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# The Retraction Penalty: Evidence from the Web of Science

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Scientific articles are retracted at increasing rates, with the highest rates among top journals. Here we show that a single retraction triggers citation losses through an author's prior body of work. Compared to closely-matched control papers, citations fall by an average of 6.9% per year for each prior publication. These chain reactions are sustained on authors' papers (a) published up to a decade earlier and (b) connected within the authors' own citation network by up to 4 degrees of separation from the retracted publication. Importantly, however, citation losses among prior work disappear when authors self-report the error. Our analyses and results span the range of scientific disciplines.

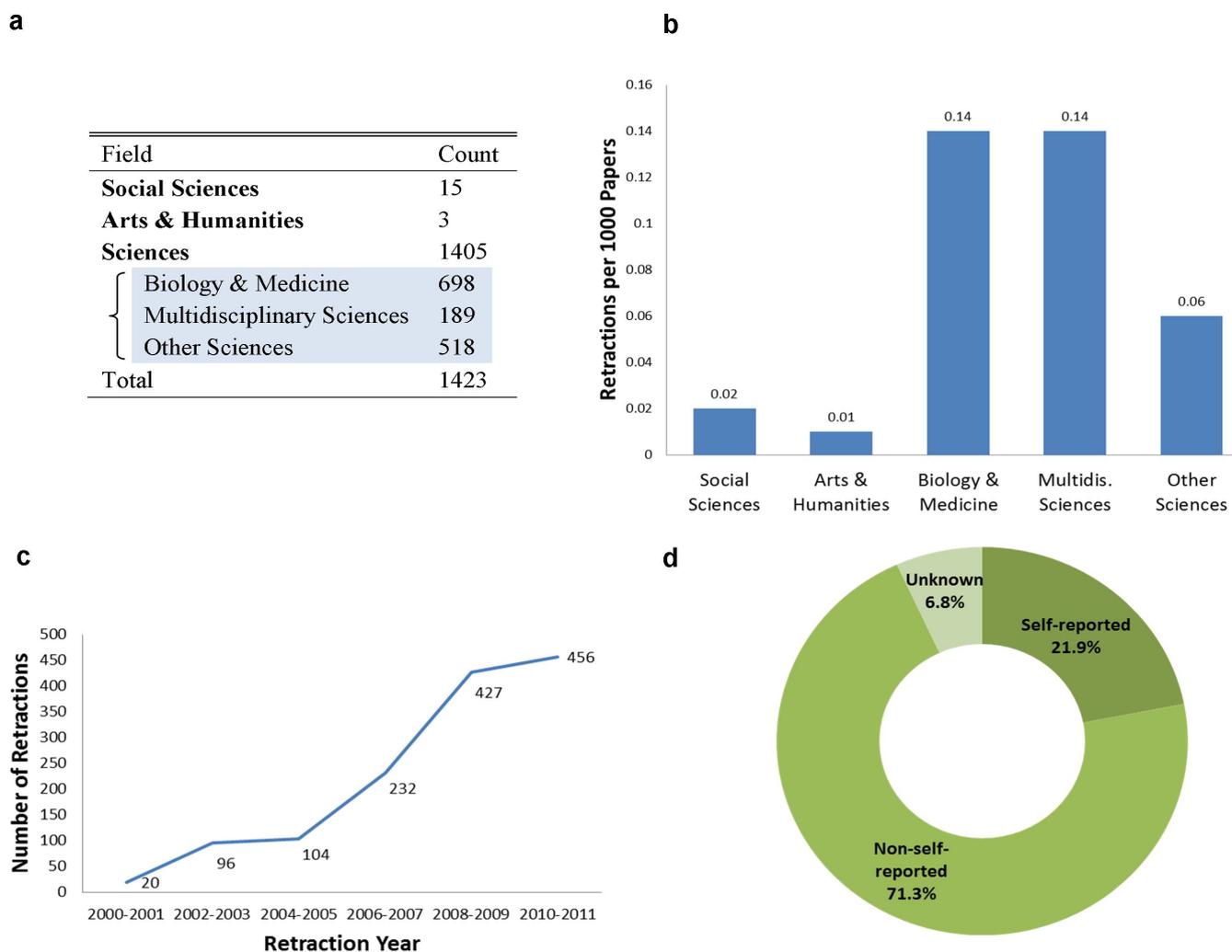
The science community regularly experiences instances of major scientific mistakes or misconduct. Prominent examples include retracted claims about cloning human embryos and harvesting their stem cells, a claimed link between the MMR vaccine and autism, and claims about super-conducting plastics that misled scientists for years across many top physics laboratories<sup>1,2</sup>. In recent years, a Nobel Prize winner has retracted 3 influential papers on the olfactory system, a Harvard evolutionary biologist resigned over scientific misconduct, and a prominent psychologist at Tilburg University admitted to pervasive falsification of data throughout his career. Survey methods, meanwhile, suggest broad doubts within the science community<sup>3</sup>, with researchers estimating in one study that 17.1% of other researchers have falsified work<sup>4</sup>. While the true rate of false science is difficult if not impossible to detect<sup>5</sup>, the problem can only be more prevalent than the discovered cases.

Prior literature on retractions primarily examines biomedical journals, using PubMed data, and finds that retractions result in a 35–65% decrease in the retracted paper's citations compared to control papers<sup>2,6</sup>. Notably, citations to retracted papers do continue, and analyses suggest that half or more of the future citations continue to accept the original claims<sup>2,6–11</sup>. Thus, false results can live on, even after formal retraction, magnifying the consequences of publishing false results in the first place.

In this paper, we draw on all retraction notices in the Web of Science (WOS) database. We focus on the post-2000 period when WOS indexing of retractions appears relatively complete (see supporting information for detailed discussion of the database) and use the WOS to expand our analysis across the known universe of fields. Our analysis can thus provide a more comprehensive cross-field view of retractions than the existing literature. Most importantly, we examine a new dimension: We analyze the effect of retraction on scientists' *prior* work, thus quantifying a potentially critical consequence, and disincentive, for being associated with false scientific results. Our analysis further shows how chain reactions to retraction hinge on whether authors self-report errors.

## Results

Figure 1 presents basic characteristics of the retraction data. Retraction is most common in the hard sciences (Figs. 1a, 1b), especially in biomedical journals (.014% of biomedical papers) and multidisciplinary journals (.014% of papers), while occurring at approximately half this rate (.006% of papers) in other science fields. Meanwhile, social sciences (.002% of papers) and arts & humanities (.001% of papers) show substantially lower rates of retraction, which may reflect lower incidence of false science or lower rates of detection, where replication norms may differ<sup>12</sup>. Retraction rates are increasing with time (see also<sup>13</sup> for PubMed analysis), measured by the year in which the retraction occurs (Fig. 1c). Based on the original publication year, retraction is more evenly distributed but still rising rapidly, with publications in 2008–2009 retracted at 2.3 times their rate in 2000–2001 (Table S1-1). Retraction is also substantially more frequent in the highest-impact journals. Papers published in Nature, PNAS, and Science are retracted at an average rate of 0.91% over the 2000–2009 period, which is 9.6 times the background retraction rate (Table S1-1), and retracted papers have higher average citations than non-retracted papers prior to retraction (Table S1-2). Among retracted articles, 312 retraction cases (21.9%) are



**Figure 1 | Retraction characteristics.** Of the 1,423 retractions indexed by the Web of Science, the percentage of total retractions is greatest in the sciences, with nearly half (49.1%) of all retractions occurring in biology & medicine journals (a). Normalizing by field publication rates, both biology & medicine and multidisciplinary sciences show the greatest retraction tendency (0.14 papers per 1000 publications) (b). The number of retractions issued in a given period has been rising rapidly since the year 2000 (c). A minority (21.9%) of retractions is due to authors' self-reporting errors to the publishing journal (d).

“self-reported”, where the authors themselves report the error to the journal (Fig. 1d). However, the majority of cases are not self-reported, as further discussed in the supporting information (see also<sup>13</sup>). In sum, the problem of false science appears across many fields and at an increasing rate. Retractions are most likely among high-impact work and pre-eminent journals, and self-reported retractions are relatively rare.

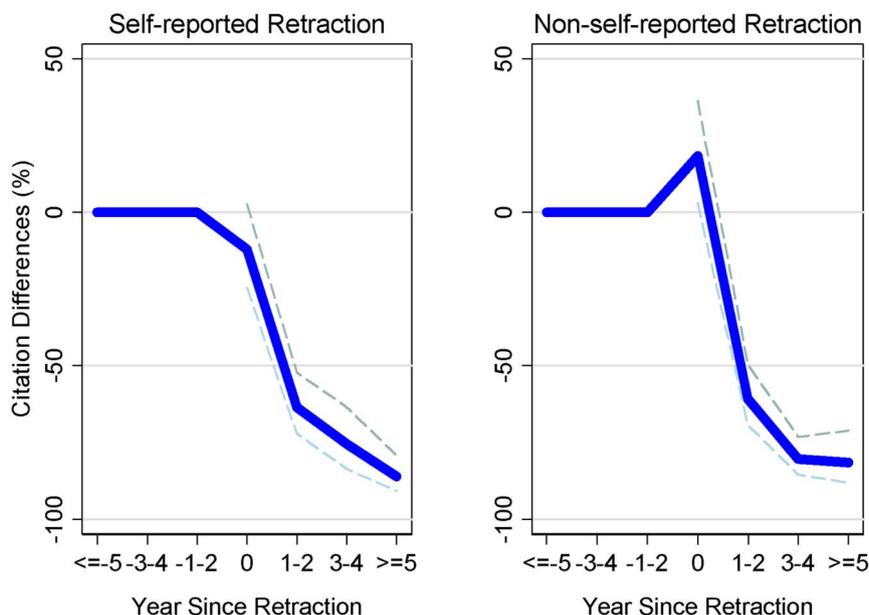
Our empirical methodology compares the citation path of “treated” papers (those written by an author involved in a retraction) with the counterfactual citation path of “control” papers. Control papers are those that have similar citations paths to a treated paper prior to the retraction event. The effect of retraction is thus determined by examining the divergence, after retraction, between a treated paper and its ex-ante controls. As described below (see Methods), we use the entire WOS to find the most closely matched control papers within each field, allowing for substantially closer matches to the treated papers than can be determined using more limited databases.

