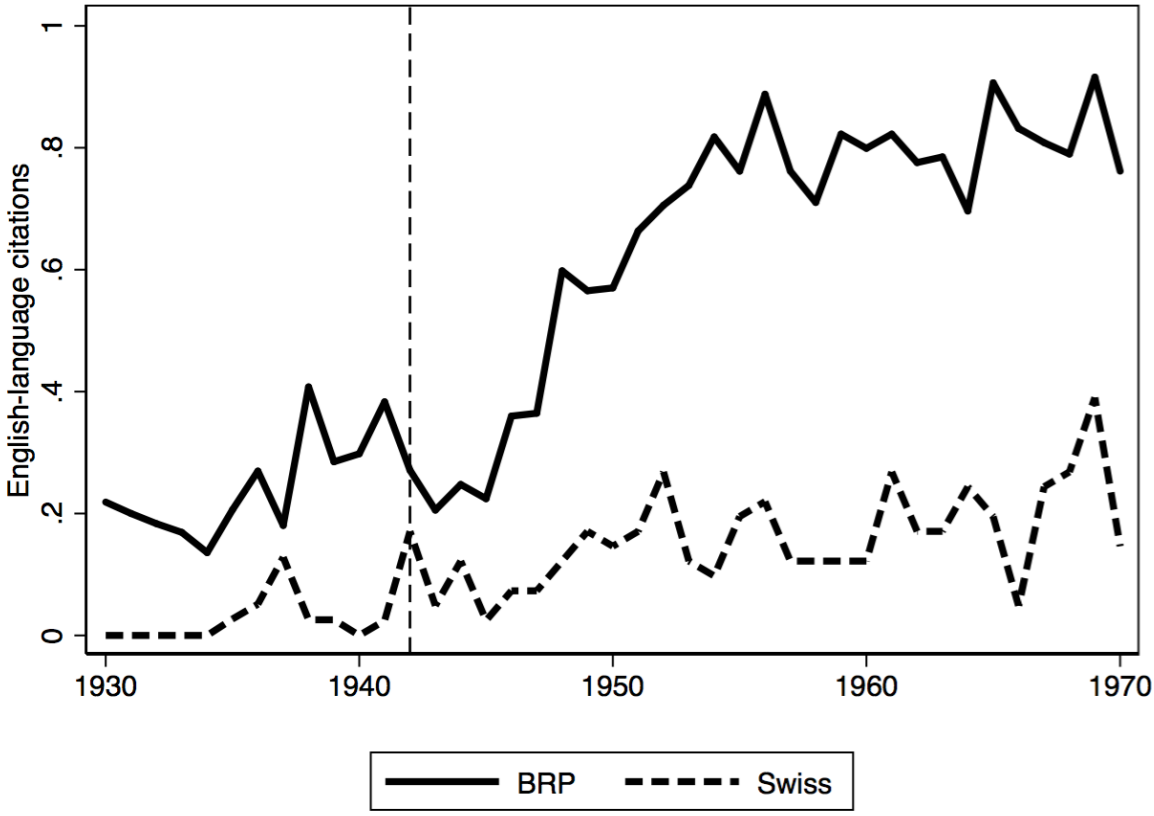
Notes: Estimates of β_s (with a 95-percent confidence interval) in the OLS regression $cite_{it} = \alpha BRP_i + \Sigma_s \beta_s BRP_i \times \tau_s + book_i + \mu(t - 1919) \times 1(1920 \leq t \leq 1941) \times BRP_i + \tau_t + \varepsilon_{it}$ $_t$ for two-year intervals 1930-131, 1932-33, …., 1969-70. Years between 1920 and 1929 are the excluded period. The dependent variable $cite_{it}$ counts scientific publications that cite book *I* in year *t*. The indicator variable BRP_i=1 for 283 books that were licensed to US publishers under the BRP; the variable τ_t is an indicator variable for 2-years intervals 1930-31, 1932-33, ….1969-70. The variable $book_i$ is a vector of book fixed effects. The term $(t - 1919) \times 1(1920 \leq t \leq 1941)$ controls for BRP-specific pre-trends. Standard errors are clustered at the level of individual books.

