The Exportation of Science from Low- and Middle-Income Countries*

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Abstract

Scholars studying systems of innovation argue that Intellectual Property Rights (IPR) systems affect the development of scientific knowledge in implementing countries. In this paper, we examine an underexplored effect of IPR implementation: the dissemination of existing scientific knowledge from low- and middle-income countries (LMICs) into high-income countries (HICs). Exploiting the staggered implementation of the Agreement on Trade-Related Intellectual Property Rights (TRIPS) in difference-in-differences analysis, we find evidence of increased diffusion of existing knowledge from LMICs to HICs. This and associated findings suggest that the implementation of an IPR system in LMICs leads to changes in the behavior of scientists in HICs. The results raise new questions about how incentives created by IPR systems affect the conduct of global science and the nature of knowledge diffusion.

Keywords: Innovation, Knowledge Diffusion, Scientific Research, Intellectual Property Rights, Global Health

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1. Introduction

Substantial research has studied the impact of patents on the diffusion of scientific knowledge. However, our understanding of the effect of intellectual property rights (IPRs) on knowledge diffusion is incomplete without considering how the adoption of IPRs in a country influences the dissemination and follow-on use of pre-existing knowledge. In this paper, we address this question by examining the effect of the staggered implementation of IPRs under the Agreement on Trade-Related Intellectual Property Rights (TRIPS) in low- and middle-income countries (LMICs). The focus is on the global diffusion and adoption of knowledge produced in LMICs. Specifically, the analysis reports on how knowledge that existed in LMICs prior to TRIPS disseminated differently after TRIPS adoption as compared to before. We also examine how the diffusion of knowledge from LMICs influenced both subsequent scientific research and invention rates in high-income countries (HICs) on the diseases that were more prevalent in LMICs versus HICs.

In 1994, a new global IPR policy regime was ratified with the claim that it would improve the availability of medicines around the world—and, particularly, stimulate the development of drugs for diseases that are prevalent in LMICs. TRIPS implementation was required of any country that sought to join the World Trade Organization (WTO), although with variation in the required dates of full implementation. TRIPS required countries to adopt a range of protections on intellectual property, upon implementation, the most significant of which was "harmonized patent protection" (hereafter "patents") with terms aligned with those in HICs such as the United States and United Kingdom. It was hoped that patents would stimulate greater corporate investment in drugs for the diseases that disproportionately affected people in LMICs by increasing the returns to innovation (see Lanjouw and Cockburn, 2001, for a discussion of contemporaneous perspectives).

Research to date suggests that the TRIPS rollout was *not* associated with the introduction of new medicines for the so-called "neglected diseases," such as tuberculosis and malaria that are prevalent primarily in LMICs (see, e.g., MSF, 2001). However, scholars have shown that the TRIPS rollout was associated with an increase in the production of basic science on both neglected and global diseases prevalent in newly compliant LMICs (Vakili and McGahan, 2016). This

finding raises the possibility that TRIPS may benefit patients in LMICs in ways that were not emphasized in the original argument for implementing TRIPS. Specifically, TRIPS may have led to better integration of LMIC researchers into the global scientific community with the consequence of more widespread diffusion of knowledge contained in LMIC researchers' publications to HIC scientists.

In this paper, we explore this possibility by examining whether the implementation of TRIPS led to the global diffusion of scientific knowledge that had been produced prior to TRIPS in LMICs. We argue that TRIPS implementation increases global scientists' attention to research from newly compliant countries. This is consistent with the argument in Vakili and McGahan (2016) that patent protections are an important component of a broader scientific system that shapes scientists' choice of research topics and attention to scientific ideas. The analysis addresses whether scientific research conducted prior to TRIPS implementation in a country becomes more highly cited by both scientists and inventors around the world as that country becomes better integrated into the global scientific system with the implementation of IPR institutions.

As evidence for knowledge diffusion, we examine the use of a piece of knowledge—i.e., a scientific publication—in both subsequent scientific publications and in patented inventions before and after a country implements TRIPS. We argue that the increase in the global diffusion of science produced in LMICs may be especially important where relevant knowledge is less developed and has received relatively less prior attention in HICs, such as in the case of neglected diseases. Finally, we consider variation in the incentives facing corporate and academic organizations engaging in both basic and commercialized science after TRIPS implementation.

The data in this paper are drawn from several sources. Scientific articles between 1985 and 2010 are drawn from Scopus and are assigned to diseases based on their keywords and abstracts. In our analysis, we only include articles published before a country became TRIPS compliant to ensure that subsequent local changes do not bias our results. We use affiliation data in Scopus to associate papers with their authors' countries. The dates of countries' TRIPS implementation are drawn from Ginarte and Park (1997), Hamdan-Livramento (2009), and Kyle and McGahan (2012)

to account for compliance rather than only the nominal date of TRIPS implementation by a country. (All references to "TRIPS implementation" refer to these estimated compliance dates.) Scopus's data on the number of citations received by a paper in each year enables comparisons before and after TRIPS implementation. Patent information and patent citations data are drawn from U.S. Patent and Trademark Office (USPTO) datasets using the patent-paper linkages in the Reliance on Science dataset (Marx and Fuegi, 2020; Marx and Fuegi, 2022).

The main analysis is difference-in-differences estimation of the effects of TRIPS compliance on scientific attention to existing papers. Specifically, we examine how citations to pre-existing papers changed after TRIPS implementation. Papers are associated with countries by examining the locations of the authors. The models include both year and paper fixed effects. The first core finding is that TRIPS implementation is associated with increased international diffusion of previously published science authored in the country of implementation. Similarly, we find that the rate at which patent applications cite research from TRIPS-implementing LMICs increases after an LMIC implements TRIPS. This effect is greater for neglected diseases (e.g., tuberculosis) than for global diseases (e.g., cardiovascular conditions). Finally, the analysis shows that the increase in patent citations to the knowledge from newly-compliant LMICs arises primarily from academic invention, rather than corporate actors. Notably, this increase is especially pronounced for neglected diseases, which were central in the original justification for TRIPS, but which have not been the target of widespread new-medicine development since TRIPS was adopted.

The results have implications for IPR policies as well as research on the incentives and institutional requirements necessary for the emergence of new medicines on neglected diseases. The mechanisms by which TRIPS influenced the emergence of new science on neglected diseases were different than those envisioned when TRIPS was initially adopted. Instead of a rapid global inventive response through new medicines that target the disease burden in poor countries, the evidence suggests that TRIPS not only increased basic knowledge production in LMICs (Vakili and McGahan, 2016) but also increased the diffusion of knowledge from LMICs into the global scientific community.

The finding of increased patent citations to scientific articles authored prior to TRIPS by LMIC scientists is also significant. This increase is primarily the result of patents applied for by academic scientists rather than corporate scientists. While the enhancement of IPRs in TRIPS appears to have led academic scientists to increase attention to scientific ideas in LMICs, it has yet to deliver a commensurate global response to the needs of the poor from corporate actors.

2. Role of Intellectual Property Rights in Knowledge Diffusion

2.1. Patents and Cumulative Innovation

Scholars have long investigated the impact of patent protection on knowledge diffusion and innovations. Murray and Stern (2007) shows that patents may hinder rather than accelerate knowledge exchange. Galasso and Schankerman (2015) reports that follow-on innovation based on a given patent increases substantially following the removal of its patent protection by court invalidation, suggesting that patenting can diminish the rate of cumulative knowledge production. Studying the field of human genome research, Williams (2013) argues that patents diminish subsequent investments in research and development "on the order of 20-30 percent" (p. 24). In a similar vein, Murray, Aghion, Kolev, Dewatripont, and Stern (2016) finds that patent protection over research tools limited new entry of scientists into a research area and narrowed the range of topics scientists explored.

Overall, these studies largely suggest that patents can negatively affect knowledge diffusion, potentially due to increased adoption or litigation costs. However, these papers predominantly focus on the impact of patenting a piece of knowledge on its subsequent diffusion and adoption. Given their empirical design, they do not fully consider the broader effect of the patent system on knowledge diffusion through the development and integration of institutions of science, such as medical schools, conference attendance, grant availability, grant administration, enforcement agencies, equipment supplies, and adoption of standardized research tools.

A second stream of research has focused on the issue of whether patent systems, and TRIPS more specifically, have stimulated innovations in LMICs. One of the first studies in this area,

Lanjouw and Cockburn (2001), found no evidence of innovation emerging from TRIPS on "neglected diseases," which are defined by the prevalence of their disease burden in LMICs relative to HICs. Lanjouw and Cockburn (2001) nevertheless cautions that there had been insufficient time to make a definitive assessment as TRIPS had only been implemented six years previously, and, even then, primarily in high-income countries. Delgado, Kyle, and McGahan (2013) finds evidence of increased trade in products with high intellectual property content in newly compliant LMICs after TRIPS. However, this effect was lower for biopharmaceuticals compared to information and communications technology, sectors which are less reliant on complementary resources in distribution and in managing compliance requirements.

Qian (2007) finds that increased rates of domestic invention after TRIPS implementation occurs only in countries with relatively high GDP per capita and with greater levels of human capital. Hassan, Yaqub and Diepeeven (2010) reviews the existing research evidence and finds that strengthening IPRs in developing countries may encourage international technology transfer, but that it may "hamper innovation… in developing countries" (p. 23). Kyle and McGahan (2012) finds evidence of increases in early-stage innovation on global diseases in response to TRIPS implementation in LMICs, but not evidence of increased innovation for neglected diseases. Rezaie, McGahan, Daar, and Singer (2012) comes to a similar conclusion. The overall implication of these studies is that, across countries, little evidence exists that TRIPS implementation sparked innovation on the neglected diseases that are prevalent in LMICs.

Recent research on TRIPS suggests that the impact of TRIPS on patents, clinical trials, and new-drug development may have been minimal because the basic science that is a prerequisite to innovations relevant to LMICs has largely been lacking (Vakili and McGahan, 2016). Finding evidence of a positive effect of TRIPS on basic science production, Vakili and McGahan (2016) argues that a significant effect of TRIPS was to encourage the development of "institutions of science" such as research institutes, funding mechanisms, and career paths for scientists in LMICs. In line with this view, Cockburn, Wilsdon, Pistollato, Jayasuriya, and Watson (2021) also finds evidence that the number of scientific publications from scientists in an LMIC increases after its

TRIPS implementation. Consistent with these results, Dutta and Sharma (2008) reports that Indian pharmaceutical firms increased research and development investment after TRIPS was implemented in India.

Collectively, these studies suggest that an increase in basic scientific production in LMICs resulting from TRIPS is unlikely to lead to meaningful innovations and drug developments unless the produced science diffuses more broadly within the global scientific community. In this paper, we explore whether TRIPS implementation led to an increase in the global diffusion of science produced in LMICs.

2.2. Impact of TRIPS on Knowledge Diffusion

The analysis in this paper focuses on the impact of TRIPS implementation in LMICs on the diffusion of scientific knowledge that had already been produced in an implementing country prior to TRIPS. By focusing on how pre-existing scientific knowledge diffuses differently after TRIPS implementation—relative to before TRIPS—we identify TRIPS itself with the global diffusion and adoption of scientific knowledge that had been generated previously in LMICs. The argument builds on findings from prior literature suggesting that TRIPS implementation led to better integration of local scientists into the global scientific community (Vakili and McGahan, 2016).

TRIPS may improve the institutional environment for conducting science within an LMIC. Scientific institutions facilitate the use by scientists, working both locally and globally, of existing knowledge from the newly compliant country. Examples of these institutions include academic medical centers, research funding, conferences, medical and scientific training programs, laboratories, and professional designations, such as licensed specialties. As these institutions of science develop, the local incentives to disseminate, and the global ability to access, the research insights developed in the country increase. TRIPS implementation may accelerate dissemination from the newly compliant country.

A second mechanism generating greater levels of interest in pre-TRIPS scientific publications may arise as both local and global scientists seek partnerships that advance their mutual and independent goals. This would occur, for instance, if a global institution seeks to develop local

scientific capacity to support subsequent product introductions or to carry out local clinical trials or other research projects. Local capacity is important both to support distribution, such as by assuring adherence to local distribution guidelines, and to conduct post-distribution analysis and reporting. Similarly, local scientists may seek international scientific partnerships for career advancement and for access to tools, networks, and funding.

A third mechanism that may lead to increased scholarly attention to pre-TRIPS publications may be increased focus on locally relevant diseases after TRIPS implementation. The profile of diseases in LMICs tends to have two main features. First, global diseases such as cardiovascular conditions and cancers are prevalent, just as they are in HICs. Second, neglected diseases such as malaria and tuberculosis that are not characteristic of HICs are prevalent, particularly among the relatively young. For this latter category—namely, diseases that are uniquely LMIC-prevalent—increased global attention to local expertise may develop for a range of reasons. With the implementation of TRIPS in LMICs, local experts with previously published scientific articles in uniquely local diseases may attract greater attention. This is because of both the greater market opportunity to sell drugs for these diseases and the increased opportunities to coordinate research projects with LMIC experts that is made possible through the emergence of new institutions.