Figure 2 presents the effect of retraction on the retracted papers themselves. The effect appears similar for both self-reported retractions (Fig. 2a) and non-self-reported retractions (Fig. 2b), with the annual flow of citations five or more years after the retraction having dropped 86.2% ( $p < .0001$ ) compared to the control papers for

self-reported retractions and 81.5% ( $p < .0001$ ) for the non-self-reported papers. The decline in citations to retracted work also appears broadly across scientific fields (Fig. S2).

Figure 3 presents our main analysis, examining retraction effects on scientists' prior work. To isolate the effect of single retractions, we exclude cases where authors have multiple retractions, leaving 667 retracted papers and 1,737 authors with prior work. We build the sample of prior work using the WOS database. Specifically, we trace citations from each retracted article to prior articles by the same author (a 1<sup>st</sup> degree self-citation), citations from these prior articles to other prior articles by the same author (a 2<sup>nd</sup> degree self-citation), and so on up to the 11<sup>th</sup> degree, at which point additional prior work is no longer revealed. We identify additional prior publications by tracing forward this citation network – locating papers by the same author that cite these past publications. The average number of prior articles per author generated is 25.9, creating a sample of 45,039 prior papers. Note that none of the prior work was itself retracted.

Figure 3 shows that retractions lead to substantial citation declines to the authors' prior work, but only if the retraction was *not self-reported*. When retractions are not self-reported, the annual flow of citations to a prior publication falls 4.7% ( $p < .0001$ ) in the first two years after the retraction and 12.5% ( $p < .0001$ ) five or more years after the retraction, compared to the control papers (Fig. 3b). Overall,

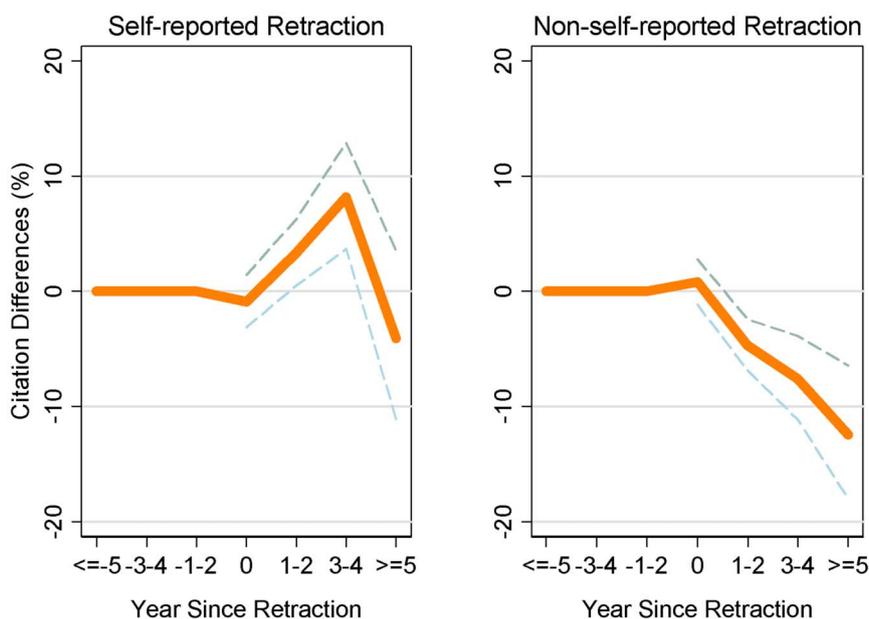


**Figure 2 | Effect of retraction on retracted papers themselves.** Citations losses, compared to control papers, are shown for (a) self-reported retractions and (b) non-self-reported retractions. Blue lines indicate mean citation losses and dashed lines present 95% confidence intervals. Compared to the control papers, citation losses are 86.2% ( $p < .0001$ ) for self-reported retractions and 81.5% ( $p < .0001$ ) for non-self-reported retractions, annually, five or more years after retraction.

the average loss after retraction is 6.9% ( $p < .0001$ ), as shown in Table S2. By contrast, self-reported retractions do not show any statistically significant relationship to losses in citations to prior work, with point estimates suggesting essentially zero effect five years later and, if anything, increased citations at first (Fig. 3a). Thus, while retractions of both types have similar effect on the retracted paper itself, only retractions that are non-self-reported present large and sustained citations losses on the authors' prior body of work. Large citation losses to prior publications appear after non-self-reported retractions across the various sub-fields when analyzed separately,

including biomedicine, multidisciplinary sciences, and other sciences (Fig. S3). Considering the smaller number of cases where an author experiences multiple retractions, as opposed to a single retraction, one sees more severe citation loss effects on prior work (Table S6).

The magnitude of the effect on prior work (Fig. 3) appears smaller than the effect on the retracted papers themselves (Fig. 2). However, recalling that authors on average have 25.9 prior papers, the prior publication penalty is in fact substantially magnified. In terms of linear citation counts (see Table S2), the average retracted paper loses



**Figure 3 | Effect of retraction on authors' prior body of work.** Citations losses for prior work, compared to control papers, are presented after (a) self-reported retractions and (b) non-self-reported retractions. Orange lines indicate mean citation losses and dashed lines present 95% confidence intervals. After non-self-reported retractions, the authors' prior work loses 12.5% ( $p < .0001$ ) of citations per year per prior publication five or more years after the retraction event, compared to control papers. By contrast, citation losses for the authors' prior body of work do not appear after self-reported retractions.



2.88 citations per year after retraction, compared to controls. A prior publication (for non-self-reported retractions) loses 0.091 citations per year on average, or 2.36 citations collectively (0.091 citations per paper  $\times$  25.9 papers per author), which is similar to the loss for retracted paper themselves. Moreover, five or more years after a non-self-reported retraction, the collective citation loss on an author's prior work rises to 5.39 citations per year ( $.208 \times 25.9$  papers, see Table S4-2).

Focusing on non-self-reported retractions, Figure 4 examines the spillover effect on prior work, analyzing the distance between the retracted paper and the prior publications. Retraction spillovers remain negative and statistically significant for prior work published up to a decade earlier (Fig. 4a). For example, prior work published 6–10 years earlier sees citations fall 7.2% ( $p < .01$ ) on average. The citation loss is similar in magnitude but not statistically significant for still older work. Examining citation losses by degrees of separation from the retracted paper (Fig. 4b), negative citation spillovers are found for papers up to four degrees of separation in the citation network (looking backwards in time). Prior publications three or four degrees of separation from the retracted paper experience citation declines of 14.3% ( $p < .01$ ). The citation loss is similar in magnitude but not statistically significant for prior publications at five or more degrees of separation. Note that ongoing citations to older work are already low, which makes further declines difficult to estimate.

## Discussion

In sum, retractions can create substantial citations penalties well beyond the retracted paper itself. Citation penalties spread across publication histories, measured both by the temporal distance and the degrees of separation from the retracted paper. These broad citation penalties for an author's body of work come in those cases, the large majority, where authors do not self-report the problem leading to the retraction. By contrast, self-reporting mistakes is associated with no citation penalty and possibly positive citation benefits among prior work. The lack of citation losses for self-reported retractions may reflect more innocuous or explainable

errors, while any tendency toward positive citation reactions in these cases may reflect a reward for correcting one's own mistakes.

These empirical findings are more broadly consistent with an informal policing mechanism among the scientific community, which reduces citations to the prior work of authors who are found to engage in a single instance of false science and fail to self-report. Fear of these broader penalties may discourage the publication of false results in the first place. Meanwhile, the opportunity to avoid them through self-reporting may encourage acknowledgment of mistakes, both helping to support, albeit imperfectly, core scientific norms regarding truth that stand at the center of scientific progress. Examining retraction effects on broader research activity in a field, the influence of retraction publicity and accusations of fraud, and differential effects across collaborators are all fascinating additional dimensions in this area of research<sup>15</sup>.

## Methods

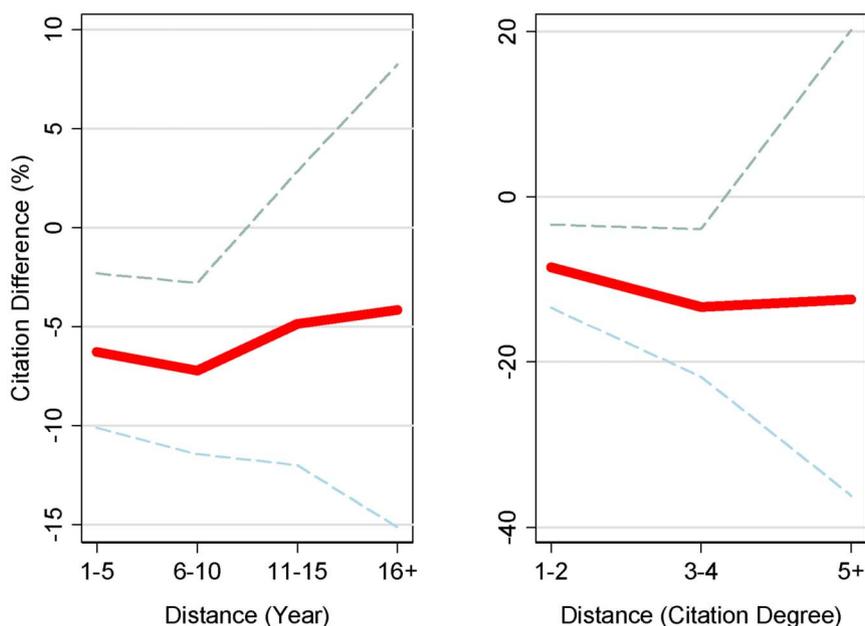
In this paper, we draw on all retraction notices in the Web of Science (WOS) database. We focus on the post-2000 period when WOS indexing of retractions appears relatively complete and use the WOS to expand our analysis across the known universe of fields. Our analysis can thus provide a more comprehensive cross-field view of retractions than the existing literature.