FIGURE A7 – TIME-VARYING EFFECTS OF PRICE IN MATHEMATICS



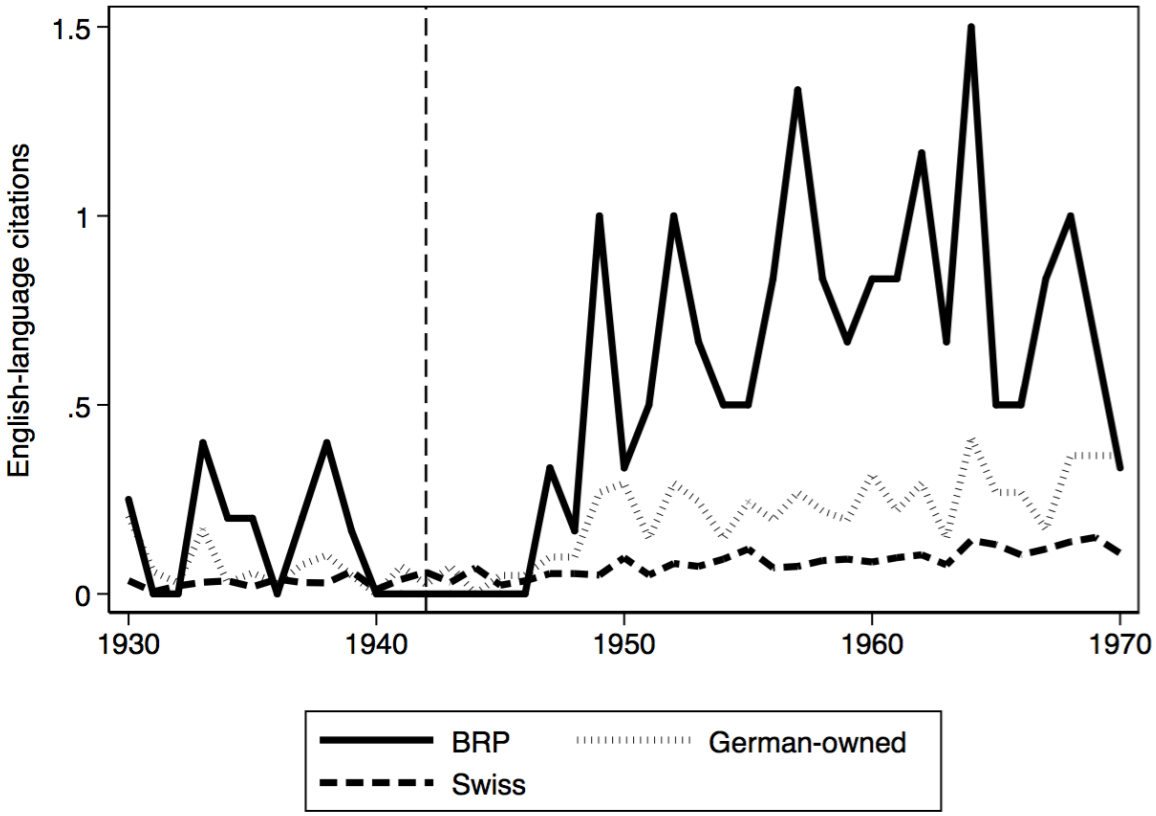
Notes: Estimates of the coefficient θ_s (with a 95-percent confidence interval) in the OLS regression $cite_{it} = \alpha\ BRP_i + \beta\ BRP_i \times post_t + \Sigma_s\ \theta_s\ \Delta p_i \times BRP_i \times \tau_s + book_i + \mu(t - 1919) \times 1(1920 \leq t \leq 1941) \times BRP_i + \tau_t + \varepsilon_{it}$ for two-year intervals 1930-131, 1932-33, …., 1969-70. Years between 1920 and 1929 are the excluded period. The dependent variable $cite_{it}$ counts scientific publications that cite book *i.* in year *t.* The indicator variable BRP_i=1 for 55 books in mathematics that were licensed to US publishers under the BRP; the variable τ_t is an indicator for 2-years intervals 1930-31, 1932-33, ….1969-70. The variable Δp measures the difference between the original (pre-BRP) price for book *i* and the price that the US publisher charged under the BRP, normalized by the original price. The variable $book_i$ is a vector of book fixed effects. The term $(t - 1919) \times 1(1920 \leq t \leq 1941)$ controls for a BRP-specific linear pre-trend. Standard errors are clustered at the book level.

FIGURE A8 – MATCHED SAMPLE: ENGLISH-LANGUAGE CITATIONS PER BOOK AND YEAR.