In sum, we expect local scientists in newly TRIPS-compliant countries to face raised incentives to communicate and present their scientific achievements to the global scientific community. Complementary to this development, we also expect that the global scientific community will pay more attention to scientific developments in newly compliant TRIPS countries due to the increased opportunities for research and development in these areas. We expect the interaction of these two forces to foster a faster rate of knowledge diffusion from LMICs to HICs.

Following this line of reasoning, the increased rates of knowledge diffusion will be particularly pronounced in areas where relevant basic scientific knowledge has traditionally been less developed prior to TRIPS and where the TRIPS-implementing LMIC has greater local expertise—i.e., on neglected diseases with a high local disease burden. The implementation of patent systems and the increased activities of local scientists in newly TRIPS-compliant countries can provide

new opportunities for scientists globally to advance the knowledge frontier in domains that previously received less attention.

The impact of TRIPS on global attention to neglected diseases may be particularly important for the diffusion of knowledge to the patent literature for two main reasons. First, where there is a dearth of existing invention for neglected diseases, increased scientific attention to neglected disease papers may have a larger marginal impact on follow-on invention compared to greater attention to LMIC papers on disease that are the subject of greater scientific and inventive effort ex ante. Second, TRIPS impact on the market incentives is likely to be greater for diseases that do not have large existing markets in HICs. Where there already are large global markets for particular diseases, the local burden of disease may have less impact on scientific and inventive attention to a country's papers after TRIPS implementation. In this case, there is relatively little change in the market incentives to focus on a disease that also has a higher burden in a TRIPS-implementing country. Additionally, local actors have less incentive to push engagement with the global scientific community on high burden non-neglected diseases if significant global effort is already targeting treatments for that disease. Instead, local scientists' engagement with the global scientific community may be based more on either the quality of local capabilities that country can offer or strategic decisions of where it is most commercially or scientifically valuable for that country's scientists to engage in the global systems of medical research and drug development.

3. Empirical Analysis

3.1. Data

Scientific articles are drawn from Scopus between 1985 and 2010 and are assigned to diseases based on their keywords and abstracts. Articles are associated with countries based on the affiliations listed on the paper in Scopus. We rely on prior research by Ginarte and Park (1997), Hamdan-Livramento (2009), and Kyle and McGahan (2012) for the dates of countries' implementation of TRIPS. Scopus is also the source of data on the number of paper-to-paper citations received by an article in each year before and after TRIPS implementation. The locations

of authors of the citing paper as reported in Scopus determine whether a citation comes from scientists in the same country as at least one of the focal paper's authors versus from scientists in different countries. This facilitates examination of how global scientific attention to existing scientific ideas changes when the authors' countries implement TRIPS.

There are papers from 132 LMICs in our sample. We exclude papers whose authors are only located in China from the sample. We do this because China may not be representative of other LMICs, due to factors such as its size, large-scale investments in science, rapid economic growth, and increasingly central position in the global economy during the period in which most LMICs were implementing TRIPS. Had we included papers authored in China, these papers would comprise more than one-third of the sample. Hence, it would be difficult to isolate observed effects linked to TRIPS implementation worldwide from the observed effects linked to the timing of TRIPS implementation in China.

Patent-to-paper citations are developed from two sources. First, we use the Reliance on Science dataset (Marx and Fuegi, 2020; Marx and Fuegi, 2022) to match our scientific papers to citing patents using PubMed IDs. We then use data on patent assignees from the USPTO to identify whether a patent assignee is an academic or corporate organization and to determine their locations. This allows us to assess whether the citing patent is from an organization located in the same country as a focal paper's authors or in a different country. We use the patents' application years to calculate the annual number of patent-to-paper citations a focal paper receives.

We also draw on the Reliance on Science dataset for information on whether patent citations are by applicants or examiners and whether they appear on the frontpage or in the body of a patent. We use this information in robustness tests to show that our results do not change substantively with the exclusion of examiner-added citations and of citations that appear only on the front page of a patent. This information is important because these types of citations may arise from instrumental changes in citing behavior that occur when countries adopt TRIPS without reflecting inventors building on information in the cited paper at a higher rate (Alcacer and Gittelman, 2006, Bryan, Ozcan and Sampat, 2020).

The analysis is based on a final sample comprising 5,217 scientific articles that have a LMIC author with 69,364 paper-year observations. For each article, we have a yearly count of citations to the article from other publications according to the following respective criteria: (1) Excluding self-citations (i.e., there is no common author between citing and cited papers); (2) Foreign citations from any other country worldwide (i.e., there is no common country between authors' institutions on the citing and cited papers); (3) Same country citations (i.e., there is a common country between authors' institutions on the citing and cited papers). There are 2,613 patent-to-paper citations to 574 papers in the sample. There are 138 papers in our Scopus sample that do not have PubMed IDs. Because we use PubMed IDs to match papers to citing patents, we exclude these papers in the patent-to-paper citation analysis. This reduces our sample size by 1,145 yearly observations relative to the paper-to-paper citation analysis. The interpretation of results in the paper-to-paper citation models is not affected by the exclusion of the 138 papers that do not have a PubMed ID.

3.2. Identification Strategy

We use difference-in-differences analysis to estimate the effects of TRIPS implementation on scientific attention to existing papers. This identification strategy involves examining how citations to papers change once the authors' countries are TRIPS compliant. The staggering of TRIPS implementation across different countries provides treated and control papers for each year in the panel. A paper is included in the control group until all its authors' countries have implemented TRIPS, after which the paper is moved into the treatment group. By the end of the panel, 60 percent of papers have been treated and 40 percent remain in the untreated control group.

Crucially, we focus only on papers that existed prior to a country's TRIPS implementation. This assures consistency in the base of scientific knowledge that is being analyzed. It prevents bias that may emerge from analyzing differences in citations to a country's new papers if there are wider changes in a country's scientific research programs that occur after TRIPS implementation that may affect the quality, topics, or set of co-authors associated with papers. Our core identifying

assumption is that the timing of TRIPS implementation in a country is orthogonal to the characteristics of the publications that were produced in the country before it implemented TRIPS.

We use paper fixed effects to control for time-invariant characteristics of a paper (such as its quality, topic, and authors) and year fixed effects to control for yearly variation in average citation rates to papers. This means that any changes in the quality, topics, or author networks associated with a country's scientific research that occur after a country implements TRIPS do not affect our analysis. Instead, we hold each paper's characteristics and the ideas it contains constant before and after its authors are covered by TRIPS. Our main regression model is specified as follows:

$$\ln(1+\textit{Number of Citations}_{it}) = \beta_0 + \beta_1 \textit{POST-TRIPS}_{it} + \Delta X_{it} + \gamma_i + \tau_t + \varepsilon_{it}$$

The main dependent variable in analysis of paper-to-paper citations is the natural logarithm of one plus the number of citations a focal paper *i*, receives in a given year *t*, from other scientific journal articles. To obtain evidence about the mechanisms underlying changes in scientific attention to papers after TRIPS coverage, we use versions of this dependent variable that only incorporate citations from certain countries. The precise construction of these variables is explained when they are presented in the results section of this paper.

The central independent variable is an indicator equal to one if all the authors on a paper *i* are from countries that are fully TRIPS compliant in year *t*, and zero otherwise (i.e., in the years prior to the full TRIPS "treatment"). The treatment effect is thus captured by the coefficient on this variable, β_1. The variables γ_i and τ_t represent the paper and year fixed effects. In some models, we also incorporate disease-year fixed effects to ensure that our results are not being driven by changes in the diseases of interest to the global scientific community over time.

The vector X_{it} contains a range of control variables. We control for a paper's cumulative citations, which is measured as the natural logarithm of one plus paper *i*'s cumulative paper-to-paper citations up to year *t*-1. In the models with patent-to-paper citations, we include an equivalent variable measuring a paper *i*'s cumulative prior citations in the patent literature up to year *t*-1. We also control for the natural logarithm of the disability-adjusted life years lost per 100,000 population (DALYs) associated with paper *i*'s diseases of focus in the authors' countries in year *t*.

This is to ensure that changes in the burden of a disease in a paper's country over time are not driving changes in scientists' attention to a paper. We also include an age fixed effect, which is defined as the difference in years between year *t* and the year in which paper *i* was published. This is to ensure that our results are not driven by heterogeneity in citation rates over a paper's lifecycle.

In addition to implementing TRIPS, many countries also joined the WTO during our sample period. An associated concern could be that changes in the burden of specific diseases in a country are correlated with the country's integration into global economic institutions as a consequence of becoming a WTO member. To ensure that increased integration into the global trading system is not driving the results, all regression models include an indicator variable denoting whether the authors on a paper are all from WTO member countries. Models including an interaction between the TRIPS coverage variable and the neglected disease indicator variable also contain interactions of the WTO coverage variable with this indicator. Therefore, our identification strategy capitalizes on the difference in time between a country's joining the WTO and its compliance with the IPR requirements in TRIPS. LMICs were allocated specified periods of time to comply with TRIPS after joining the WTO. For the papers in our sample, the median time between the first year in which all a paper's authors are from countries in the WTO and all its authors are from TRIPS-compliant countries is six years.

To examine the effects of TRIPS coverage on invention, we use a linear probability model to identify the marginal effects of TRIPS implementation on the probability that a paper is cited by a patent. Because these citations are relatively rare, it is more informative to examine changes in the relative probability that a paper is cited in the patent literature rather than to focus on the marginal changes in its yearly citation rate. Comparing the marginal increase in the probability that a paper is cited by a patent after its authors are covered by TRIPS to the baseline probability of being cited by a patent supports a meaningful and intuitive interpretation of the results. It also ensures that our results are not being driven by a small number of papers being cited by a large number of closely related patents that build on highly similar knowledge. The dependent variable in the linear probability models is an indicator variable that is equal to one if paper *i* is cited by a USPTO patent

application in year *t*, and zero otherwise. Only patents that were ultimately granted are included to ensure a minimal quality threshold on the patents in the sample. We use the same set of control variables as in the paper-to-paper citation models. The Online Appendix reports replications of our core results using the number of patent-to-paper citations as the dependent variable. Summary statistics are presented in Table 1.

[INSERT TABLE 1 HERE]

4. Results

4.1. Diffusion of Knowledge in Global Science

The first set of hypotheses examines how a country's TRIPS implementation influences the diffusion of scientific knowledge from that country into the global scientific community. The results in Table 2 show a general increase in the rate of academic citations to pre-existing papers by scientists located in TRIPS-implementing countries. In Column 1, the dependent variable is all citations to a focal paper from articles in scientific journals (excluding authors' self-citations). There is a positive and significant effect of TRIPS compliance on the rate at which papers are cited. This establishes the main result, which is that knowledge produced prior to TRIPS implementation is cited by scientists after TRIPS implementation more intensively than papers published elsewhere with authors are not fully covered by TRIPS.

[INSERT TABLE 2 HERE]

To examine whether TRIPS led to an international diffusion of knowledge, we examine whether the citing and cited authors are located at institutions in the same country or in different countries. In Column 2, the dependent variable includes only citations from scientists that are not affiliated with institutions in the same country as any of the authors of the focal paper. The results show clear evidence of an international diffusion of knowledge from TRIPS-implementing countries to the wider global scientific community. The point estimates imply that, on average, TRIPS coverage is associated with papers receiving approximately 7 percent more citations per year from scientists in other countries relative to the pre-TRIPS mean citation rates. Column 3 reports the

results of an analysis in which observations are only included on citations by scientists based in the same country as at least one of the focal paper's authors. Overall, our results are consistent with the idea that TRIPS implementation increased global scientific attention to scientific research in the implementing country.

In Columns 4 to 6, we replicate our analysis incorporating disease-year fixed effects into our models. This ensures that yearly variation in global scientific attention to the diseases in a focal paper are not driving our results. We again find that there is a significant increase in the rate at which global scientists cite a focal paper after its authors are fully covered by TRIPS. In Table A.1 of the Online Appendix, we replicate these results excluding papers that have more than one disease as their topic. The disease-year fixed effects models yield highly conservative estimates. When an LMIC adopts TRIPS, it may become more attractive to scientists to do research on topics of relevance to that country. These are likely to be the same diseases in which the LMIC's prior research is focused. If scientists are incentivized to focus more effort on these diseases after an LMIC implements TRIPS, there may also be spillovers in scientists' attention to research papers from other countries on the same diseases. This would lead to a downward bias on the estimated coefficients in models with disease-year fixed effects. This effect may be particularly pronounced for neglected diseases for which there are not markets in HICs with strong IPR systems to provide market-based incentives for scientific research.