To analyze retraction effects, we use a “treatment” and “control” methodology<sup>2,10</sup>. Treated papers are either the retracted papers themselves or, in our main analysis, prior publications by the same authors. Control papers are those with similar citation patterns to treated papers prior to the date of retraction. The control group generates the counterfactual comparison of what would typically happen to papers with similar initial citation patterns, had the retraction not occurred.

Control papers are those that minimize the distance from the treated papers' citation pattern prior to the retraction year. Specifically, define the set of papers in field  $f$  with publication year  $p$  as  $N_{fp}$ . For a treated paper  $i \in N_{fp}$ , we search the WOS to find control papers  $j \in N_{fp}$  that minimize

$$D_{ij} = \left[ \sum_{t=p}^{r-1} (c_{it} - c_{jt})^2 \right]^{1/2} \quad (1)$$

where  $c_{it}$  denotes the citations paper  $i$  receives in year  $t$  and  $r$  is the year of retraction. Computationally, we define fields based on the 252 field categories in the WOS and locate, for each treated paper, ten control papers (with the same field and publication year as the treated paper) with the lowest  $D_{ij}$ . In our main analysis, we take the two nearest neighbors, one from above and one from below the treated paper in terms of



**Figure 4 | Effect on author's prior body of work by distance measures from retracted paper.** Considering the effect of non-self-reported retractions, citation losses are sustained on the authors' prior work published up to 10 years before the retraction event (a), with negative but statistically insignificant losses for still earlier work. Citation losses on the authors' prior work are also sustained up to 4 degrees of separation away from the retracted paper in the author's citation network (b), with negative but statistically insignificant effects on work at higher degree of separation. Red lines indicate mean citation losses, and dashed lines present 95% confidence intervals. After many years, publications tend to have few annual citations, limiting the capacity for change vis-à-vis matched control papers and resulting in noisier estimates at high distance.



average citations prior to the retraction event. Because we access over 26 million articles in the WOS, this control strategy succeeds for the majority of treated papers (66.4%) in finding control paper pairs that on average have exactly the same citation pattern prior to the retraction event. We use this set for our primary analysis. The supporting information shows that the main results of the paper are robust to numerous alternative definitions of the control sample.

The regression calculates the decline in citations to treated papers, after the retraction event, compared to the counterfactual citation path of the control papers. Following standard methodology, we estimate regressions of the form

$$\Pr[y_{it}] = f(\alpha_i + \mu_t + \beta_{post} \cdot Post_{kt} + \beta_{dif} \cdot Treat_i \cdot Post_{kt}) \quad (2)$$

where the dependent variable,  $y_{it}$ , is the number of citations received by paper  $i$  in year  $t$ . Fixed effects for each paper ( $\alpha_i$ ) and each year since publication ( $\mu_t$ ) capture the mean citation pattern of articles.  $Treat_i$  is a dummy variable that equals 1 if article  $i$  is a treatment paper, and  $Post_{kt}$  is a dummy variable that equals 1 if year  $t$  is after the retraction event for a given treatment and control group  $k$ . The coefficient of interest ( $\beta_{dif}$ ) captures any difference in citations for the treated paper, after the retraction event, compared to its control papers. In practice, we can use variations of  $t^2$  to understand retraction effects for different periods after retractions, for different types of retractions, and for prior work that is more or less distant from the retracted paper. We estimate<sup>2</sup> using the standard Poisson model for count data, given its robustness properties<sup>14</sup>. The supporting information shows that the results are robust to using many other regression models.

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## Author contributions

B.J. wrote the main manuscript text, S.L. prepared all figures and tables, G.J. wrote the supporting materials and B.U. prepared the data for analysis. All authors helped define the research questions and methodologies. All authors reviewed and edited the manuscript and Supplementary Information.

## Additional information

Supplementary information accompanies this paper at <http://www.nature.com/scientificreports>

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Supporting Information for

# The Retraction Penalty: Evidence from the Web of Science

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This document describes the data sources, sample definition, econometric models, and robustness checks as cited in the paper.

### *1. Data sources*

Our author, publication, citation, and citation network data come from the Web of Science (WOS) database collected by Thomson Reuters. Spanning 1945 to 2011, the WOS includes over 26 million journal articles published in over 10,000 of journals worldwide in all three major fields of scientific research: (1) science and engineering, (2) social sciences, and the (3) arts and humanities, which in aggregate include 252 subfields (physics, biology, sociology, architecture, English, etc.). The WOS provides information on citations of articles and the name, address and affiliation of authors. While the WOS is the largest known repository of scientific knowledge, it does not include every article in every subfield. For example, among the 4962 medical-specific journals covered in Medline, 57% are covered in WOS (<http://science.thomsonreuters.com/news/2005-04/8272968/>). The WOS's broad coverage of scientific publications implies that our analysis covers a nearly universal range of disciplines but cannot be fully exhaustive of papers in each discipline. The WOS also records retraction notices across the above fields.

Through an agreement with Thomson Reuters, our research group accesses the raw WOS directly, which is built into a database through 2009. With this database, we can perform analyses that are not possible using the publically available online system. In particular, we are able to build networks of prior publications by the authors of retracted articles, and we are also able to locate among the millions of indexed publications appropriate control papers with similar citation patterns to the authors' work (as discussed below).

WOS indexes retraction by inserting "retracted article" in the title of the original publication and "retraction of xxx" in the title of the retraction notice. Searching for "retracted article", "retraction article," and "retraction of" in the title for all articles published in the online WOS database as of August 31, 2011, we located 1,465 retracted articles and 1,614 retraction notices. Comparing the two lists, we found that some retraction notices retracted non-article type documents or articles that did not have full information in WOS. These cases were excluded from the count of retracted articles. Some retraction notices refer to articles included in WOS, but the original articles are not flagged by "retracted article" in the title. Adding these cases to the list of retracted articles and excluding retracted papers that were published after 2009, our sample of retractions included 1,423 original articles that had been retracted and have full records in the cleaned WOS database.

WOS began indexing retractions in 2003 and retroactively indexed retractions from earlier publication years. Given this timing, the WOS database does not appear comprehensive in early years (especially years before 2000). Hence, time trends in our sample appear accurately measured only in this past decade. Comparing retraction rates per publication in our analysis to

(13), which used PubMed data, we see similar retraction rates (and rises therein) in the last decade, while the PubMed database shows higher retraction rates prior to the 2000 than the WOS database. In practice, in either sample, retraction frequencies and rates are far higher in recent years.

For the 1,423 retracted articles, we classified the reasons for retraction by consulting the official retraction notices and other resources, such as Retraction Watch ([www.retractionwatch.wordpress.com](http://www.retractionwatch.wordpress.com)). There are many bases for retraction, such as plagiarism, data fabrication, failure to replicate, and author error. These classifications are not mutually exclusive and in many cases the retraction reason is not agreed upon (e.g. authors of the paper disagree) or the initially stated retraction reason may not be accurate upon further investigation (e.g. by the grant agency or authors' institutions), as shown by (13). We focused on a simple distinction that is usually unambiguously reported: whether or not the paper was retracted because the author(s) self-reported the error to the publishing journal. Note that while this approach enables objective classification, it cannot determine authors' underlying motives. The decision to self-report may include the desire to correct honest mistakes but it may also include cases where the author(s) have private information about misconduct, which they fear will otherwise come to light. To the extent that self-reporting signals honesty, or at least obfuscates misconduct, it might lead to differentially positive effects on how the science community interprets the same author's other work after the retraction. Note also that any systematic differences between self- and non-self-reported retractions that are constant across a retracted paper's history are adjusted for by our paper level and group level fixed effects in the regression analysis (see below). As reported in the paper, 312 of the 1423 retracted articles are coded "self-reported" in our data, and 1,014 of the 1423 are "non-self-reported." For a minority of cases (97 of 1423) we are unable to determine the retraction reason, despite extensive bibliographic research. Notably, the rate of self-reported retractions in our sample (21.9%) is very similar to the 21.3% rate of retractions due to error reported by (13).

When we study the effect on retracted papers, we use 1,085 of the 1,423 retracted papers only, because not all papers have the necessary information for that first analysis. In particular, 298 papers were retracted in the same year they were published, which makes matching with control papers implausible (see discussion of matching process further below). Meanwhile, 29 papers were published too recently to witness citation paper ex-post of retraction, and 11 papers do not have clear retraction years.

To study the spillover effect of retraction on prior work, we start by reintroducing the 298 papers that were retracted during the publication year (giving 1,383 retraction events to study). This larger sample is usable because the prior work was published some years before, which allows observation of pre-retraction histories for the prior work and allows matching to proceed. At the same time, when looking at prior work, we focus on authors with a single retraction only. This focus ensures that the spillover from a single retraction can be identified (rather than

contaminating the results with cases where the prior work is itself retracted). In focusing on authors with single retractions, the sample is limited to 667 retracted papers, which lead to 45,039 prior publications by authors of the retracted work. We discuss analysis of authors with multiple retractions further below.