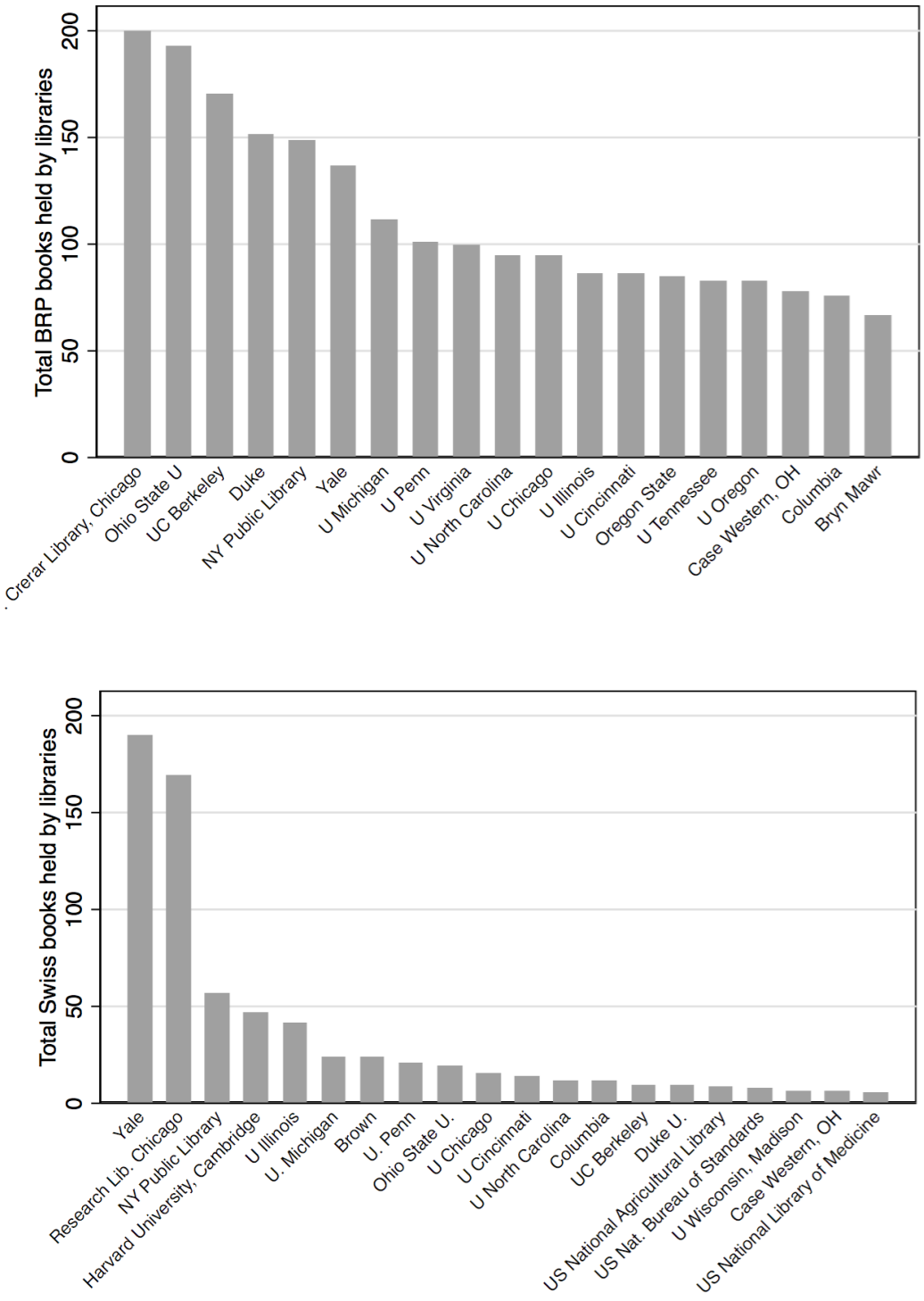
Notes: Citations by scientific publications per book and citation year for a matched sample of 214 BRP books and 41 Swiss books. Books are matched with a Mahalanobis propensity score matching procedure using *subjects* (including 25 within chemistry and 8 within mathematics) and the stock of *pre-1942 citations by German-language publications* as matching variables. Citations from http://scholar.google.com, accessed July 1st-25th, 2014.