The disease-year fixed effects models also imply that global disease-specific funding changes are not driving our results. If the availability of funding for research on a disease is increasing in the global scientific community, it is not clear why they would increase attention to papers from newly TRIPS-compliant countries relative to other papers on the same disease produced by scientist in different countries.

Figure 1 shows how the yearly number of citations received by papers is affected when their authors are in newly TRIPS-compliant countries (using the most conservative disease-year fixed effect models). The figure demarcates the year of TRIPS implementation in the countries of the papers' authors to facilitate comparison of citation rates before and after treatment. Panel A shows

the results for paper-to-paper citation rates restricting citations only to those by scientists in a different country to the focal paper's authors. The results indicate that there is no trend in citation rates in the years immediately prior to the adoption of TRIPS. However, citations to knowledge produced prior to TRIPS in newly compliant countries increases markedly after they implement TRIPS. Panel B shows the equivalent trend for citations to papers from the authors' own countries following TRIPS implementation. Again, there is no evidence of a trend in domestic paper-to-paper citation rates before TRIPS implementation. There is also little evidence of a post-TRIPS increase in domestic paper citation rates that would suggest TRIPS induced greater diffusion of existing scientific knowledge within the TRIPS implementing country.

[INSERT FIGURE 1 HERE]

In Table A.2, we repeat this analysis including an interaction term denoting whether the topic of a paper is a neglected disease. There is a larger increase in citations to neglected disease papers after TRIPS implementation in the models that compare post-TRIPS citation rates to those of the full set of control papers. However, after controlling for disease-year fixed effects, both neglected and non-neglected disease papers appear to experience a similar increase in paper-to-paper citations after TRIPS implementation. When LMICs begin adopting TRIPS, this may change scientists' incentives to focus on particular types of disease that are more prevalent in the implementing LMICs, but which have limited impact on HICs. This may create spillovers in scientists' attention to control papers in the neglected diseases group. Figure A.1 shows that in the early-2000s, after many LMICs have implemented TRIPS, untreated papers start to experience a significant within-paper increase in citation rates despite there being no prior evidence of differential trends.

One concern is that the results may be driven by specific diseases that increased in prominence during our sample period. While the disease-year fixed effects models help address this concern, we also replicate our results in analyses that exclude key global diseases that received significantly increased international attention during the sample period. These are HIV/AIDS, malaria, and tuberculosis (of which tuberculosis and malaria are categorized as neglected diseases in our

sample). This ensures that our results are not driven by increased international attention from global actors focused on these diseases. The Global Fund to Fight AIDS, Tuberculosis, and Malaria was established during the sample period to fund projects and treatments for these three diseases. By the late-2000s, The Global Fund disbursed 3-4 billion USD in grants annually. This increases in resources for the treatment and prevention of these diseases could have significantly affected global scientists' incentives to conduct and cite research in these areas.

The results of the robustness tests are presented in Table A.3 of the Online Appendix and are consistent with the main results. In Table A.4, we exclude papers with an HIC co-author to show that our results hold for papers by LMIC-only research teams. This is to ensure that our results are not driven by HIC co-authors being the primary mechanism through which increased diffusion takes place once all a paper's authors are covered by TRIPS. Finally, in Online Appendix B, we replicate the core results presented in the paper using stacked regression models (Cengiz, Dube, Lindner, and Zipperer, 2019; Baker, Larker, and Wang, 2022). This is to ensure that our results are not driven by using staggered difference-in-differences models in which papers treated in earlier time periods are part of the comparison set for papers treated in later time periods (Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021; Sun and Abraham, 2021; Athey and Imbens, 2022).

4.2. Demand-Pull vs. Supply-Push Mechanisms

The results in Table 2 show that there is a significant increase in global scientists' citations to papers after the authors are fully covered by TRIPS. This cannot be explained by increased global attention to the paper's focal diseases. There are two main channels that may explain this effect. First, as countries join the global IPR system, actors in the TRIPS-implementing country may invest more effort disseminating research and engaging with the global scientific community. Second, prior research has shown that some academic scientists are sensitive to IPRs and commercialization incentives (Lach and Schankerman, 2008; Czarnitzki, Doherr, Hussinger, Schliessler, and Toole, 2016; Hvide and Jones, 2018; Ejermo, and Toivanen, 2018). As a result, they may respond to potential demand from newly TRIPS compliant countries leading to an increase in citations to papers containing relevant local knowledge. We would expect this demand-

pull mechanism to be more relevant for neglected disease papers because, unlike non-neglected diseases, these lacked existing IPR system covered markets to incentivize ex ante research efforts. The supply-push mechanism, by contrast, could emerge for either type of paper. On the one hand, local actors may seek to engage the global scientific community on research that is relevant to existing large global markets (and so is potentially more commercially valuable). On the other, local actors may seek to push engagement with the global scientific community on those neglected diseases that most affect their country.

In Table 3, we further examine the potential mechanisms driving this diffusion of knowledge after TRIPS. We analyze how the response from global scientists varies according to the local burden of a disease and whether the topic of a paper is a neglected or non-neglected disease. We measure the local burden of disease according to the DALYs associated with a paper's diseases in a country in a given year (both as a rate per 100,000 and as the total number of DALYs across a country's population). Where papers have authors from multiple countries or cover multiple diseases we weight each country-disease-paper-level observation in inverse proportion to the number of unique country-disease-paper observations associated with the focal paper. We present results from regressions using standardized DALYs variables to facilitate simpler comparisons across models. We report results from the more conservative disease-year fixed effect models. In Table A.5 of the Online Appendix, we replicate the results using the year fixed effects and excluding papers with authors from multiple countries or that cover multiple diseases.

[INSERT TABLE 3 HERE]

The results in Columns 1 and 2 of Table 3 show that, for non-neglected disease papers, the increase in paper-to-paper citations from global scientists after TRIPS implementation is unrelated to the burden of disease in a country (controlling for overall trends in attention to specific diseases through disease-year fixed effects). This is consistent with a supply-push mechanism in which countries become more integrated with the global scientific community after TRIPS, leading to increased attention to papers from that country as they relate to diseases already of interest to the global scientific community.

Conversely, for neglected disease papers, the increase in global scientists' paper-to-paper citation rates after TRIPS implementation is increasing in the local burden of disease. This suggests that the increase in global scientists' attention to neglected disease papers is driven by increased attention to papers from countries where the burdens of those diseases are higher (controlling for disease-year fixed effects). This finding could be consistent with either a supply or demand channel. On the one hand, these would be the populations most in need of, and largest markets for, new treatments creating demand-side incentives. On the other hand, the results are also consistent with a supply-side mechanism if local actors have greater motivation to invest effort building connections between domestic science and the global scientific community, specifically on those diseases with the greatest local burden. This could then lead to greater increases in global citation rates to previously written, locally authored papers on these diseases after TRIPS implementation (relative to other countries' papers on the same neglected diseases). Note that since we exclude citations from papers with a domestic author from our global diffusion dependent variable, the effect cannot simply be driven by an increase in citations from post-TRIPS collaborative papers with scientists from that country.

Overall, we find clear evidence of increased global scientific attention to knowledge from LMICs after TRIPS implementation. For non-neglected diseases, our results are consistent with a supply-push mechanism being primarily responsible for this increase in attention as changes in paper-to-patent citations from foreign scientists are unrelated to the local burden of disease. For neglected diseases, the local burden of disease is strongly linked to changes in global scientific attention, which could imply either a demand-pull mechanism or a supply-push mechanism in which local actors focus primarily on pushing neglected disease research for those diseases with a higher local burden.

4.3. Diffusion of Knowledge in Global Invention

The increased diffusion of knowledge from newly TRIPS compliant countries into the wider global scientific community is an important finding. However, it does not constitute evidence that new medicines, or other inventions relevant to the health of those in LMICs, were developed because

of TRIPS. We next turn to the question of whether TRIPS implementation led to the diffusion of scientific knowledge produced prior to TRIPS into patented inventions. This mechanism of impact was a core reason given by advocates of TRIPS for LMICs to accede to the policy as a condition of membership in the WTO. To address this question, we examine whether patents granted by the USPTO cited papers that had been produced in newly compliant LMICs at a higher rate after those countries implemented TRIPS.

Table 4 shows how the probability that a paper is cited by a patent in a given year varies according to whether all of the paper's authors are located in countries covered by TRIPS. We use a linear probability model to identify marginal effects on the probability that a paper is cited by a patent. Since patent-to-paper citations are rare in our sample, we believe that identifying marginal effects and comparing these to the baseline probability of citation offers the most meaningful available information about the magnitude of this effect. It also ensures that our results are not driven by an increase in closely related patents being applied for after TRIPS that all contain a citation to the same paper. For robustness, Table A.6 of the Online Appendix reports a replication of the results using the number of patent-to-paper citations as the dependent variable.

[INSERT TABLE 4 HERE]

The results in Column 1 provide estimates of the effects of TRIPS implementation on the probability that a paper is cited in a USPTO patent (based on the year of patent application). Notably, the results in Columns 2 and 3 indicate that this effect is more pronounced for papers on neglected diseases than non-neglected diseases. The point estimates imply that a paper is 0.6 percentage points more likely to be cited by a patent after TRIPS implementation in the countries of the authors. For a neglected disease paper, the point estimates imply that the increase in the probability of citation is 0.9 percentage points. Relative to the baseline pre-TRIPS probability that a paper is cited by a USPTO patent, the probability of citation increases by approximately 20 percent for all papers and 60 percent for neglected disease papers. However, for non-neglected disease papers, there is little evidence of an effect of TRIPS on the probability that the paper is cited by a USPTO patent.

Panel A of Figure 2 shows how the yearly within-paper probability that a neglected disease paper is cited by a patent changes during a ten-year window around the implementation of TRIPS by its authors' home countries. There is no evidence of differential trends in the probability of papers receiving patent-to-paper citations prior to the implementation of TRIPS. In Panel B, we replicate this analysis for non-neglected disease papers. We can see that, for neglected disease papers, the probability that a paper is cited by a patent increases after it is fully covered by TRIPS. However, there is no evidence of an effect of TRIPS among non-neglected disease papers.

[INSERT FIGURE 2 HERE]

Overall, the results suggest that TRIPS implementation had a greater effect on neglected diseases patents than on patents for other diseases. It is consistent with TRIPS implementation having a greater effect on inventive attention to a country's neglected diseases, and its scientific expertise in these areas, than on inventive attention to non-neglected diseases for which there already is a larger global market. Table A.7 of the Online Appendix shows that the changes in patent-to-paper citations are consistent for both drug and non-drug patents. Thus, our results are not primarily driven by one distinct type of invention. We also replicate the results with disease-year fixed effects in Table A.8 to show that changes in inventive attention to specific diseases over time are not driving our results.

4.4. Diffusion to Academic and Commercial Invention

Next, we examine which type of patent applicant is citing papers from newly TRIPS-compliant countries. We separately analyze the changes in the likelihood of patent-to-paper citations according to whether the citation is assigned to an academic or corporate organization. This is important because TRIPS was originally justified on grounds that it would provide pharmaceutical companies greater incentives to mobilize their resources to develop drugs for neglected diseases.

There are several reasons why academic and corporate institutions may have responded differently to TRIPS. Pharmaceutical companies would have required the incentives from enhanced IPR protection to be large enough to justify the investment in new disease areas. The potential profits from neglected disease drugs may not have been sufficient to justify this

investment, even with enhanced IPRs. In contrast, the research direction of academic scientists is less defined by purely commercial logic. Academic scientists receive credit-based rewards from the wider academic community based on the scientific and social value of their research outputs (Merton, 1957; Dasgupta and David, 1994). Public science funding does not allocate research resources to projects based only on the expected economic returns. As a result, academic scientists with proximate scientific knowledge and skills may have shifted their research programs to neglected diseases affecting TRIPS-implementing countries. Conversely, pharmaceutical companies may have lacked ex ante research capabilities and the incentives provided by TRIPS may have been insufficient to spur their development.

[INSERT TABLE 5 HERE]

In Columns 1 to 3 of Table 5, we replicate the analysis from Table 4 for a modified dependent variable that indicates whether a paper is cited by a patent with an academic assignee. In Columns 4 to 6, the dependent variable indicates whether a paper is cited by a patent with a corporate assignee. Prior to TRIPS implementation, the probabilities that a paper is cited by an academic or corporate patent are relatively similar (approximately 1 percent per year across all papers). The results show that there is a significant increase in the probability that a paper is cited by a patent with an academic assignee after TRIPS coverage. Notably, this effect is larger for neglected disease papers. However, there is little evidence of changes in the rate at which corporate patents cite papers after TRIPS coverage.