Finally, we manually created a crosswalk between the field code in WOS and the discipline codes used in NSF and CASPAR<sup>1</sup> and classified fields into five major groups: (a) biology & medicine, which includes biological, medical and other life sciences, (e) multidisciplinary sciences, which includes multidisciplinary journals such as Nature, PNAS, and Science, (c) other sciences, which includes mathematics, physics, chemistry, engineering, earth and space sciences, agricultural sciences, and other science and technology areas, (d) social sciences, which includes economics, business, sociology, history, and other social studies, and (e) arts and humanities, which includes literature, poetry, dance, theater, film, and television production among other arts and humanities fields.

## 2. *Sample definition*

Our study design compares the citation patterns of “treated” and “control” articles. There are two types of treated articles. The first is the set of 1,423 retracted articles discussed above. The second is the set of prior publications by the same authors. Because multiple researchers may share the same name and the same author may change address and affiliation over time, we use citation links in the WOS database to identify prior work. In particular, we start with the articles cited in each retracted paper. Some of these cited articles share the same author name(s) as in the retracted article. We assume such a same-name author is the same author as in the retracted article and label these same-author articles as 1<sup>st</sup> degree self-citations. We then trace citations from these prior articles to other prior articles by the same author (a 2<sup>nd</sup> degree self-citation), and so on up to the 12<sup>th</sup> degree, at which point additional prior work is no longer revealed. All the above actions trace backward through the WOS. We also trace forward the citation network and further locate papers by the same author that cite these past publications. This process is repeated for every author of every retracted article until no more prior work can be found. By this definition, we capture prior work of the same authors that are directly or indirectly related to the retracted article. If an author published an article that is completely unrelated, or the publication is not covered by our WOS database, the article will not be counted as prior work. The average number of prior articles per author generated is 25.9, creating a sample of 45,039 prior papers.

Table S1-2 shows that, prior to their retraction, retracted papers have higher average citations than other papers. This tendency suggests that retracted papers are initially higher-profile papers. It also suggests that one cannot draw control papers at random within a field.

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<sup>1</sup> See <https://webcaspar.nsf.gov/nsf/srs/webcaspar/data/gradstud.htm>

Instead, one needs to carry out a matching process to locate control papers that share the same citation patterns with the treatment papers in the pre-retraction periods.

For a treated paper  $i$  published in field  $f$  and year  $p$ , we search for its control papers within the same field and the same publication year, where field is defined by the 252 field categories in the WOS. For each non-treated paper  $j$  in this pool, we define the arithmetic distance between  $i$  and  $j$  as

$$AD_{ij} = \sum_{t=p}^{r-1} (c_{it} - c_{jt})$$

and the Euclidean distance between  $i$  and  $j$  as:

$$ED_{ij} = \left[ \sum_{t=p}^{r-1} (c_{it} - c_{jt})^2 \right]^{1/2}$$

where  $c_{it}$  denotes the citations paper  $i$  receives in year  $t$  and  $r$  is the year of retraction. Both distances attempt to measure the citation discrepancy between paper  $i$  and paper  $j$ , but arithmetic distance  $AD_{ij}$  indicates where  $j$  were cited less or more than  $i$  up to the year before retraction while Euclidean distance  $ED_{ij}$  is direction-free.

The quality of control group matching is assessed in Figure S1, which examines matches for authors' prior publications. A crude choice of control papers focuses on the ten papers with the lowest Euclidean distance to a treated paper. The upper-left graph of Figure S1 shows that the average Euclidean distance of the ten controls has high density around zero, which suggests close matches to the treated papers. In the bins for greater-than-zero distances, the density drops gradually except for the bin of 50 or more (which is driven by some retracted papers that were exceptionally highly cited). Because Euclidean distance is direction-free, there is no guarantee that the arithmetic distance of these ten control papers are distributed evenly on the two sides of the treated paper. As shown in the bottom-left graph of Figure S1, the average arithmetic distance of the ten controls has substantially more density on the negative side, so that these controls on average underestimate the citation flow of the treated papers.

If we restrict choice of control to only the one paper with the lowest Euclidean distance, we are able to find perfect match (with zero  $AD$ ) for 39.7% of the treated papers. As shown in the bottom-middle graph of Figure S1, when we cannot find a perfect match, the arithmetic distance of the one control is still negative on average, though it is more evenly distributed on both sides of zero than the ten-control sample.

To achieve a more careful match, where control papers have low Euclidean distance and low average distance, we further consider the two nearest neighbors, one from above (with

positive  $AD$ ) and one from below (with negative  $AD$ ). As shown in the bottom-right panel of Figure S1, the density of the average arithmetic distance of these two controls is either exactly zero or concentrated in the neighborhood of zero. In particular, the two nearest neighbors now yield an average of zero distance for a substantially larger share (66.4%) of our treated papers. This sample, with zero average distance, is the main sample used in our analysis, as presented in the text. In this supporting information, we also consider a series of less conservative (but more inclusive) control strategies as robustness checks. The sample including all two-paper controls is labeled as two-control-full (all papers in the right-most panels in Figure S1). We also include an intermediate case including two-paper controls where the duration between retraction and publication is at least 2 years and where the average arithmetic distance is below 0.092 (the 95<sup>th</sup> percentile case, to limit outliers). This intermediate, refined sample is labeled as two-control-refined.

To summarize, we have constructed five alternative samples based on choice of control: two-control-zero (C2\_zero), two-refined-control (C2\_Refined), two-control-full (C2\_full), one-control (C1), and ten-control (C10).

**Table S1-1: Retraction Frequency by Retraction Year and Publication Year**

	Retraction Year		Publication Year			
	Frequency		Frequency		Retraction per 1000 Papers	
	All Journals	Nature, PNAS, Science	All Journals	Nature, PNAS, Science	All Journals	Nature, PNAS, Science
2000-2001	20	4	132	29	0.055	1.739
2002-2003	96	25	150	7	0.060	0.419
2004-2005	104	14	242	27	0.089	1.535
2006-2007	232	20	400	9	0.134	0.500
2008-2009	427	15	319	7	0.127	0.428
2010-2011	456	14	29	1		
Mean					0.095	0.914

Note: There are 1.423 retractions in the WOS sample. Of these, 11 are not included in this table because the retraction year could not be determined and 77 occur prior to the year 2000.

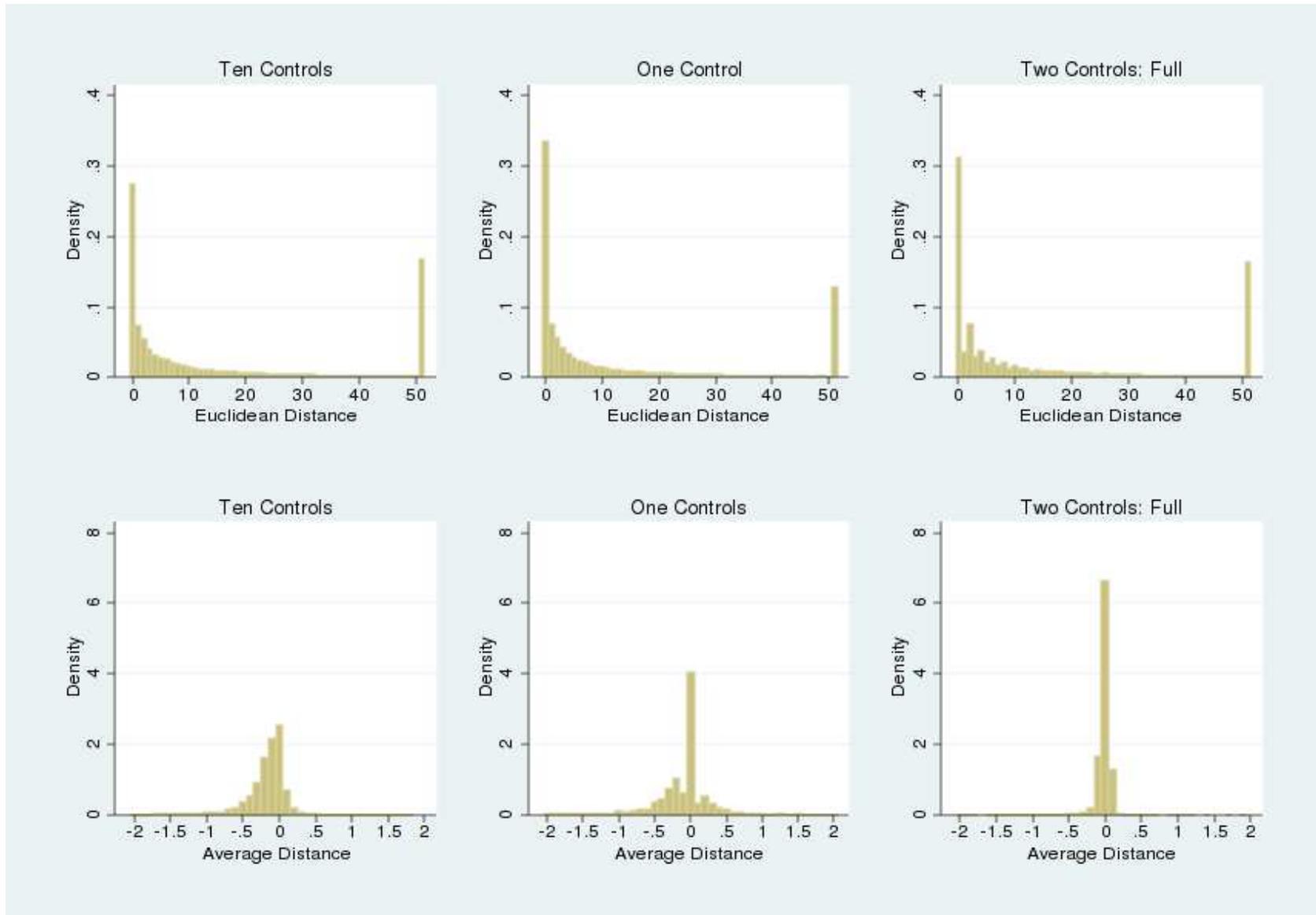
**Table S1-2: Retraction Frequency by Duration since Publication and Citation Impact**