FIGURE A9 – CITATIONS PER BOOK AND YEAR,
BRP VS. GERMAN-OWNED VS. SWISS BOOKS IN THE SWISS NATIONAL LIBRARY



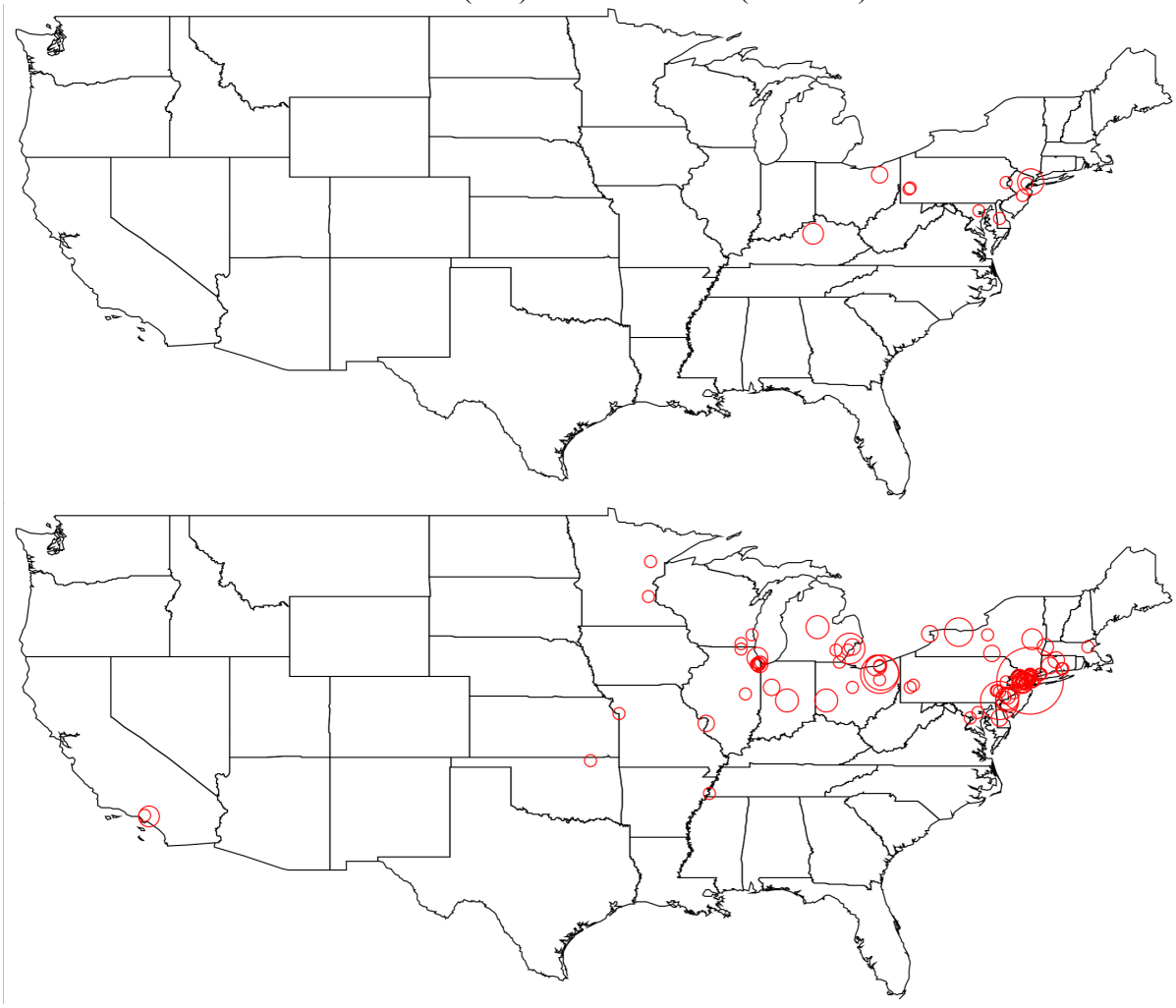
Notes: Citations per year for 6 books that were licensed to US publishers under the BRP listed in the Swiss National Library (*BRP*), 41 books with German-owned copyrights (*German-owned*), and a control group of 247 Swiss books in the same library. Citations from Google Scholar (http://scholar.google.com) accessed between July 1st and September 25th, 2014.

FIGURE A10 – COUNTS OF BRP BOOKS (TOP)
AND SWISS BOOKS (BOTTOM) HELD BY US LIBRARIES



Notes: BRP books (top panel) and Swiss books (bottom panel) held by a library. For example, the Crerar Library at the University of Chicago held at least one copy each of 283 BRP books (top) and at least one copy each of 247 Swiss books. Data from the National Union Catalog (Mansell 1968-1981), accessed at the Hoover Institution Library and Archives.