[INSERT FIGURE 3 HERE]

Figure 3 shows how the yearly changes in the probability that a neglected disease paper is cited by a patent change in the interval of TRIPS implementation. It shows that there is a significant increase in the rate at which academic patents cite newly TRIPS covered neglected disease papers. However, there is no evidence of any changes in the attention corporate actors pay to these papers. Academic scientists' increased attention to research from TRIPS-compliant countries—and to relevant neglected diseases in particular—appears to have led to increased diffusion of knowledge from TRIPS-implementing countries into patented inventions. Nonetheless, the incentives from

TRIPS coverage appear to have been insufficient to lead to shifts in the attention of corporate research and development programs.

In line with the paper-to-paper citation results, the changes in the probability that a paper is cited in the patent literature after it is fully covered by TRIPS are driven primarily by the international (rather than domestic) diffusion of knowledge. We categorize patent-to-paper citations based on whether an inventor on the patent is from the same country as an author on the paper. The results in Columns 1 and 2 of Table 6 show that there is a significant increase in the probability that a paper is cited by patent inventors from different countries after all its authors are covered by TRIPS. In contrast, the results in Column 4 do not indicate that there is a significant change in the probability that a paper is cited by a patent from inventors in the same countries as its authors. This provides strong evidence that TRIPS implementation led to greater international diffusion of knowledge into the global patent literature—as well as into the global scientific community. In Table A.9 of the Online Appendix, we again replicate our results using the number of patent-to-paper citations as the dependent variable, separately counting patent-to-paper citations according to the inventors' locations.

[INSERT TABLE 6 HERE]

One concern is that our results may be driven by changes in patenting behavior, rather than by changes in the use of the knowledge contained in a paper, after a paper's authors are fully covered by TRIPS. For example, as countries become integrated into the global IPR system, inventors from those countries might be more likely to patent inventions. These inventors may also be more likely to build on domestic scientific knowledge. The results in Table 6 show that these possibilities are unlikely. Specifically, increases in patenting from inventors in a newly TRIPS-compliant country is unlikely to be driving the main effect. Were this the case, we would expect to find positive and significant results in Columns 4 and 5. Instead, we find that the increases in patent-to-paper citation rates are greater for inventors in different countries to the authors of a focal paper. This is consistent with the international diffusion of knowledge from these papers to inventors.

In Panel A of Table A.10 of the Online Appendix, we show that excluding citations by patents with a foreign priority patent does not affect our results. This implies that our results are not driven by global harmonization of IPR systems leading inventors to apply for patents at the USPTO for inventions that were already the subject of patent applications in other jurisdictions. We also carry out additional robustness tests to ensure that the patent-to-paper citations represent knowledge diffusion leading to cumulative innovation, rather than being driven by changes in citation behavior. The results in Panel B of Table A.10 show that our core findings are also robust to excluding examiner-added citations. This means our results are not driven by changes in USPTO examiners' attention to potential references from other countries after they have joined the international IPR regime. Finally, the results in Panel C show that our findings are also robust to including only references that are found in the body of a patent, rather than exclusively on the front page. Prior research has shown that in-body references better capture inventors' use of knowledge than citations listed on a patent's frontpage (Bryan, Ozcan, and Sampat 2020).

Taken together, the robustness tests support hypotheses of international knowledge diffusion after TRIPS implementation in LMICs. They contrast with an unsupported explanation that the standardization of global IPRs leads to symbolic changes in citation behavior in which examiners or inventors have a higher propensity to cite papers from newly TRIPS-compliant countries (regardless of whether these were important sources of knowledge to the patented invention). They also contrast with a hypothesis that applicants are more likely to apply for USPTO patents for existing inventions that are already patented elsewhere as global IPR regimes are harmonized.

5. Discussion and Conclusion

The effect of IPRs on the dissemination of knowledge has mainly been considered in the literature as emanating from two sets of incentives: those created by patents that enable inventors to generate returns on innovation investments; and those that emerge from the foreclosure of returns on innovative investment due to the rights conferred by IPR systems on patent holders (Galasso and Schankerman, 2015; Williams, 2013). In this paper, we consider a different set of mechanisms by

which the implementation of IPR systems influences the diffusion of knowledge. The focus in this paper is on the effect of IPRs on the integration of a county's scientific research into the global scientific community. IPR systems may play an important role in the development of institutions of science, such as medical schools, accreditation systems, enforcement protocols, and career opportunities. To examine the effect of these institutions, we specifically assess changes after TRIPS implementation on the dissemination of knowledge that had existed in newly compliant countries prior to TRIPS implementation.

The findings suggest that the influence of IPRs on the diffusion of knowledge is significant. Papers written by authors prior to TRIPS are cited more frequently after TRIPS has been implemented in the authors' countries. This finding is stronger and larger for authors located in different countries to the focal article's authors, which we interpret as evidence that the implementation of an IPR system is associated with increased global dissemination of knowledge from a newly compliant country. Notably, we find significant increases in the diffusion of knowledge about neglected diseases after TRIPS implementation. This shows that the strengthened IPR system was associated with significant increases in the diffusion of knowledge in areas of science where existing knowledge was most lacking.

Additional analyses delineate how TRIPS' impact on global scientists' attention to papers varies in important ways for neglected and non-neglected diseases. Even after controlling for disease-year effects, we find a persistent effect of TRIPS implementation on global scientific attention to papers from LMICs. This is consistent with countries' greater integration into the institutions of global science leading to increased diffusion of scientific knowledge. Notably, for non-neglected diseases this effect is unrelated to a disease's local burden. Thus, we find evidence of a supply-push mechanism in which changes in local institutions led to greater dissemination of a country's previously published scientific findings from local actors to the global scientific community.

The finding that the increase in citations to previously written papers on neglected diseases is linked to the local disease burden could be consistent with either a supply-push or demand-pull mechanism. On the one hand, local actors may have greater incentives to push for greater

integration into the global scientific community where the local disease burden is greatest in neglected diseases for which prior attention has been low. However, it could also indicate that global scientists are responding to greater incentives to focus research attention on neglected diseases and relevant local knowledge where these have a greater health impact in a TRIPS-implementing country. Overall, the effects of an IPR system are nuanced, subtle, and influential across a range of scientific activities. We show that scientists' research attention to papers responded significantly to IPRs implementation in LMICs.

Moreover, following the increased diffusion of knowledge into new scientific research, we find that academic scientists also play a central role in expanding inventive attention to this knowledge in patented inventions. This leads to an increase in cumulative invention that builds on knowledge from TRIPS-implementing LMICs. The effects include increased interest in knowledge on locally relevant neglected diseases. In areas in which existing scientific knowledge and invention is most lacking, the introduction of an IPR system appears to have stimulated greater follow-on invention that builds on existing ideas from countries that became covered by that IPR system. Yet these effects appear only to affect academic scientists. The introduction of an IPR system had little impact on follow-on corporate invention in neglected or non-neglected diseases. The precise mechanisms require further research that considers a broader range of channels beyond the direct incentives created by patents. Further research that investigates the character of IPR systems is required to understand how vital, life-saving knowledge diffuses through their implementation.

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Tables & Figures

Table 1: Summary statistics

Variable	Obs	Mean	Std Dev	Min	Max
TRIPS Coverage of Authors	69,364	0.432	0.495	0	1
WTO Coverage of Authors	69,364	0.735	0.441	0	1
Neglected Disease	69,364	0.384	0.486	0	1
ln(1+Paper Citations)	69,364	0.675	0.769	0	4.635
ln(1+Foreign Paper Citations)	69,364	0.568	0.692	0	4.454
ln(1+Same Country Paper Citations)	69,364	0.332	0.595	0	4.078
1(Is Cited by Patent)	68,219	0.023	0.151	0	1
1(Is Cited by Academic Patent)	68,219	0.012	0.109	0	1
1(Is Cited by Corporate Patent)	68,219	0.013	0.112	0	1
1(Is Cited by Foreign Patent)	68,219	0.014	0.117	0	1
1(Is Cited by Same Country Patent)	68,219	0.011	0.103	0	1
ln(1+DALYs Rate)	69,364	5.472	2.457	0	11.048
Paper Age	69,364	8.060	5.954	0	25
ln(1+Cumulative Paper Citations)	69,364	1.853	1.363	0	6.431
ln(1+Cumulative Patent Citations)	68,219	0.088	0.3669	0	4.868

Notes: There are fewer observations for patent-to-paper citation variables because we lack PubMed IDs for 195 papers. Without PubMed IDs we cannot match a focal paper to citing patents in the USPTO database. The

Table 2: Effect of TRIPS coverage on paper-to-paper citations

	Number of Citations					
	Paper and Year FE			*Paper and Disease-Year FE*		
	All Citations	*Only Foreign Citations*	*Same Country Citations*	*All Citations*	*Only Foreign Citations*	*Same Country Citations*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.047***	0.041***	0.019**	0.030**	0.023*	0.010
	(0.009)	(0.009)	(0.007)	(0.010)	(0.009)	(0.008)
	[0.000]	[0.000]	[0.009]	[0.002]	[0.011]	[0.214]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Disease-Year FE	No	No	No	Yes	Yes	Yes
Papers	5,217	5,217	5,217	5,217	5,217	5,217
Paper-Diseases	–	–	–	6,528	6,528	6,528
Observations	69,364	69,364	69,364	85,013	85,013	85,013

Notes: The dependent variable is measured as $\ln(1+\text{N Citations}_{it})$. In Columns (1) and (4), the dependent variable is all paper-to-paper citations (excluding authors' self-citations). In Columns (2) and (5), the dependent variable is all paper-to-paper citations from scientists in different countries to a focal paper's authors. In Columns (3) and (6), the dependent variable is all paper-to-paper citations from scientists in the same country as a paper's authors. 'Post-TRIPS' is an indicator variable equal to one if all the paper's authors' institutions are in countries that have implemented TRIPS in year *t* and zero otherwise. Models in Columns (1) to (3) include paper and year FEs. Models in Columns (4) to (6) include paper and disease-year FEs. There are 976 papers with multiple disease topics. In the disease-year FE models, we recreate the panel at the paper-disease level and weight papers with multiple disease topics inversely according to the number of topics in the regressions. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table 3: Effect of TRIPS coverage on global paper-to-paper citations by type and local burden of disease

	Number of Foreign Paper-to-Paper Citations			
	Non-Neglected Disease Papers		*Neglected Disease Papers*	
	(1)	(2)	(3)	(4)
Post-TRIPS	0.029*	0.030*	0.012	0.008
	(0.012)	(0.012)	(0.015)	(0.015)
	[0.011]	[0.012]	[0.410]	[0.584]
Post-TRIPS*	-0.004		0.023**	
DALYs/100,000	(0.011)		(0.007)	
	[0.672]		[0.001]	
Post-TRIPS*		-0.003		0.022**
Total DALYs		(0.011)		(0.007)
		[0.807]		[0.002]
Controls	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes
Disease-Year FE	Yes	Yes	Yes	Yes
Papers	3,136	3,136	2,077	2,077
Unique Paper-Years	42,732	42,732	26,616	26,616
Observations	82,365	82,365	60,764	60,764

Notes: The dependent variable is measured as $\ln(1+\text{N Citations}_{it})$ and includes all paper-to-paper citations from scientists in different countries to a focal paper's authors. In Columns (1) and (3), DALYs are measured according to the (log) rate of DALYs/100,000 for a focal disease in a focal country. In Columns (2) and (4), the DALYs rate is multiplied by a country's total population in the focal year to create a total DALY variable at the country-disease level (and then log-transformed). DALYs are measured at the country-disease-year level. We then standardize these variables to facilitate more straightforward interpretation of the estimated coefficients. Papers with multiple diseases and author countries are weighted in inverse proportion to the number of country-disease-specific observations. All models contain paper and disease-year FEs and the full set of control variables described in the methods section of the paper (with country-disease specific values for the DALYs control variable. As in the neglected disease interaction models, the DALYs variables are interacted with the binary WTO coverage control variable. The DALYs variables are also interacted with the year FEs to ensure that trends in global scientists' response to disease burdens are not driving the results. The results (available from the authors) are almost identical without the DALYs by year FE interactions. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table 4: Effect of TRIPS coverage on the probability that a paper is cited by a patent

	Is Cited in Patent Literature		
	All Papers	*Neglected Diseases*	*Non-neglected Diseases*
	(1)	(2)	(3)
Post-TRIPS	0.005*	0.009**	0.003
	(0.002)	(0.004)	(0.003)
	[0.025]	[0.009]	[0.379]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Papers	5,079	2,024	3,055
Observations	68,219	26,183	42,036