Years	Duration until Retraction		Total Prior Citaitons (mean)		Prior Citations per Year (mean)	
	Number of Papers	Percentage of Papers	Retracted Papers	Non-Retracted Papers	Retracted Papers	Non-Retracted Papers
0	186	13.2	0	0	0	0
1	358	25.4	1	0	1	0
2	252	17.8	7	2	3	1
3	220	15.6	8	4	3	1
4	106	7.5	19	6	5	1
5	76	5.4	35	14	7	3
6	64	4.5	40	11	7	2
7	41	2.9	29	10	4	1
8	31	2.2	46	13	6	2
9	24	1.7	35	10	4	1
>=10	54	3.8	54	13	5	1
Total	1412	100.0	14	4	3	1

Note: There are 1.423 retractions in the WOS sample. Of these, 11 are not included in this table because the retraction year could not be determined.



**Figure S1: Distributions of Different Samples**



### 3. *Econometric models*

Our main dependent variable is the number of citations an article received in a particular year after publication. This variable is constructed by aggregating all the citation information in our WOS database. Because yearly citations are a form of count data (i.e. non-negative integers), we emphasize the Poisson model, given its robustness properties. However, we also consider the negative binomial model and classical ordinary least squares model (OLS).

Count models are estimated by maximum likelihood, based on a specification for the conditional mean of the count variable. Denote  $y_{it}$  as the number of citations that article  $i$  received in year  $t$  (since publication),  $Post_{kt}$  as the dummy of whether  $t$  is after the retraction year for a given treatment and control group  $k$  that  $i$  belongs to, and  $Treat_i$  as the dummy of whether  $i$  is a treated paper. The expected number of citations is defined as

$$E(y_{it}) = \exp(\alpha_i + \mu_t + \beta_{post} \cdot Post_{kt} + \beta_{dif} \cdot Treat_i \cdot Post_{kt}). \quad (S1)$$

where fixed effects for each paper ( $\alpha_i$ ) capture the mean citation of articles and fixed effects for each year since publication ( $\mu_t$ ) capture the average citation pattern over years. The parameters are determined such that they maximize the overall likelihood of all observations.

The methodology of conditional maximum likelihood to estimate a Poisson model with fixed effects in panel data is developed in (16). More generally, (17) shows that the Poisson estimates are generally consistent as long as the conditional mean assumption (equation S1) is correct, making Poisson a conservative and robust estimator that imposes little structure on the underlying data generating process. While the consistency of Poisson estimates does not depend on any assumption on the variance of the count-data distribution, its standard error needs to be corrected for this generality. We correct the standard error of our Poisson estimates following (17). (Note that, in practice, this means that the Poisson estimate is consistent even when the variance and mean of the distribution are not equivalent, so that a Poisson estimator is not in fact imposing a Poisson distribution on the data for large samples.) The negative binomial model uses the same equation (1) for the mean of  $y_{it}$  but assumes  $y_{it}$  itself conforms to a negative binomial distribution, meaning that the estimator is not consistent if the count process is not negative-binomial. The negative binomial model also faces computational challenges in using large numbers of fixed effects. For these reasons, our main analysis uses Poisson, although we also present negative binomial models below.

Note that, because retractions happen at various points in the calendar year, we identify control papers (see Section 2 above) based on years strictly before the calendar year of retraction, and we identify the effects of retraction for years strictly after the calendar year of retraction. In the tables below, we thus decompose  $Post_{kt}$  into  $Post(t = 0)$  meaning the timing relative to

retraction is ambiguous, and  $Post(t \geq 1)$  meaning  $t$  is strictly after the retraction year. Our analysis focuses on the coefficient  $\beta_{dif}$  in this post period ( $t \geq 1$ ), which cleanly estimates the effect of retraction by comparing the citations of treated papers compared to the counterfactual citation paths of the treated papers' controls.

OLS models provide simple alternatives to count models. OLS does not address the fact that yearly citations are strictly positive or integers, but it allows an extensive number of control variables and its estimation coefficient directly reflects the linear effect of retraction on citations (rather than the percentage effects revealed by count models). The simple OLS model can be written as:

$$y_{it} = \alpha_i + \mu_t + \beta_{post} \cdot Post_{kt} + \beta_{dif} \cdot Treat_i \cdot Post_{kt} + \varepsilon_{it} \quad (S2)$$

where the error term is clustered at the treatment-control paper group level. A more sophisticated version of the OLS model takes each group of treated and control papers as the unit of observation and defines the citation difference between treated and control papers as the dependent variable. More specifically, let  $n_k$  denote the number of control papers in group  $k$ , we can write this "first-difference" model as:

$$\Delta y_{kt} = y_{it|Treat_i=1} - \frac{\sum_{j \in k} y_{jt|Treat_j=0}}{n_k} = \alpha_k + \mu_t + \beta_{dif} \cdot Post_{kt} + \varepsilon_{it}. \quad (S3)$$

#### 4. *Main results and robustness checks*

Focusing on single retractions and related prior work, Tables S2-S5 and Figures S2-S4 report our main results by samples, by regression models, by retracted and prior work, by duration, by citation degree, by broad disciplines, and by author order.

#### 5. *Results for multiple retractions*

The analyses above focus on single retraction cases. For completeness, this section reports additional findings for multiple retractions. Authors with multiple retractions are a minority of cases (15% of authors with a retraction). In addition to the smaller sample size, these cases raise two technical difficulties for analysis. First, multiple retractions often happen over multiple years, so there is not a single event date to employ in the empirical strategy. Second, with multiple retractions, different retractions involving the same author may be self-reported and non-self-reported, making binary classification of the type less clear than in the single retraction cases. With these constraints in mind, one can perform analyses for multiple retraction cases by pooling the type of retraction and using the first retraction as the event date. The results are shown in column 1 of Table S6. We find that, for years  $t \geq 1$ , multiple retractions provoke similar mean citation losses to prior work as single retractions. However, multiple retractions also show a large, immediate effect in the year of retraction. This finding is further reinforced in

column (2), where we limit the multiple retraction cases to those authors where all their retractions happen in a single year. This sample specification allows for a single event date and a hence a more careful experimental design. The results shows increasingly negative point estimates for both the immediate and following citation losses. Overall, the greater immediate consequences and larger cumulative consequences for multiple retractions are consistent with the natural idea that multiple retractions will impose greater consequences for an individual than single retractions.

**Table S2: Effects of Retraction on Retracted Papers and Prior work**

	Retracted Papers						Prior Work					
	All Cases		Self-reported Cases		Non-self-reported Cases		All Cases		Self-reported Cases		Non-self-reported cases	
	Poisson	OLS	Poisson	OLS	Poisson	OLS	Poisson	OLS	Poisson	OLS	Poisson	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Treated*Post(t=0)	0.112** (0.056)	0.527** (0.240)	-0.111 (0.081)	-0.475 (0.557)	0.181** (0.075)	0.791*** (0.289)	0.009 (0.007)	0.062*** (0.019)	-0.009 (0.012)	-0.023 (0.032)	0.008 (0.010)	0.084*** (0.025)
Treated*Post(t≥1)	-1.090*** (0.104)	-2.881*** (0.412)	-1.240*** (0.154)	-3.591*** (0.768)	-1.189*** (0.139)	-3.037*** (0.586)	-0.038*** (0.011)	-0.029 (0.018)	0.031* (0.017)	0.108*** (0.031)	-0.071*** (0.015)	-0.091*** (0.023)
Year-Since-Publication Dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	16,118	18,507	4,447	4,686	10,080	11,967	999,262	1,044,486	371,188	384,852	558,703	587,517
R-squared		0.085		0.138		0.069		0.161		0.170		0.162

Standard errors are clustered by groups

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using our most closely-matched sample (C2\_zero, see Section 2 above), this table reports Poisson and simple OLS estimates for the impact of single retraction events on the retracted paper itself and on prior work. The estimation coefficients are reported, with standard errors in parentheses. The coefficient of Treated\*Post(t≥1) represents the effect of retraction on the mean yearly citations of the treated paper (compared to controls) averaging across all years after retraction. For the Poisson model, the coefficient of Treated\*Post(t≥1) can be translated into percentage terms as  $\exp(\text{coefficient})-1$ . For example, in column (1), the Poisson coefficient of Treated\*Post(t≥1) implies that retraction reduces yearly citations of the retracted paper itself by  $\exp(-1.090)-1=66.4\%$  ( $p<.0001$ ). The OLS model provides results directly in lost citation counts. In column (2), the effect is seen as 2.88 fewer citations per year. Across all columns, Poisson estimates suggest that self-reported retractions lead to 71.1% ( $p<.0001$ ) decline in the yearly citation of the retracted paper and 3.15% ( $p<.1$ ) increase of citation to the prior work of same author(s). Non-self-reported retractions lead to a 69.6% ( $p<.0001$ ) decline in the yearly citation of retracted papers and 6.85% ( $p<.0001$ ) decline in citations to prior work.