FIGURE A11 – LOCATION OF INVENTORS FOR PATENTS THAT CITE BRP BOOKS: 1920-1941 (TOP) AND 1942-1970 (BOTTOM)



Notes: Inventor locations for patents that cite BRP books as relevant scientific knowledge. Patents issues for 1920-1941 (top) and 1942-1970 (bottom). We have constructed data on inventor locations by searching the full text of patent documents in the United States Patent and Trademark Office Bulk Downloads https://www.google.com/googlebooks/uspto.html).

TABLE A1 – SUMMARY STATISTICS, BRP BOOKS

	N	Mean	St. Dev.	Median
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
Percentage decline in p	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
Percentage decline in p	55	27.44	21.11	23.47

Notes: Counts, means, standard deviations and means of prices of BRP books in chemistry and mathematics with non-missing price information. BRP books and their prices are collected from the Report of the Alien Property Custodian (1942).

TABLE A2 – FULL SAMPLE (NOT RESTRICTED TO BOOKS IN THE NUC) - OLS, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR

	All books (columns 1-4)				Books with price data (columns 5-8)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BRP x post	0.393***	0.585***	0.236***	0.420***	0.107	0.238**	-0.022	0.116
	(0.083)	(0.157)	(0.068)	(0.085)	(0.076)	(0.114)	(0.077)	(0.078)
BRP				0.220***				0.141**
				(0.057)				(0.059)
BRP x Δp x post					0.971***	0.961***	0.952***	1.068***
					(0.338)	(0.336)	(0.334)	(0.305)
Δp								0.306
								(0.213)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Linear BRP pre-trend	No	Yes	No	No	No	Yes	Yes	No
Flexible BRP pre-trend	No	No	Yes	No	No	No	Yes	No
Publication Year and subject FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.550	0.551	0.551	0.146	0.554	0.554	0.554	0.167
N	20,191	20,191	20,191	19,702	19,844	19,844	19,844	19,383
Pre-1942 Mean	0.263	0.263	0.263	0.268	0.264	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: The dependent variable counts the number of new scientific publications (including articles and books) that cite 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 copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 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. Columns 2 and 6 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for the 1920 to 1941.

TABLE A3 – CHANGES IN PRICE AND IN CITATION BY 5 MOST FREQUENT RESEARCH SUBJECTS, BRP AND SWISS BOOKS IN CHEMISTRY (TOP) AND MATHEMATICS (BOTTOM)

	BRP Books					Swiss Books		
	Price		Citations		N	Citations		N
	Original	% decline	Pre-1941	Post-1941		Pre-1941	Post-1941	
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
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

Notes: Matched subject classification for 283 BRP and 247 Swiss books in the US National Union Catalog. Subjects fields are created by matching subject codes of the Alien Property Custodian (1942) and the *Katalog* (vols. 1921-1939 and 1931-1940) of the Swiss National Library.

TABLE A4 –BOOKS IN THE US LIBRARY OF CONGRESS. OLS, DEPENDENT VARIABLE IS CITATIONS PER YEAR

	(1)	(2)	(3)	(4)	(5)	(6)
BRP x post	0.361***	0.507***	0.439***	0.070	0.167	0.148
	(0.089)	(0.150)	(0.151)	(0.083)	(0.133)	(0.155)
BRP x Δp x post				0.992***	0.991***	1.000***
				(0.342)	(0.342)	(0.316)
BRP			0.742***			0.613**
			(0.259)			(0.264)
Δp						0.378
						(0.287)
Citation Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Publication Year & Subject FE	No	No	Yes	No	No	Yes
Linear BRP pre-trend	No	Yes	No	No	Yes	No
R-squared	0.548	0.589	0.156	0.551	0.591	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

The dependent variable counts the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 283 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 19 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality) and that are also included in the Library of Congress. The variable *post* equals 1 for years after 1941. The variable *Δp* measures the difference between the original pre-BRP price for book *i* and the price that the US publisher charged under the BRP, divided by the original price. The variable *Δp* measures the difference between the original price and the BRP price for book *i*, divided by the original price. Columns 2 and 5 include a linear BRP-specific pre-trend.