Notes: All columns report results from Linear Probability Models. The dependent variable is an indicator variable that is equal to one if a focal paper *i* is cited by any USPTO patent applied for in year *t*, and zero otherwise. In Column (1), the sample includes all papers. In Column (2), the sample is restricted to only include neglected disease papers. In Column (3), the sample is restricted to only include non-neglected disease papers. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table 5: Effect of TRIPS coverage on the diffusion of scientific knowledge to academic and corporate patents

	Is Cited in Patent Literature					
	Cited by an Academic Patent			*Cited by a Corporate Patent*		
	All Papers	*Neglected Diseases*	*Non-Neglected*	*All Papers*	*Neglected Diseases*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.005**	0.008**	0.004^{+}	0.001	-0.001	0.002
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
	[0.002]	[0.005]	[0.054]	[0.614]	[0.774]	[0.514]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,079	2,024	3,055
Observations	68,219	26,183	42,036	68,219	26,183	42,036

Notes: All columns report results from Linear Probability Models. In Columns (1) to (3), the dependent variable is whether a paper is cited by any USPTO patent applied for in year *t* and assigned to a university, hospital, or non-profit/governmental research organization. In Columns (4) to (6), the dependent variable is whether a paper is cited by any patent applied for in year *t* that is assigned to a corporation. In Columns (1) and (4), the sample includes all papers. In Columns (2) and (5), the sample is restricted to only neglected disease papers. In Columns (3) and (6), the sample is restricted to only non-neglected disease papers. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

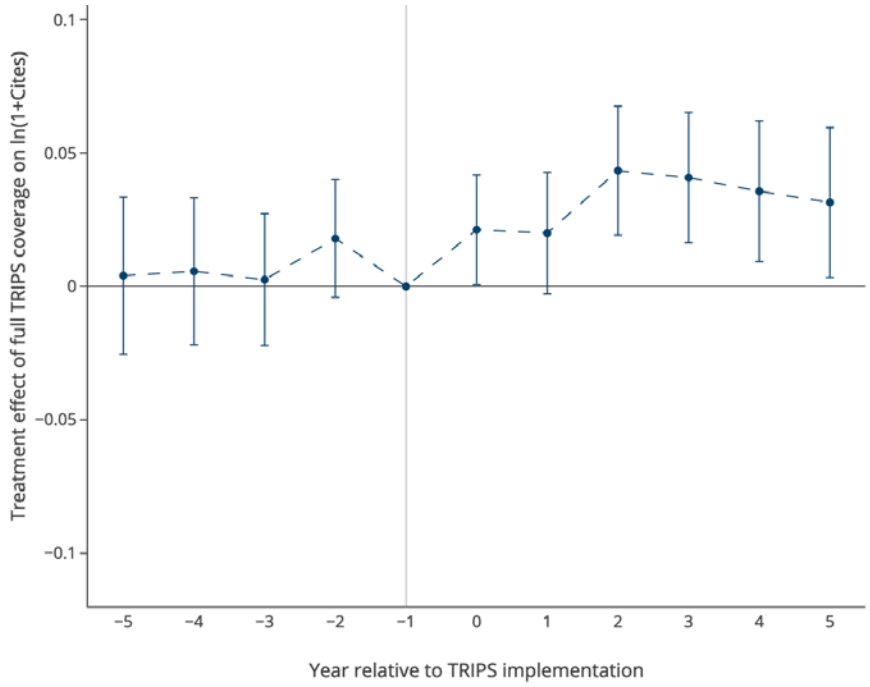
Table 6: Effect of TRIPS coverage on the global diffusion of scientific knowledge to the patent literature

	Is Cited in Patent Literature					
	Only Foreign Citations			*Same Country Citations*		
	All Papers	*Neglected Diseases*	*Non-Neglected*	*All Papers*	*Neglected Diseases*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.005**	0.006*	0.004	0.001	0.004	0.000
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
	[0.009]	[0.032]	[0.106]	[0.414]	[0.107]	[0.992]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,079	2,024	3,055
Observations	68,219	26,183	42,036	68,219	26,183	42,036

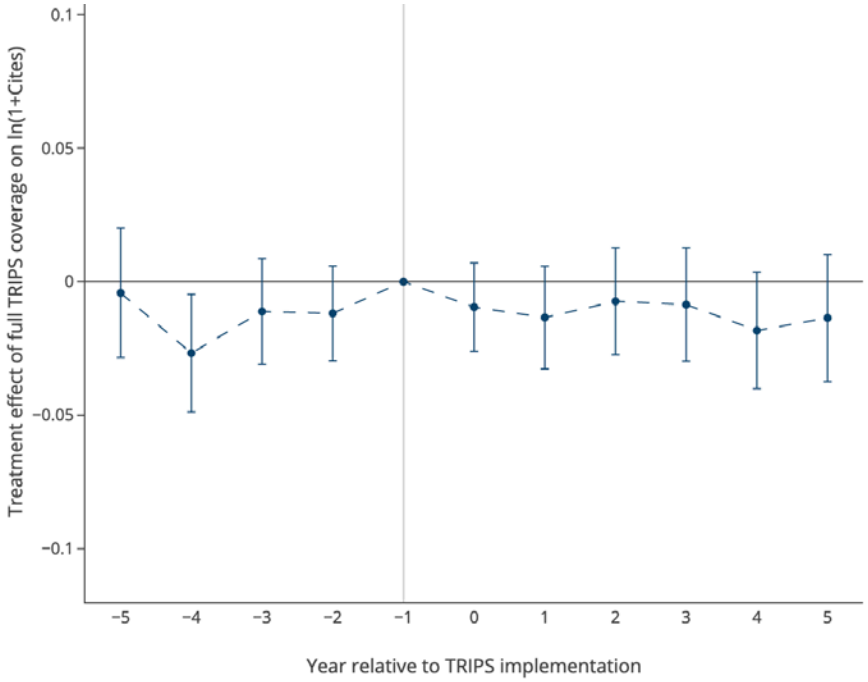
Notes: All columns report results from Linear Probability Models. In Columns (1) to (3), the dependent variable is restricted to only include a citation by a USPTO patents that does not share an assignee country with the authors on a focal paper. In Columns (4) to (6), it is restricted to only patents with at least one shared country between the assignees and the authors on a focal paper. In Columns (1) and (4), the sample includes all papers. In Columns (2) and (5), the sample is restricted to only neglected disease papers. In Columns (3) and (6), the sample is restricted to only non-neglected disease papers. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Figure 1: Effect of TRIPS coverage on annual paper-to-paper citation rates

Panel A: Only foreign citations



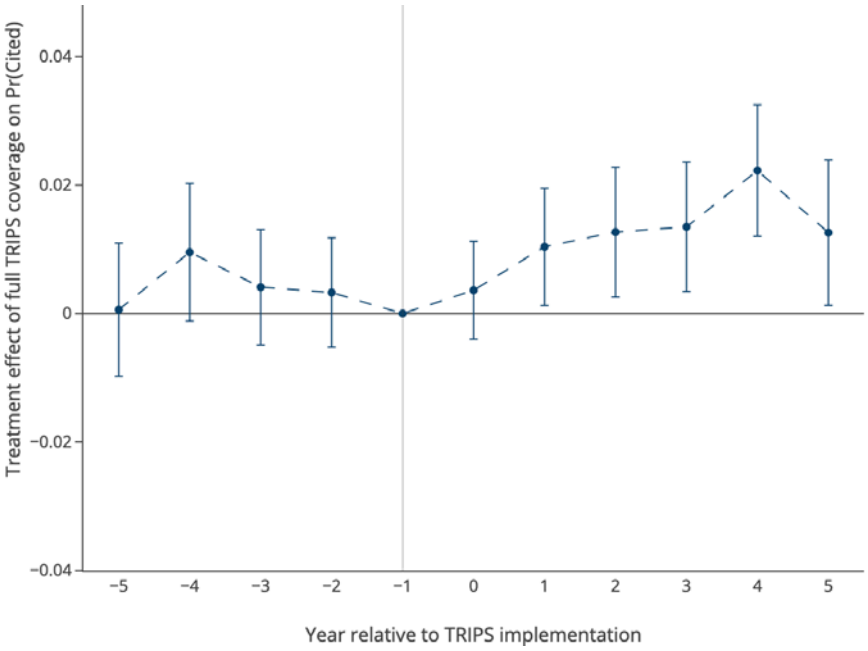
Panel B: Only same country citations



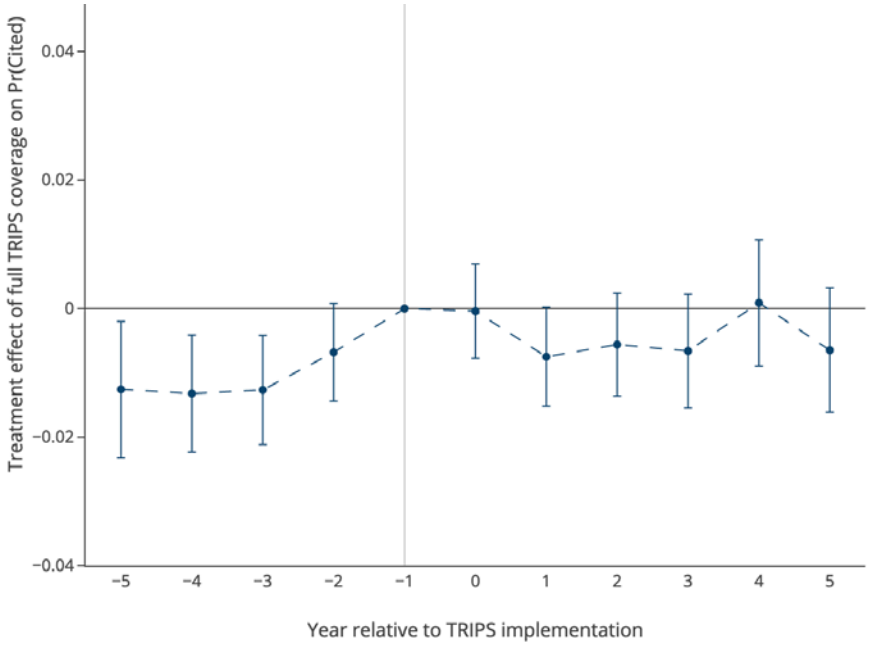
Notes: Figures show results from regression models with paper and disease-year fixed effects. Dependent variable is ln(1+N Citations$_{it}$) and restricted by location of citing paper authors. Control variables include age fixed effects, log DALYs, and WTO coverage indicator variables. Error bars represent 90% confidence intervals. Year zero is the year in which full coverage of TRIPS takes place.

Figure 2: Effect of TRIPS coverage on the probabilty that a paper is cited by a patent

Panel A: Neglected disease papers



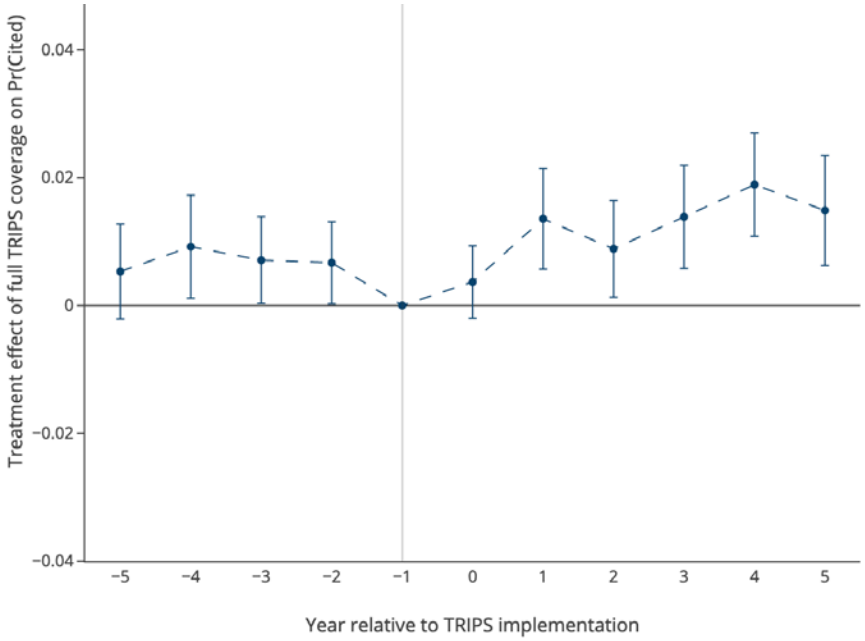
Panel B: Non-neglected disease papers



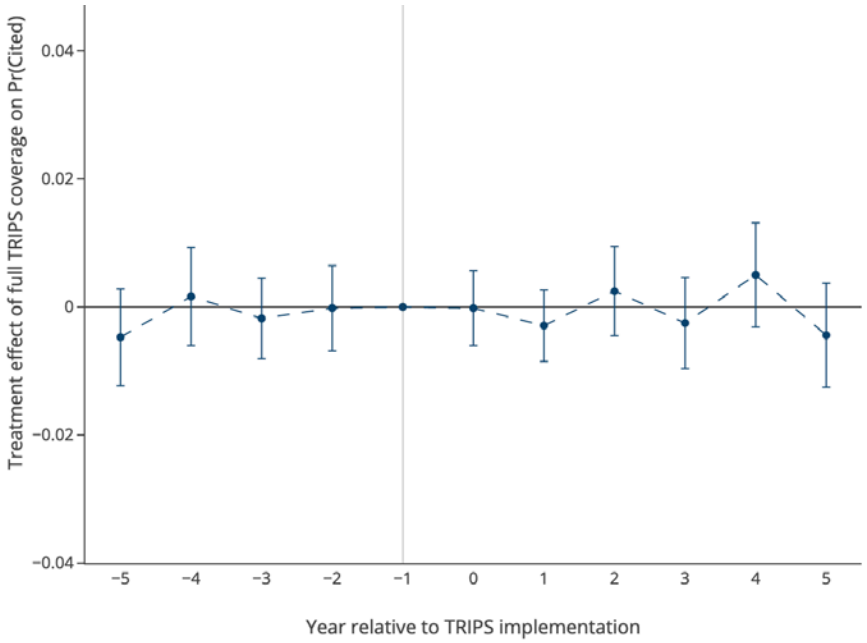
Notes: Figures show results from LPM regressions with paper and year fixed effects. Dependent variable is an indicator variable dentoing whether a paper is cited by a patent in year *t*. The sample is split by whether a paper has a neglected disease as a topic. Control variables include age fixed effects, log DALYs, and WTO coverage indicator variables. Error bars represent 90% confidence intervals. Year zero is the year in which full coverage of TRIPS takes place.