**Table S3-1: Effect of Retraction on Retracted Papers across Samples**

Samples	Self-reported Cases					Non-self-reported Cases				
	C2_Zeros (1)	C2_Full (2)	C2_One_Retract (3)	C1 (4)	C10 (5)	C2_Zeros (6)	C2_Full (7)	C2_One_Retract (8)	C1 (9)	C10 (10)
Treated*Post(t=0)	-0.128 (0.078)	-0.098 (0.064)	-0.07 (0.118)	-0.089 (0.063)	-0.119** (0.054)	0.170** (0.071)	0.101* (0.059)	0.337*** (0.064)	0.139** (0.068)	0.076 (0.050)
Treated*Post(t=1/2)	-1.008*** (0.137)	-0.902*** (0.110)	-0.915*** (0.159)	-0.894*** (0.103)	-0.914*** (0.095)	-0.935*** (0.126)	-0.981*** (0.104)	-0.623*** (0.140)	-0.940*** (0.101)	-0.980*** (0.098)
Treated*Post(t=3/4)	-1.406*** (0.204)	-1.309*** (0.176)	-1.324*** (0.202)	-1.284*** (0.139)	-1.363*** (0.142)	-1.627*** (0.157)	-1.728*** (0.140)	-1.243*** (0.193)	-1.771*** (0.151)	-1.792*** (0.140)
Treated*Post(t>=5)	-1.977*** (0.205)	-1.887*** (0.195)	-1.929*** (0.234)	-1.902*** (0.180)	-1.957*** (0.175)	-1.687*** (0.227)	-1.802*** (0.199)	-1.264*** (0.212)	-1.934*** (0.222)	-1.798*** (0.192)
Year-Since-Publication Du	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	4,447	5,218	3,031	3,482	18,929	10,080	11,637	4,473	7,814	42,313

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the Poisson model, this table compares the effect of retraction on retracted papers across different samples, including samples such as C1 and C10 that provide noisier matches with the treated papers. C2\_One\_Retract refers to the C2\_full sample conditional on the 667 single-retractions only. The other columns draw on the 1,085 retracted papers that provide necessary information for the analysis (see discussion above). Treated\*Post(t=1/2) refers to the effect of retraction in 1-2 years after retraction, similarly, Treated\*Post(t=3/4) and Treated\*Post(t>=5) refers to the effect of retraction in 3-4 years or 5-and-more years after retraction.

**Table S3-2: Effect of Retraction on Prior Work across Samples**

Samples	Self-reported Cases					Non-self-reported Cases				
	C2_Zeros (1)	C2_Full (2)	C2_Refined (3)	C1 (4)	C10 (5)	C2_Zeros (6)	C2_Full (7)	C2_Refined (8)	C1 (9)	C10 (10)
Treated*Post(t=0)	-0.009 (0.012)	0.008 (0.014)	-0.018** (0.009)	0.029** (0.013)	0.019 (0.013)	0.008 (0.010)	0.033*** (0.009)	0.006 (0.008)	0.018* (0.010)	0.047*** (0.008)
Treated*Post(t=1/2)	0.033** (0.014)	0.044** (0.017)	0.001 (0.012)	0.073*** (0.016)	0.054*** (0.015)	-0.048*** (0.012)	-0.024** (0.012)	-0.071*** (0.010)	-0.036*** (0.012)	-0.017 (0.010)
Treated*Post(t=3/4)	0.079*** (0.022)	0.092*** (0.023)	0.057*** (0.018)	0.121*** (0.023)	0.105*** (0.020)	-0.079*** (0.020)	-0.029 (0.020)	-0.067*** (0.018)	-0.053** (0.023)	-0.025 (0.019)
Treated*Post(t>=5)	-0.041 (0.039)	0.049 (0.050)	0.013 (0.032)	0.072 (0.049)	0.042 (0.041)	-0.133*** (0.034)	-0.074*** (0.028)	-0.088*** (0.029)	-0.105*** (0.035)	-0.057** (0.026)
Year-Since-Publication Dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	371,188	710,171	649,830	473,576	2,602,439	558,703	1,037,092	951,650	691,598	3,798,735

Standard errors are clustered by groups

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the Poisson model, this table compares the effect on prior work across different samples, including samples such as C1 and C10 that provide noisier matches with the treated papers. All columns use 45,039 prior publications by authors of the retracted work, based on the 667 single-retraction cases. Treated\*Post(t=1/2) refers to the effect of retraction in 1-2 years after retraction, similarly, Treated\*Post(t=3/4) and Treated\*Post(t>=5) refers to the effect of retraction in 3-4 years or 5-and-more years after retraction. Across samples, the effect of retraction after the retraction year is either zero or positive for self-reported cases; compared to 1-2 years after retraction, this effect increases slightly in 3-4 years after retraction but declines to close-to-zero in 5-and-more years after retraction. One potential explanation is that self-reporting is not only effective in separating the retracted paper from the authors' prior work, but also gives the authors and/or the prior work some positive exposure in a short period after the retraction. In comparison, the effect of non-self-reported retractions on prior work is significantly negative and persistent.

**Table S3-3: Differential Effect of Retraction on Prior Work by Duration across Samples**

Samples	Non-self-reported Cases				
	C2_Zeros (1)	C2_Full (2)	C2_Refined (3)	C1 (4)	C10 (5)
Treated*Post( $t \geq 1$ )	-0.065*** (0.021)	-0.050** (0.022)	-0.059*** (0.020)	-0.102*** (0.025)	-0.063*** (0.019)
Treated*Post( $t \geq 1$ )*Duration([6,10])	-0.010 (0.032)	0.018 (0.029)	-0.016 (0.029)	0.057* (0.033)	0.029 (0.026)
Treated*Post( $t \geq 1$ )*Duration([11,15])	0.015 (0.045)	0.054 (0.056)	-0.030 (0.036)	0.113* (0.061)	0.092* (0.050)
Treated*Post( $t \geq 1$ )*Duration( $\geq 16$ )	0.022 (0.066)	0.033 (0.046)	-0.017 (0.041)	0.153** (0.062)	0.163*** (0.053)
Year-Since-Publication Dummies	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	Y	Y	Y
Observations	558,703	1,037,092	951,650	691,598	3,798,735

Standard errors are clustered by groups

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

Using the Poisson model, this table reports the effect on prior work by duration since publication, using different samples, including samples such as C1 and C10 that provide noisier matches with the treated papers. All columns use 45,039 prior publications by authors of the retracted work, based on the 667 single-retraction cases. Treated\*Post( $t \geq 1$ )\*Duration(x,y) refers to the effect of non-self-reported retraction on prior work that has been published between x and y years at the time of the observation year t. All the C2 samples show no significant changes of the effect by duration. C1 and C10 show reduction of the effect for longer durations, probably because C1 and C10 have worse matches between treated and control papers than C2. The coefficients for duration 6-10, 11-15, and  $\geq 16$  are relative to the default group of duration  $\leq 5$ .

**Table S3-4: Differential Effect of Retraction on Prior Work by Citation Degree across Samples**

Samples	Non-self-reported Cases with Relevant Topics to Retracted Papers				
	C2_Zeros (1)	C2_Full (2)	C2_Refined (3)	C1 (4)	C10 (5)
Treated*Post( $t \geq 1$ )	-0.089*** (0.028)	-0.011 (0.025)	-0.062*** (0.022)	-0.048 (0.030)	-0.007 (0.024)
Treated*Post( $t \geq 1$ )*Degree(3/4)	-0.054 (0.060)	-0.096** (0.041)	-0.095** (0.039)	-0.041 (0.043)	-0.068* (0.041)
Treated*Post( $t \geq 1$ )*Degree(5+)	-0.043 (0.164)	-0.067 (0.064)	-0.078 (0.072)	0.020 (0.071)	0.009 (0.053)
Year-Since-Publication Dummies	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	Y	Y	Y
Observations	241,906	558,328	502,449	372,245	2,047,013

Standard errors are clustered by groups

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

Using the Poisson model, this table reports the effect on prior work by citation degree, using different samples, including samples such as C1 and C10 that provide noisier matches with the treated papers. All columns are conditional on non-self-reported single retractions. Citation degree is measured by degree of separation from the retracted paper in the author's citation network, looking backward over time. The coefficients for degrees of 3-4 and degrees of 5+ are relative to the default group of degrees 1-2.

**Table S4-1: Effect of Retraction on Retracted Papers across Alternative Specifications**

Specifications	Self-reported Cases				Non-self-reported Cases			
	Poisson (1)	OLS (2)	First Difference (3)	Negative Binomial (4)	Poisson (5)	OLS (6)	First Difference (7)	Negative Binomial (8)
Treated*Post(t=0)	-0.128 (0.078)	-0.474 (0.555)		-0.100 (0.091)	0.170** (0.071)	0.783*** (0.290)		0.130* (0.068)
Treated*Post(t=1/2)	-1.008*** (0.137)	-4.133*** (0.871)		-1.003*** (0.152)	-0.935*** (0.126)	-3.171*** (0.611)		-0.947*** (0.127)
Treated*Post(t=3/4)	-1.406*** (0.204)	-4.135*** (1.061)		-1.451*** (0.225)	-1.627*** (0.157)	-3.696*** (0.837)		-1.789*** (0.166)
Treated*Post(t>=5)	-1.977*** (0.205)	-1.987*** (0.723)		-2.130*** (0.250)	-1.687*** (0.227)	-2.063*** (0.615)		-1.700*** (0.207)
Post(t=0)			-0.474 (0.597)			0.783** (0.320)		
Post(t=1/2)			-4.133*** (0.936)			-3.171*** (0.674)		
Post(t=3/4)			-4.135*** (1.141)			-3.696*** (0.924)		
Post(t>=5)			-1.987** (0.777)			-2.063*** (0.679)		
Year-Since-Publication Dummies	Y	Y	Y	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	N	N	Y	Y	N	N
Group Fixed Effects	N	N	Y	N	N	N	Y	N
Treatment Dummy	N	N	N	Y	N	N	N	Y
Observations	4,447	4,686	1,562	4,686	10,080	11,967	3,989	11,967
R-squared		0.140	0.615			0.070	0.596	

Standard errors in parentheses clustered by group

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the C2\_zero sample, this table shows that the effect of retraction on retracted papers is broadly robust to different econometric models. All columns use the 1,085 retracted papers that provide necessary information for the analysis (see discussion above). Note that computational constraints prevent inclusion of either paper or group fixed effects for the negative binomial model, weakening its identification of treatment effects.