TABLE A5 – BOOKS BY ÉMIGRÉS TO THE UNITED STATES

Title	Author	Publication Year	Citations	Price	
				Original	% Decline
Methoden der mathematischen Physik	R. Courant and D. Hilbert	1931	258	28.24	0.504
Strahlenoptik	M. Herzberger	1931	2	7.75	0.161
Anschauliche Geometrie	D. Hilbert and S. Cohn-Vossen	1932	42	10.32	0.661
Mathematische Grundlagen der Quantenmechanik	J. v. Neumann	1932	56	7.85	0.554
Differenzrechnung	N. Norlund	1924	0	10.80	0.000
Aufgaben und Lehrsätze aus der Analysis	G. Pólya and G. Szegő	1925	39	14.40	0.583

Notes: Information on migration from the *International Biographical Dictionary of Central European Émigrés 1933-1945* (Strauss et al. 1983) and from the *Mathematics Genealogy Project*, which lists universities, advisers, and advisees for 186,596 mathematicians between 1666 and 2015 (available at http://genealogy.math.ndsu.nodak.edu, accessed February 1st to 18th, 2015).

TABLE A6– DIFFERENTIAL EFFECTS FOR BOOKS BY ÉMIGRÉS AND OTHER MATHEMATICS
OLS, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR FOR BRP AND SWISS BOOKS IN MATHEMATICS

	(1)	(2)	(3)	(4)
BRP x post	0.935***	0.556*	0.953***	1.433***
	(0.278)	(0.331)	(0.280)	(0.455)
US émigré * BRP * post	1.114	1.132	1.140	1.119
	(1.475)	(1.475)	(1.497)	(1.502)
BRP			0.163	-0.318
			(0.144)	(0.245)
US émigré			-0.387	-0.364
			(0.414)	(0.422)
Citation year FE	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	No
BRP linear pre-trend	No	Yes	Yes	Yes
Publication year and subject FE	No	No	Yes	Yes
R-squared	0.595	0.595	0.236	0.236
N	5,292	5,292	5,292	5,292
Pre-1942 Mean	0.230	0.230	0.230	0.230

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

Notes: The dependent variable counts the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 55 mathematics books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 86 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 for years after 1941. The indicator variable *US émigré* equals 1 for 4 books by 7 mathematicians who emigrated to the United States after the Nazi government took power in 1933. Columns 2 and 4 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for the 1920 to 1941.

TABLE A7 – AVERAGE CITATIONS PER YEAR – MATCHED SAMPLE

	1920-41	1942-1970	Difference
Full Sample (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 (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 214 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The sample is obtained using a Mahalanobis matching procedure based on subjects and pre-1942 average German language citations per year.Citations from Google Scholar (http://scholar.google.com), July 1st to September 25th, 2014.

TABLE A8 – OLS MATCHED SAMPLE, DEPENDENT VARIABLE IS CITATIONS PER BOOK AND YEAR

	(1)	(2)	(3)	(4)	(5)	(6)
BRP x post	0.386***	0.650***	0.438***	0.056	0.258**	0.085
	(0.101)	(0.174)	(0.117)	(0.089)	(0.126)	(0.101)
BRP			0.116			0.022
			(0.143)			(0.141)
BRP x Δp x post				1.116***	1.110***	1.201***
				(0.376)	(0.375)	(0.361)
Δp						0.307
						(0.302)
Citation year FE	Yes	Yes	Yes	Yes	Yes	Yes
Book FE	Yes	Yes	No	Yes	Yes	No
Linear BRP pre-trend	No	Yes	No	No	Yes	No
Publication year & subject FE	No	No	Yes	No	No	Yes
R-squared	0.558	0.558	0.182	0.562	0.562	0.205
N	9,365	9,365	9,365	9,302	9,302	9,302
Pre-1942 mean	0.283	0.283	0.283	0.284	0.284	0.284

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

Notes: The dependent variable counts the number of new scientific publications (including articles and books) that cite book *i* per year *t* between 1920 and 1970. The indicator *BRP* equals 1 for 214 books in the National Union Catalog (NUC) that were licensed to US publishers under the 1942 Book Republication Program (BRP). The control group covers 39 Swiss books in the NUC (that were not available for copyright licensing due to Switzerland's neutrality). The variable *post* equals 1 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. Columns 2 and 5 include a linear BRP-specific pre-trend. Columns 3 and 7 allow for BRP-specific year fixed effects for the 1920 to 1941. BRP and Swiss books are matched using the Mahalanobis propensity score algorithm with subjects and pre-1942 average German language citations per year as matching variables.