Figure 3: Effect of TRIPS coverage on the probabilty that a neglected disease paper is cited by a patent (by assignee type)

Panel A: Academic patents



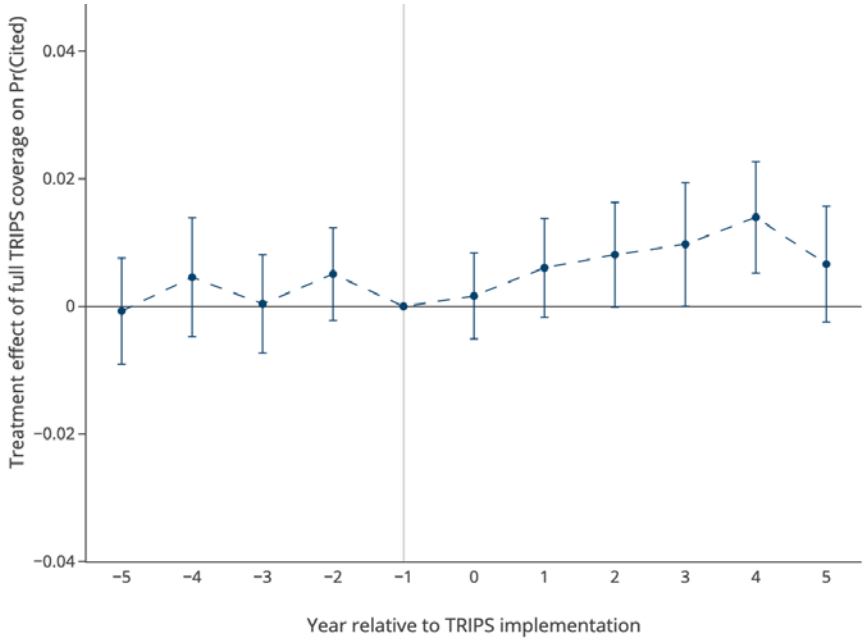
Panel B: Corporate patents



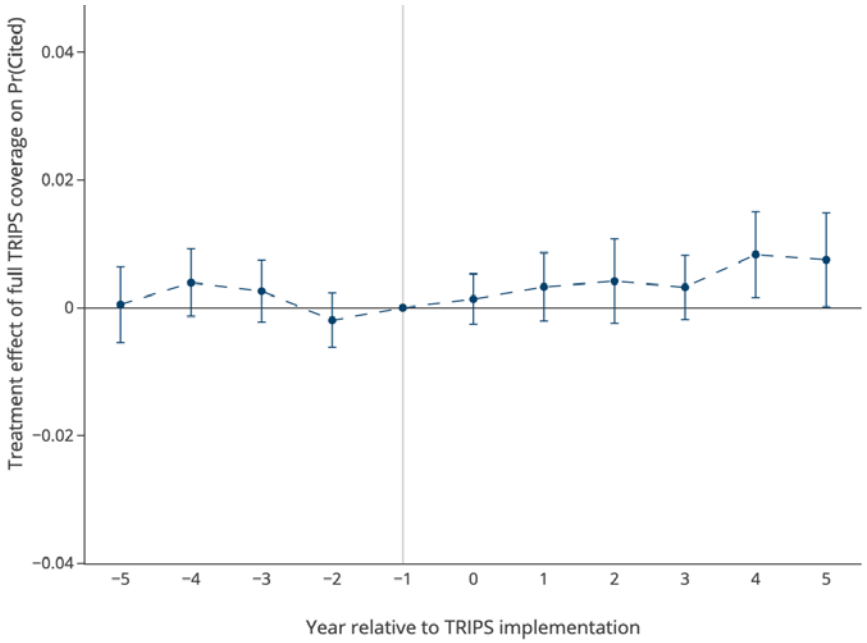
Notes: Figures show results from LPM regressions with paper and year fixed effects. Control variables include age fixed effects, log DALYs, and WTO coverage indicator variables. Error bars represent 90% confidence intervals. Year zero is the year in which full coverage of TRIPS takes place.

Figure 4: Effect of TRIPS coverage on the probabilty that a neglected disease papers is cited by a patent (by inventor location)

Panel A: Only foreign country inventors



Panel B: At least one same country inventor



Notes: Figures show results from LPM regressions with paper and year fixed effects. Control variables include age fixed effects, log DALYs, and WTO coverage indicator variables. Error bars represent 90% confidence intervals. Year zero is the year in which full coverage of TRIPS takes place.

Online Appendix A: Additional Tables & Figures

Table A.1: Replicating Table 2 excluding papers with multiple diseases

	Number of Citations					
	Paper and Year FE			*Paper and Disease-Year FE*		
	All Citations	*Only Foreign Citations*	*Same Country Citations*	*All Citations*	*Only Foreign Citations*	*Same Country Citations*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.042***	0.039***	0.015*	0.027*	0.023*	0.005
	(0.010)	(0.010)	(0.008)	(0.011)	(0.010)	(0.009)
	[0.000]	[0.000]	[0.047]	[0.011]	[0.028]	[0.590]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Disease-Year FE	No	No	No	Yes	Yes	Yes
Papers	4,241	4,241	4,241	4,241	4,241	4,241
Observations	57,286	57,286	57,286	57,286	57,286	57,286

Notes: Replicates Table 2 excluding the 976 papers with multiple disease topics. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.2: Effect of TRIPS coverage on paper citations to neglected disease papers

	Number of Citations					
	Paper and Year FE			*Paper and Disease-Year FE*		
	All Citations	*Only Foreign Citations*	*Same Country Citations*	*All Citations*	*Only Foreign Citations*	*Same Country Citations*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All Papers						
Post-TRIPS	0.033**	0.031**	0.013	0.026*	0.023*	0.010
	(0.011)	(0.011)	(0.009)	(0.012)	(0.011)	(0.010)
	[0.004]	[0.003]	[0.127]	[0.031]	[0.049]	[0.325]
Post-TRIPS*	0.041**	0.029*	0.018	0.010	0.002	-0.000
Neglected Disease	(0.015)	(0.014)	(0.012)	(0.019)	(0.017)	(0.014)
	[0.007]	[0.047]	[0.140]	[0.582]	[0.906]	[0.976]
Papers	5,217	5,217	5,217	5,217	5,217	5,217
Paper-Diseases	–	–	–	6,528	6,528	6,528
Observations	69,364	69,364	69,364	85,013	85,013	85,013
Panel B: Only Single Disease Papers						
Post-TRIPS	0.030*	0.030**	0.011	0.030*	0.027*	0.010
	(0.012)	(0.011)	(0.009)	(0.013)	(0.013)	(0.011)
	[0.012]	[0.009]	[0.245]	[0.025]	[0.033]	[0.386]
Post-TRIPS*	0.036*	0.025	0.017	-0.009	-0.013	-0.014
Neglected Disease	(0.017)	(0.016)	(0.013)	(0.022)	(0.021)	(0.017)
	[0.032]	[0.119]	[0.206]	[0.685]	[0.535]	[0.420]
Papers	4,241	4,241	4,241	4,241	4,241	4,241
Observations	57,286	57,286	57,286	57,286	57,286	57,286
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	No	No	No
Disease-Year FE	No	No	No	Yes	Yes	Yes

Notes: The dependent variable is measured as $\ln(1+\text{N Citations}_{it})$. Panel A includes all papers in the sample and Panel B includes only papers with a single disease topic. There are 976 papers with multiple disease topics. In the disease-year FE models, we recreate the panel at the paper-disease level and weight papers with multiple disease topics inversely according to the number of topics in the regressions. In Columns (1) and (4), the dependent variable is all paper-to-paper citations (excluding authors' self-citations). In Columns (2) and (5), the dependent variable is all paper-to-paper citations from scientists in different countries to a focal paper's authors. In Columns (3) and (6), the dependent variable is all paper-to-paper citations from scientists in the same country as a paper's authors. The variable 'Neglected Disease' is an indicator variable equal to one if the paper's topic is a neglected disease. The neglected disease indicator variable is also interacted with the 'Post-WTO' control variable in all models. Models in Columns (1) to (3) include paper and year FEs. Models in Columns (4) to (6) include paper and disease-year FEs. All models contain the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.3: Paper-to-paper results excluding papers on HIV/AIDS, tuberculosis, and malaria

	Number of Citations		
	All Papers	*Neglected Diseases*	*Non-neglected Diseases*
	(1)	(2)	(3)
Panel A: All Paper Citations			
Post-TRIPS	0.040***	0.040^{+}	0.044***
	(0.011)	(0.020)	(0.013)
	[0.000]	[0.051]	[0.000]
Panel B: Foreign Citations			
Post-TRIPS	0.035***	0.039*	0.035**
	(0.010)	(0.020)	(0.012)
	[0.001]	[0.048]	[0.003]
Panel C: Same Country Citations			
Post-TRIPS	0.024**	-0.013	0.032**
	(0.008)	(0.014)	(0.010)
	[0.003]	[0.339]	[0.001]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Papers	3,327	1,030	2,297
Observations	49,550	14,990	34,580

Notes: Replicates key paper-to-paper citation results excluding papers for which HIV/AIDS, tuberculosis, or malaria are a focal disease from the sample. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.4: Paper-to-paper results excluding papers with a HIC co-author

	Number of Citations		
	All Papers	*Neglected Diseases*	*Non-neglected Diseases*
	(1)	(2)	(3)
Panel A: All Paper Citations			
Post-TRIPS	0.038***	0.041*	0.042**
	(0.011)	(0.018)	(0.015)
	[0.001]	[0.020]	[0.004]
Panel B: Foreign Citations			
Post-TRIPS	0.035**	0.034^{+}	0.039**
	(0.011)	(0.018)	(0.014)
	[0.001]	[0.056]	[0.005]
Panel C: Same Country Citations			
Post-TRIPS	0.018**	0.007	0.028**
	(0.007)	(0.011)	(0.009)
	[0.009]	[0.531]	[0.002]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Papers	2,576	970	1,606
Observations	44,837	17,179	27,658

Notes: Replicates key paper-to-paper citation results excluding focal papers that involve an HIC co-author are excluded from the sample. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.5: Effect of TRIPS coverage on global diffusion by paper characteristics

	Number of Foreign Paper-to-Paper Citations			
	Non-Neglected Disease Papers		*Neglected Disease Papers*	
	(1)	(2)	(3)	(4)
Panel A: All Papers				
Post-TRIPS	0.052***	0.054***	0.019	0.018
	(0.011)	(0.011)	(0.014)	(0.014)
	[0.000]	[0.000]	[0.181]	[0.205]
Post-TRIPS*	0.008		0.022**	
DALYs/100,000	(0.011)		(0.007)	
	[0.417]		[0.002]	
Post-TRIPS*		-0.002		0.021**
Total DALYs		(0.010)		(0.007)
		[0.841]		[0.004]
Papers	3,136	3,136	2,077	2,077
Paper-Country-Diseases	7,573	7,573	6,467	6,467
Unique Paper-Years	42,732	42,732	26,616	26,616
Observations	82,365	82,365	60,764	60,764
Panel B: Only Single Disease-Single Country Papers				
Post-TRIPS	0.038**	0.042**	0.002	-0.015
	(0.014)	(0.015)	(0.020)	(0.022)
	[0.008]	[0.007]	[0.925]	[0. 494]
Post-TRIPS*	0.036		0.049*	
DALYs/100,000	(0.024)		(0.020)	
	[0.134]		[0.016]	
Post-TRIPS*		-0.002		0.100**
Total DALYs		(0.029)		(0.033)
		[0.937]		[0.003]
Papers	1,421	1,421	725	725
Observations	24,611	24,611	12,992	12,992
Controls	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: Replicates Table 3 with year FEs instead of disease-year FEs. In Panel A, papers with multiple diseases and author countries are weighted in inverse proportion to the number of country-disease-specific observations. In Panel B, we exclude all papers with either more than one country of author affiliation or more than one disease topic (or both) from the sample. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.6: Patent-to-paper citations as the dependent variable