**Table S4-2: Effect of Retraction on Prior Work across Alternative Specifications**

Specifications	Self-reported Cases				Non-self-reported Cases			
	Poisson (1)	OLS (2)	First Difference (3)	Negative Binomial (4)	Poisson (5)	OLS (6)	First Difference (7)	Negative Binomial (8)
Treated*Post(t=0)	-0.009 (0.012)	-0.023 (0.032)		-0.001 (0.012)	0.008 (0.010)	0.085*** (0.025)		0.031*** (0.010)
Treated*Post(t=1/2)	0.033** (0.014)	0.126*** (0.037)		0.049*** (0.015)	-0.048*** (0.012)	-0.034 (0.027)		-0.013 (0.012)
Treated*Post(t=3/4)	0.079*** (0.022)	0.200*** (0.050)		0.105*** (0.023)	-0.079*** (0.020)	-0.095** (0.038)		-0.029 (0.022)
Treated*Post(t>=5)	-0.041 (0.039)	-0.006 (0.043)		-0.096* (0.051)	-0.133*** (0.034)	-0.208*** (0.038)		-0.072* (0.042)
Post(t=0)			-0.023 (0.033)				0.085*** (0.026)	
Post(t=1/2)			0.126*** (0.039)				-0.034 (0.029)	
Post(t=3/4)			0.200*** (0.052)				-0.095** (0.040)	
Post(t>=5)			-0.006 (0.045)				-0.208*** (0.040)	
Year-Since-Publication Dummies	Y	Y	Y	Y	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	N	N	Y	Y	N	N
Group Fixed Effects	N	N	Y	N	N	N	Y	N
Treatment Dummy	N	N	N	Y	N	N	N	Y
Observations	371,188	384,852	128,284	384,852	558,703	587,517	195,839	587,517
R-squared		0.171	0.405			0.163	0.370	

Standard errors in parentheses clustered by group

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the C2\_zero sample, this table shows that the effect of retraction on prior work is broadly robust to different econometric models. All columns use 45,039 prior publications by authors of the retracted work, based on the 667 single-retraction cases. Note that computational constraints prevent inclusion of either paper or group fixed effects for the negative binomial model, weakening its identification of treatment effects.

**Table S4-3: Effect of Retraction on Prior Work by Duration across Alternative Specifications**

	Non-self-reported Cases			
	Poisson (1)	OLS (2)	First Difference (3)	Negative Binomial (4)
Treated*Post(t≥1)	-0.065*** (0.021)	-0.123** (0.060)		-0.002 (0.030)
Treated*Post(t≥1)*Duration([6,10])	-0.010 (0.032)	0.015 (0.070)		-0.101** (0.042)
Treated*Post(t≥1)*Duration([11,15])	0.015 (0.045)	0.093 (0.065)		-0.052 (0.052)
Treated*Post(t≥1)*Duration(>=16)	0.022 (0.066)	0.110* (0.062)		-0.029 (0.074)
Post(t≥1)			-0.123** (0.063)	
Post(t≥1)*Duration([6,10])			0.015 (0.073)	
Post(t≥1)*Duration([11,15])			0.093 (0.068)	
Post(t≥1)*Duration(>=16)			0.110* (0.065)	
Year-Since-Publication Dummies	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	N	N
Group Fixed Effects	N	N	Y	N
Treatment Dummy	N	N	N	Y
Observations	558,703	587,517	195,839	587,517
R-squared		0.165	0.370	

Standard errors in parentheses by group

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the C2\_zero sample, this table shows that the differential effect of retraction on prior work by duration is robust to different econometric models. All columns are conditional on non-self-reported single retractions. Note that computational constraints prevent inclusion of either paper or group fixed effects for the negative binomial model, weakening its identification of treatment effects.

**Table S4-4: Effect of Retraction on Prior Work by Citation Degree across Alternative Specifications**

	Non-self-reported Cases with Relevant Topics to Retracted Papers			
	Poisson (1)	OLS (2)	First Difference (3)	Negative Binomial (4)
Treated*Post(t≥1)	-0.089*** (0.028)	-0.250*** (0.075)		-0.068* (0.037)
Treated*Post(t≥1)*Degree(3/4)	-0.054 (0.060)	0.112 (0.092)		-0.058 (0.068)
Treated*Post(t≥1)*Degree(5+)	-0.043 (0.164)	0.206** (0.094)		-0.059 (0.193)
Post(t≥1)			-0.260*** (0.076)	
Post(t≥1)*Degree(3/4)			0.125 (0.093)	
Post(t≥1)*Degree(5+)			0.218** (0.095)	
Year-Since-Publication Dummies	Y	Y	Y	Y
Paper Fixed Effects	Y	Y	N	N
Group Fixed Effects	Y	Y	Y	N
Treated Dummy	N	N	N	Y
Observations	241,906	242,538	80,846	242,538
R-squared		0.218	0.266	

Standard errors in parentheses by group

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the C2\_zero sample, this table shows that the differential effect of retraction on prior work by citation degree is robust to different econometric models. All columns are conditional on non-self-reported single retractions. Citation degree is measured by degree of separation from the retracted paper in the author's citation network, looking backward over time. The coefficients for degrees of 3-4 and degrees of 5+ are relative to the default group of degrees 1-2. Note that computational constraints prevent inclusion of either paper or group fixed effects for the negative binomial model, weakening its identification of treatment effects.

**Table S5: Effect of Retraction on Prior Work, by Author Position in Retracted Paper**

	Non-self-reported Cases		
	First Author	Middle Author	Last Author
	(1)	(2)	(3)
Treated*Post(t=0)	0.020 (0.037)	0.011 (0.018)	0.001 (0.013)
Treated*Post(t≥1)	-0.118*** (0.045)	-0.091*** (0.027)	-0.054*** (0.019)
Year-Since-Publication Dummies	Y	Y	Y
Paper Fixed Effects	Y	Y	Y
Observations	42,187	199,537	308,204

Standard errors in parentheses clustered by groups

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Using the C2\_zero sample and the Poisson model, this table shows the effect of retraction on citations to the prior work of the authors, dividing the authors sample into three groups depending on whether they were the first, last, or a middle author on the retracted paper. All columns are conditional on non-self-reported single retractions.

**Table S6: Effect of Retraction on Prior Work, Authors with Multiple Retractions**

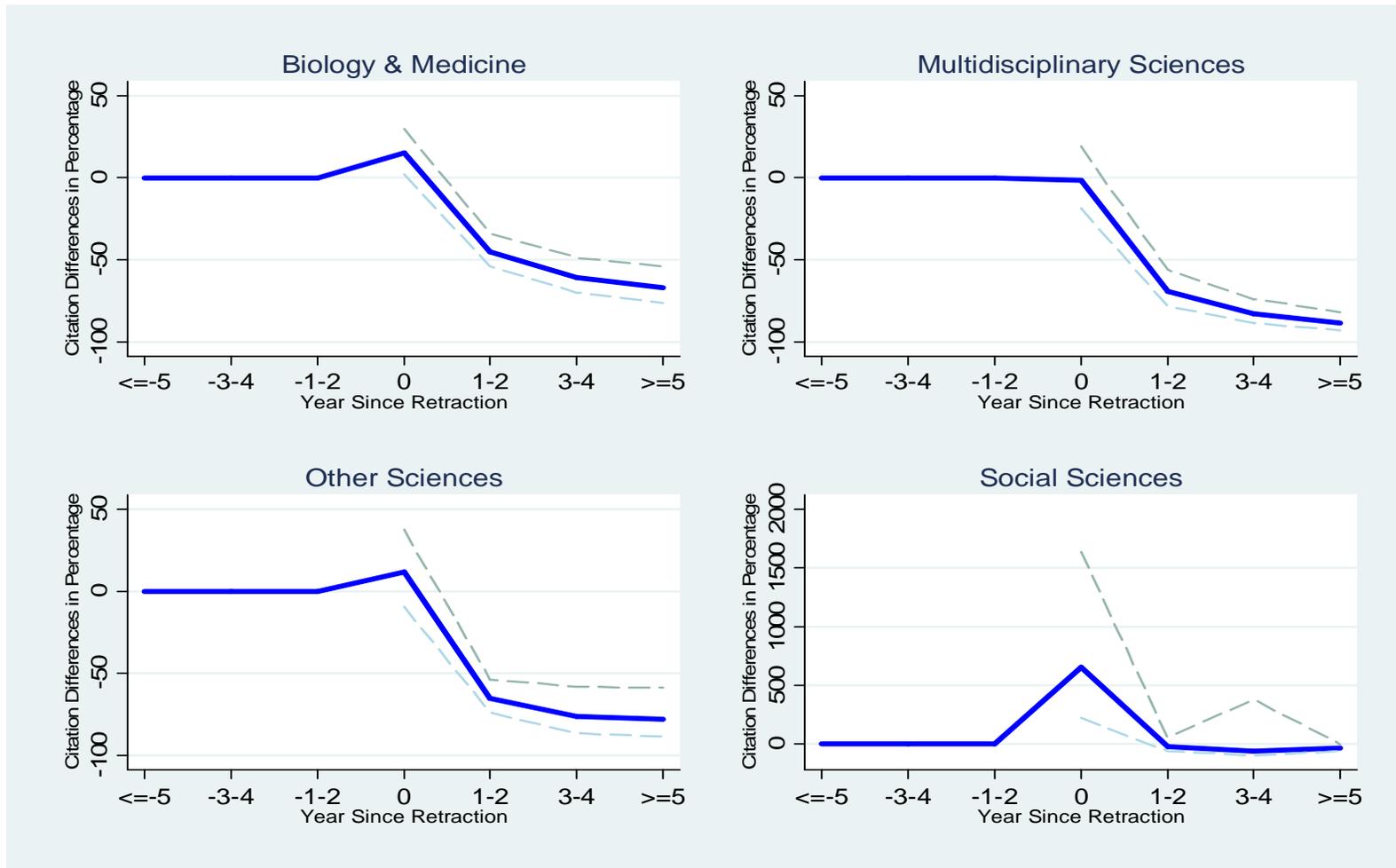
	All cases (1)	Same Year (2)
Treated*Post(t=0)	-0.072*** (0.015)	-0.093*** (0.022)
Treated*Post(t≥1)	-0.057** (0.025)	-0.076** (0.035)
Year-Since-Publication Dummies	Y	Y
Paper Fixed Effects	Y	Y
Observations	337,522	207,173
Number of Paper id	28,297	17,127

Standard errors in parentheses clustered by group

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

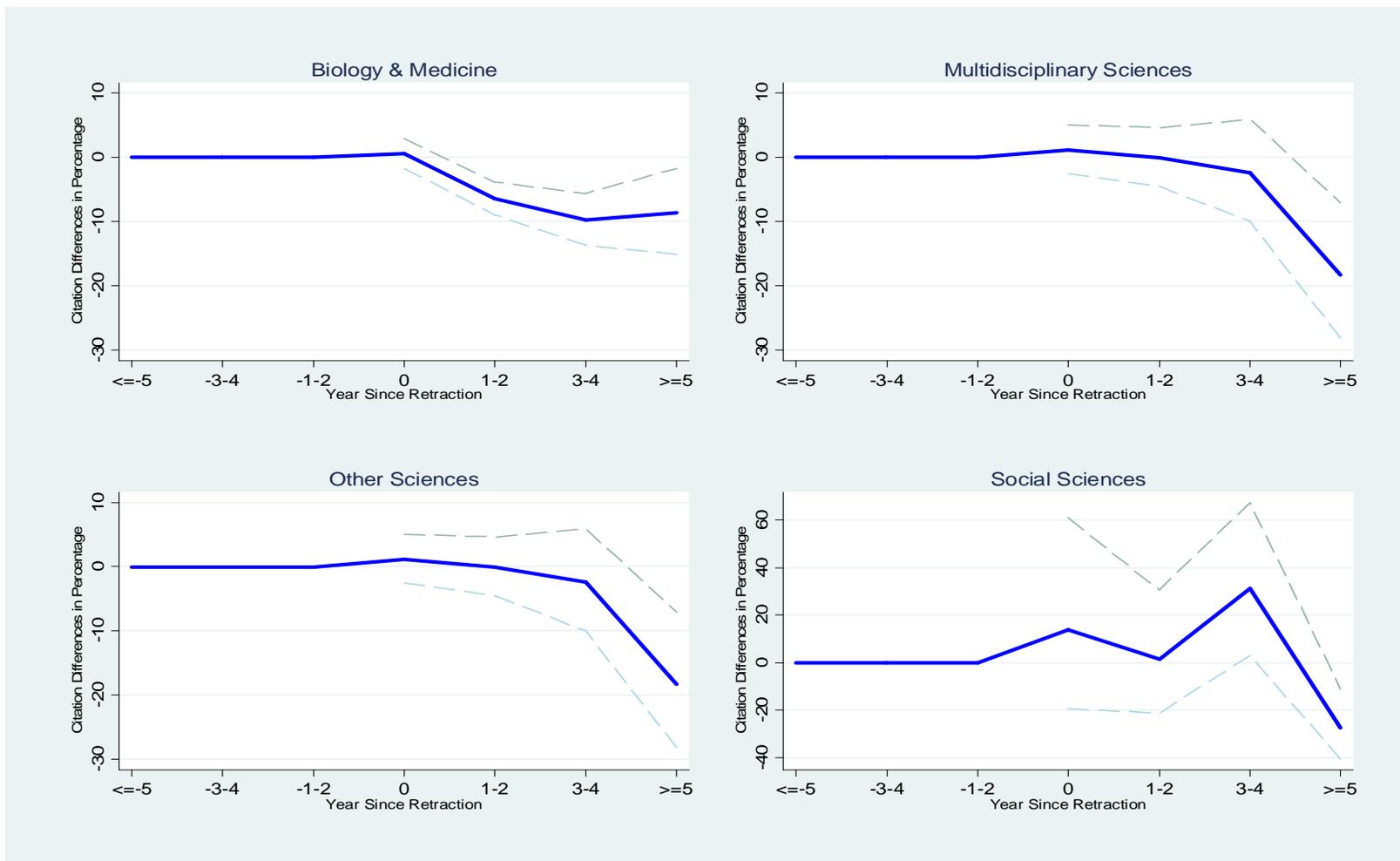
Using the C2\_zero sample and the Poisson model, this table shows that the citation losses to prior work for authors who have 2 or more retractions. The event date is taken as the date of the first retraction. Column (1) considers all multiple retraction cases, while column (2) considers only those multiple retraction cases where all of the author's retractions occurred in the same year.

**Figure S2: Effect of Retraction on Retracted Papers by Fields**



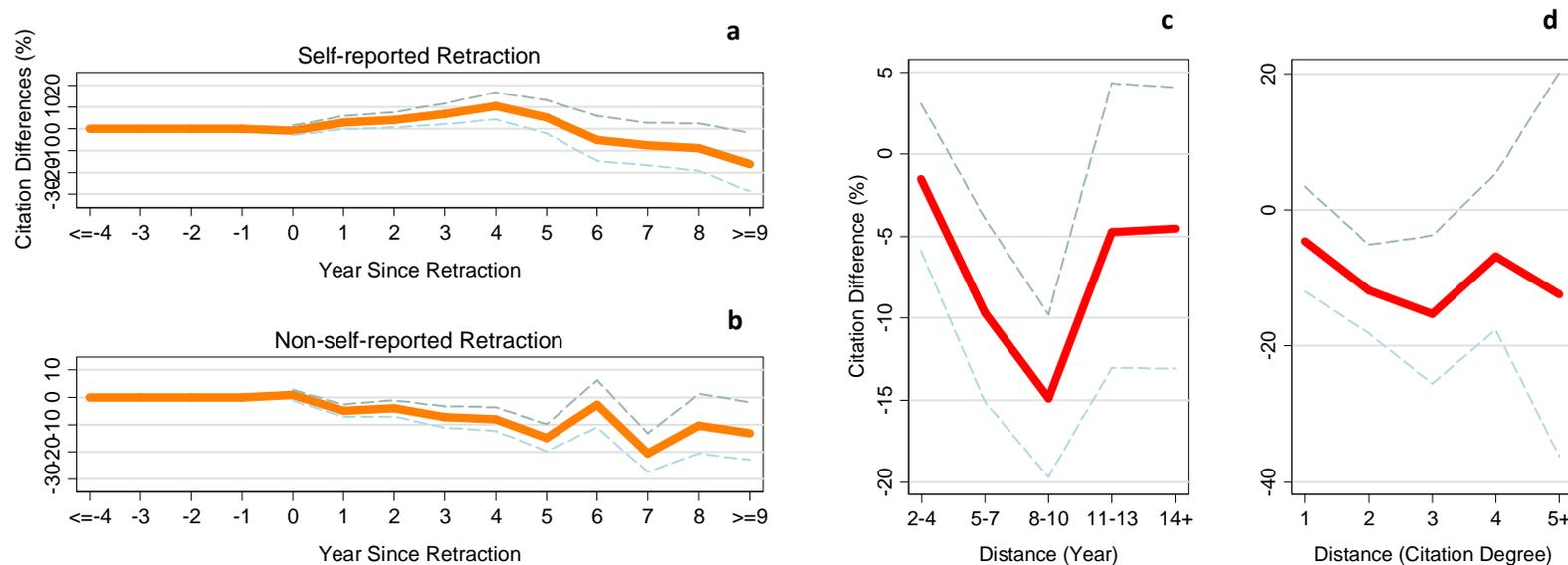
Using the C2\_zero sample and the Poisson model, this figure plots the effect of retraction on retracted papers over time by broad disciplines. Dashed lines show the 95% confidence interval. Accurate inference for Social Sciences is difficult because there are only 15 such retractions in the sample.

**Figure S3: Effect of Retraction on Prior Work by Fields, Non-Self-Reported Cases**



Using the C2\_zero non-self-reported sample and the Poisson model, this figure plots the effect of retraction on prior work over time by broad disciplines. Dashed lines show the 95% confidence interval. Inference for Social Sciences is more challenging, due to fewer observations in this case.

**Figure S4: Main Results, Further Disaggregating Effects**



The results in Fig. 3 (main text) are further disaggregated by individual years since retraction (**a** and **b**). The results in Fig. 4 (main text) are further disaggregated by duration since publication of prior work (**c**) and network degree distance (**d**).