	Number of Citations		
	All Papers	*Neglected Diseases*	*Non-neglected Diseases*
	(1)	(2)	(3)
Panel A: All Patent Citations			
Post-TRIPS	0.006**	0.008*	0.005^{+}
	(0.002)	(0.003)	(0.003)
	[0.007]	[0.019]	[0.093]
Panel B: Academic Patent Citations			
Post-TRIPS	0.005***	0.007**	0.005*
	(0.002)	(0.002)	(0.002)
	[0.001]	[0.005]	[0.030]
Panel C: Corporate Patent Citations			
Post-TRIPS	0.001	-0.001	0.003
	(0.002)	(0.002)	(0.003)
	[0.421]	[0.764]	[0.301]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Papers	5,079	2,024	3,055
Observations	68,219	26,183	42,036

Notes: Replicates key patent-to-paper citation results using $\ln(1+\text{N Citations}_{it})$ ss the dependent variable. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.7: Separating patent-to-paper citations from drug and non-drug patents

	Is Cited in Patent Literature					
	Cited by Drug Patent			*Cited by Non-Drug Patent*		
	All	*Neglected*	*Non-Neglected*	*All*	*Neglected*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.003	0.006*	0.001	0.003	0.005*	0.001
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
	[0.128]	[0.042]	[0.781]	[0.112]	[0.031]	[0.600]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,079	2,024	3,055
Observations	68,219	26,183	42,036	68,219	26,183	42,036

Notes: Replicates Table 5 splitting the sample by patent category. All columns report results from Linear Probability Models. In Columns (1) to (3), the dependent variable is an indicator variable denoting whether a paper is cited by any patent applied for in year *t* that is in USPC classes 424 or 514. In Columns (4) to (6), the dependent variable indicates whether a paper is cited by any patent applied for in year *t* that is not in USPC classes 424 or 514. All models contain paper year FEs and the full set of control variables. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.8: Patent citation results (disease-year FE models)

	Is Cited in Patent Literature		
	All Papers	*Neglected Diseases*	*Non-Neglected Diseases*
	(1)	(2)	(3)
Panel A: All Patents			
Post-TRIPS	0.003	0.008*	0.000
	(0.003)	(0.004)	(0.004)
	[0.213]	[0.040]	[0.975]
Panel B: Academic Patents			
Post-TRIPS	0.005**	0.006*	0.004
	(0.002)	(0.003)	(0.002)
	[0.009]	[0.049]	[0.102]
Panel C: Corporate Patents			
Post-TRIPS	-0.000	0.001	-0.001
	(0.002)	(0.003)	(0.003)
	[0.973]	[0.807]	[0.846]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Disease-Year FE	Yes	Yes	Yes
Papers	5,079	2,024	3,055
Paper-Diseases	6,369	2,870	3,499
Observations	83,724	35,518	48,206

Notes: Replicates key patent citation results in models with disease-year FEs. Results from Linear Probability Models. All models contain paper and disease-year FEs and all control variables. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.9: Patent-to-paper citations as dependent variable (by location of inventors)

	Number of Citations					
	Only Foreign Citations			*Same Country Citations*		
	All Papers	*Neglected Diseases*	*Non-Neglected*	*All Papers*	*Neglected Diseases*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Post-TRIPS	0.005**	0.005*	0.004^{+}	0.002	0.003	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
	[0.005]	[0.026]	[0.070]	[0.185]	[0.239]	[0.370]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,080	2,025	3,055
Observations	68,219	26,183	42,036	68,226	26,190	42,036

Notes: using $\ln(1+\text{N Citations}_{it})$ ss the dependent variable. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table A.10: Excluding citations from patents with foreign priority patents, added by examiners, and only appearing on a patent's frontpage

	Is Cited in Patent Literature		
	All Papers	*Neglected Diseases*	*Non-Neglected Diseases*
	(1)	(2)	(3)
Panel A: No Foreign Priority Patent			
Post-TRIPS	0.006**	0.010**	0.004
	(0.002)	(0.003)	(0.003)
	[0.009]	[0.023]	[0.146]
Panel B: Only Applicant Citations			
Post-TRIPS	0.005*	0.006*	0.004
	(0.002)	(0.003)	(0.003)
	[0.013]	[0.016]	[0.156]
Panel C: Only In-Text Citations			
Post-TRIPS	0.004*	0.005*	0.003
	(0.002)	(0.002)	(0.002)
	[0.021]	[0.032]	[0.162]
Controls	Yes	Yes	Yes
Paper FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Papers	5,079	2,024	3,055
Observations	68,219	26,183	42,036

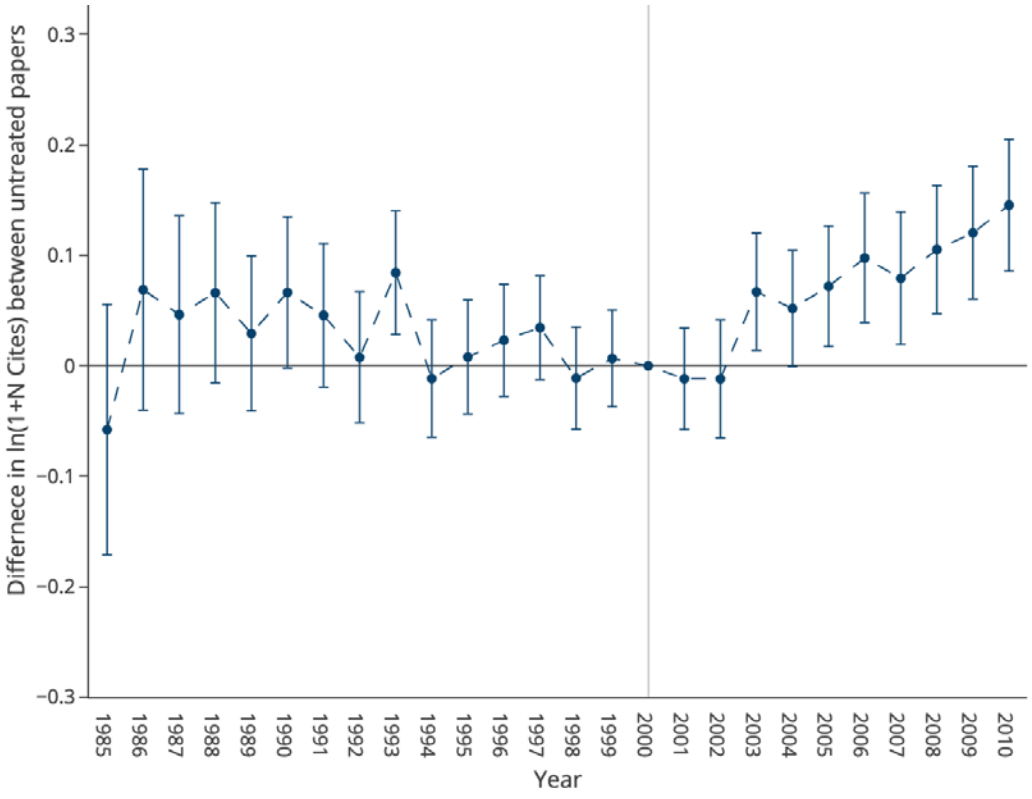
Notes: Replicates Table 5 restricting patent citations by feature of the patent or the citation. All columns report results from Linear Probability Models. In Panel A, the dependent variable is an indicator variable denoting whether a paper is cited by any patent applied for in year *t* that has no foreign priority patent listed on its USPTO application. In Panel B, the dependent variable indicates whether a paper is cited by any patent applied for in year *t* where only applicant-added citations are included. In Panel C, the dependent variable indicates whether a paper is cited by any patent applied for in year *t* where citations only appearing on the frontpage of the patent and not in the body of the patent text are excluded. All models contain paper and year FEs and the full set of control variables described in the methods section of the paper. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Figure A.1: Changes in relative citation rates between neglected and non-neglected diseases

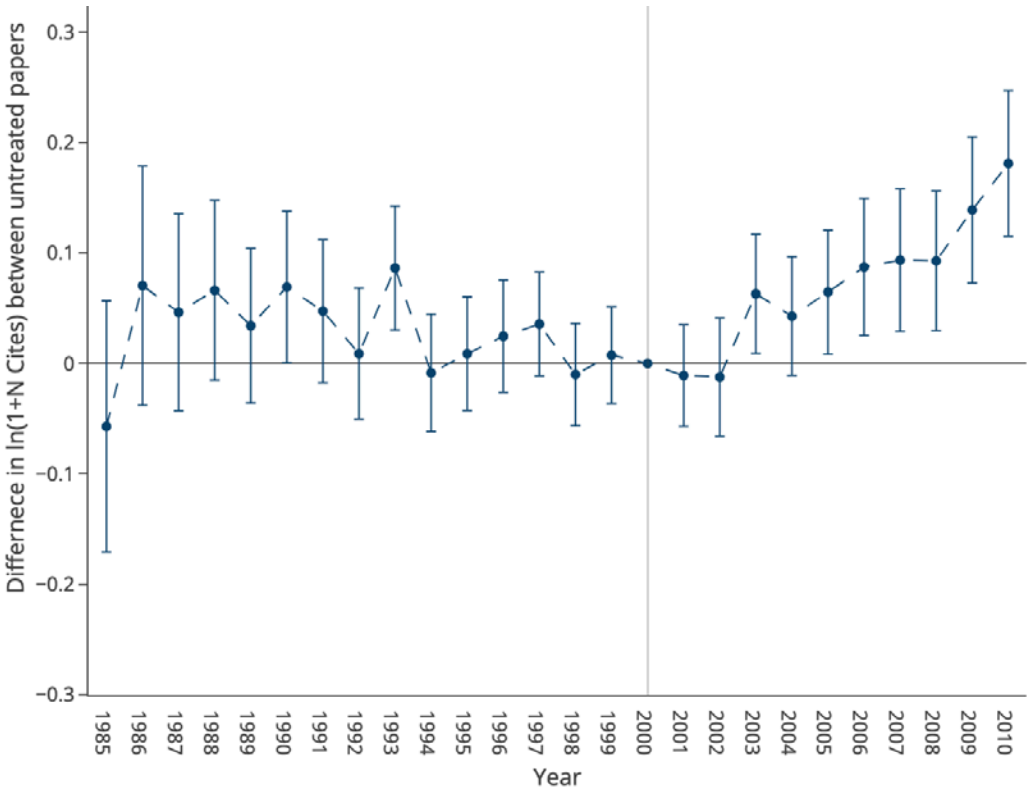
The figures in each panel show the difference in yearly paper-to-paper citations to untreated neglected disease papers and untreated non-neglected disease papers in regression models with paper and year fixed effects and the control variables used in the paper. The median year in which a paper in our sample becomes fully covered by TRIPS is 2001 for papers that are ever treated and 2005 including untreated papers. The year 2000 serves as an arbitrary base year. The error bars represent the 90% confidence intervals from the regression model estimates.

The sample for the estimates shown in Panel A includes all untreated papers to show the general trend. The sample for the estimates shown in Panel B only includes papers published before the apparent relative increase in neglected disease citation rates in 2003 to ensure that the observed trend is not driven by changes in the quality of newly published papers after this point. Finally, the sample for the estimates shown in Panel C only includes papers that are never treated to ensure that the observed trend is not driven by switch of lower quality papers from the untreated to treated groups. There are fewer observations in the earlier years of the sample leading to wider confidence intervals and a more volatile trend.

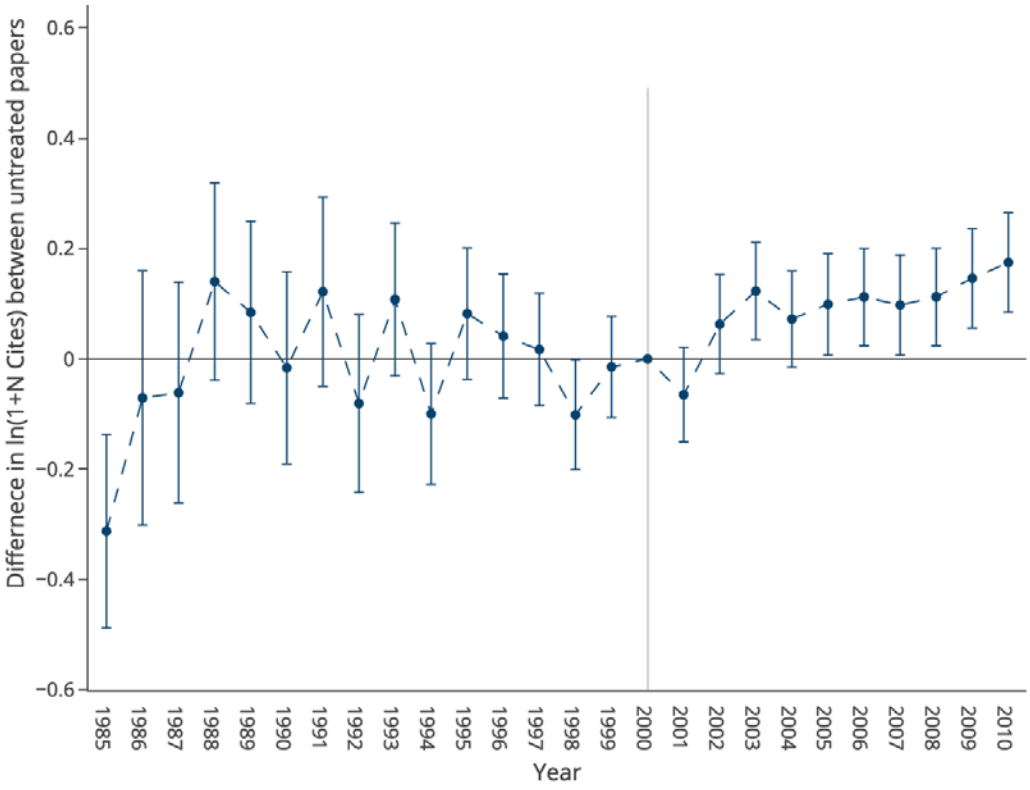
Panel A: All untreated papers



Panel B: Only untreated papers published before 2003



Panel C: Only never treated papers



Online Appendix B: Stacked Regression Results

In this section, we report the results of our core diffference-in-diferences models using stacked regression techniques (Cengiz, Dube, Lindner, and Zipperer, 2019; Baker, Larker, and Wang, 2022). This approach ensures that eariler treated units are not used as controls for later treated units in ways that could bias our results. Specifically, for each year in which any paper *i* in our sample becomes fully covered by TRIPS, we identify: (1) the set of focal papers, s^f, that become covered in that year t^*; and (2) the set of papers, s^c, that are not covered by TRIPS at t^* and are still not covered by TRIPS until more than five years after t^*. We then inclulde all observations for each paper in s^f and s^c during the period t^*-5 to t^*+5.

This yields separate 'stacks' for each year in which any paper becomes covered by TRIPS that comprises the papers that become treated in that stack and a set of control papers that are never treated in that stack's window. Thus, each ever treated papers is included in treatment set s^f in one and only one stack. Papers can serve in the control group for multiple stacks provided they are never treated in that stack's time window. Later treated papers can only serve in the control group for a focal stack if they remain untreated for the duration of that stack's window. To account for the presence of a paper in mutiple stacks, we cluster standard errors by article to allow for correlation in the error term for papers across stacks. This provides more conservative standard errors than clustering at the level of the stack or stack-paper. We weight the observations in each stack by the share of the total number of treated units in our sample that are in that stack. This is to account for differences in the size of the stacks that are due to the relative availabilty of control units for the treated units in that stack.

In all regression models we include paper-stack and year-stack fixed effects to ensure our analysis is within a given stack and within a year within that stack. We follow the emerging consensus to show how difference-in-differences results are sensitive to the inclusion of control variables, particularly parametric controls (Baker, Larker, and Wang, 2022). As a baseline, we first replicate our core results in stacked regressions with covariates that can vary across stacks. This is our main model in the paper. We include the lagged accumulated citation, WTO coverage, DALYs, and paper age fixed effects controls along with the paper-stack and year-stack fixed effects (and lagged accumulated patent citations in models with a patent citation-derived dependent variable). Hence, we are not estimating values of the control variables separately by stack, although we use paper-stack and year-stack fixed effects to control for year- and paper-specific heterogeneity within the specific stack.

Next, we exclulde all continuous covariates. We include only the WTO coverage indicator variable and age fixed effects as controls. These are theoretically important to ensure that any effects from countries' WTO accession do not confound our results and to account for differences in citation rates over a paper's lifecycle. We saturate the model by interacting the included WTO indicator and the age fixed effects with the fixed effect for each stack. We also interact the disease-year fixed effect with our stack fixed effects in the relevant models. This means that are regerssion model is estimating the TRIPS treatment effect within each stack and then yields a weighted average across stacks as our estimated coefficient. Finally, we inculde all continuous covariates in the stacked regressions. We fully saturate the model by interacting both the binary and continuous covariates with the stack fixed effects. The results are highly consistent across all three approaches.

They are also very similar to the results presented in the traditional staggered difference-in-differences analysis in the main body of the paper. Results from separate regressions for each stack are available from the authors on request.

Table B.1: Replication of core paper-to-paper citation results in stacked regressions

	Number of Citations					
	Paper and Year FE			*Paper and Disease-Year FE*		
	All Citations	*Only Foreign Citations*	*Same Country Citations*	*All Citations*	*Only Foreign Citations*	*Same Country Citations*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Using Baseline Specifications						
Post-TRIPS	0.056***	0.058***	0.007	0.024*	0.025*	-0.011
	(0.012)	(0.011)	(0.009)	(0.012)	(0.011)	(0.010)
	[0.000]	[0.000]	[0.466]	[0.050]	[0.027]	[0.266]
Panel B: No Time-varying Covariates						
	0.056***	0.058***	0.005	0.026^{+}	0.026*	-0.011
	(0.012)	(0.012)	(0.009)	(0.014)	(0.013)	(0.011)
	[0.000]	[0.000]	[0.576]	[0.058]	[0.042]	[0.307]
Panel C: All Covariates Interacted by Stack						
	0.057***	0.057***	0.008	0.028*	0.027*	-0.012
	(0.012)	(0.011)	(0.009)	(0.013)	(0.012)	(0.011)
	[0.000]	[0.000]	[0.413]	[0.040]	[0.029]	[0.287]
Paper-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Disease-Year FE	No	No	No	Yes	Yes	Yes
Papers	5,217	5,217	5,217	5,217	5,217	5,217
Paper-Diseases	–	–	–	6,528	6,528	6,528
Papers-Stacks	28,991	28,991	28,991	28,991	28,991	28,991
Paper-Diseases-Stacks	–	–	–	36,394	36,394	36,394
Observations	154,416	154,416	154,416	194,598	194,598	194,598

Notes: The dependent variable is measured as $\ln(1+\text{N Citations}_{it})$. Models in Panel A include paper-stack and year-stack FEs along with the control variables from the equivalent regressions in Table 2. Models in Panel B exclude the continuous control variables and interact the other control variables with the stack FE (full WTO coverage indicator, age FE, and disease-year FE in Models (4) to (6)). Models in Panel C interact includle continuous control variables and interact all the control variables with the stack FE. Observations are weighted in each stack according to the share of treated units in the full sample that are in that stack. The 976 papers with multiple diseases are inversely weighted according to the number of diseases in the paper (multiplied by the stack weight). Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table B.2: Replication of core patent citation results using stacked regressions

	Is Cited in Patent Literature		
	All Papers	*Neglected Diseases*	*Non-neglected Diseases*
	(1)	(2)	(3)
Panel A: Using Baseline Specifications			
Post-TRIPS	0.004	0.011*	0.002
	(0.003)	(0.005)	(0.004)
	[0.160]	[0.040]	[0.575]
Panel B: No Time-varying Covariates			
Post-TRIPS	0.004	0.010*	0.001
	(0.003)	(0.005)	(0.004)
	[0.192]	[0.035]	[0.899]
Panel C: All Covariates Interacted by Stack			
Post-TRIPS	0.004	0.011*	0.002
	(0.003)	(0.005)	(0.004)
	[0.204]	[0.033]	[0.693]
Paper-Stack FE	Yes	Yes	Yes
Year-Stack FE	Yes	Yes	Yes
Papers	5,079	2,024	3,055
Papers-Stacks	28,456	11,991	16,465
Observations	152,259	67,386	84,873

Notes: All columns report results from Linear Probability Models. The dependent variable is an indicator variable that is equal to one if a focal paper *i* is cited by any USPTO patent applied for in year *t*, and zero otherwise. In Column (1), the sample includes all papers. In Column (2), the sample is restricted to only include neglected disease paper. In Column (3), the sample is restricted to only include non-neglected disease papers. Control variables are as per the notes to Table B.1 with the addition of the lagged cumulative patent-to-paper citation control variable, which is treated like other continuous time-varying control variables. Observations are weighted in each stack according to the share of treated units in the full sample that are in that stack. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table B.3: Replication of patent citation results by assignee using stacked regressions

	Is Cited in Patent Literature					
	Academic Patents			*Corporate Patents*		
	All Papers	*Neglected Diseases*	*Non-Neglected*	*All Papers*	*Neglected Diseases*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Using Baseline Specifications						
Post-TRIPS	0.005*	0.009*	0.003	-0.000	0.000	-0.000
	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
	[0.030]	[0.022]	[0.205]	[0.883]	[0.967]	[0.888]
Panel B: No Time-varying Controls						
Post-TRIPS	0.004^{+}	0.008*	0.002	0.000	0.000	-0.001
	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
	[0.052]	[0.022]	[0.349]	[0.920]	[0.970]	[0.827]
Panel C: All Covariates Interacted by Stack						
Post-TRIPS	0.005*	0.009*	0.003	-0.001	0.001	-0.001
	(0.002)	(0.004)	(0.003)	(0.002)	(0.004)	(0.003)
	[0.036]	[0.031]	[0.300]	[0.779]	[0.866]	[0.813]
Paper-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,079	2,024	3,055
Papers-Stacks	28,456	11,991	16,465	28,456	11,991	16,465
Observations	152,259	67,386	84,873	152,259	67,386	84,873

Notes: All columns report results from Linear Probability Models. The dependent variable is an indicator variable that is equal to one if a focal paper *i* is cited by any USPTO patent applied for in year *t*, and zero otherwise. In Columns (1) to (3) only citations from a patent with an academic assignee are included in constructing the dependent variable. In Columns (4) to (6) only citations from a patent with a corporate assignee are included in constructing the dependent variable. In Columns (1) and (4), the sample includes all papers. In Columns (2) and (5), the sample is restricted to only include neglected disease papers. In Columns (3) and (6), the sample is restricted to only include non-neglected disease papers. Control variables are included as per the notes to Table B.2. Observations are weighted in each stack according to the share of treated units in the full sample that are in that stack. Standard errors clustered by paper are in parentheses with p-values in brackets. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.

Table B.4: Replication of patent citation results by location using stacked regressions

	Is Cited in Patent Literature					
	Only Foreign Citations			*Same Country Citations*		
	All Papers	*Neglected Diseases*	*Non-Neglected*	*All Papers*	*Neglected Diseases*	*Non-Neglected*
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Using Baseline Specifications						
Post-TRIPS	0.005*	0.007^{+}	0.005	0.000	0.004	-0.002
	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
	[0.038]	[0.073]	[0.117]	[0.951]	[0.224]	[0.559]
Panel B: No Time-varying Covariates						
Post-TRIPS	0.005*	0.006^{+}	0.005	-0.000	0.004	-0.003
	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
	[0.025]	[0.078]	[0.126]	[0.829]	[0.197]	[0.290]
Panel C: All Covariates Interacted by Stack						
Post-TRIPS	0.005*	0.007^{+}	0.005	-0.000	0.004	-0.003
	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
	[0.043]	[0.072]	[0.102]	[0.886]	[0.211]	[0.336]
Paper-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Stack FE	Yes	Yes	Yes	Yes	Yes	Yes
Papers	5,079	2,024	3,055	5,079	2,024	3,055
Papers-Stacks	28,456	11,991	16,465	28,456	11,991	16,465
Observations	152,259	67,386	84,873	152,259	67,386	84,873

Notes: All columns report results from Linear Probability Models. The dependent variable is an indicator variable that is equal to one if a focal paper *i* is cited by any USPTO patent applied for in year *t*, and zero otherwise. In Columns (1) to (3) only citations from a patent that has no inventor located in the same country as at least one of the author of the focal paper are used in constructing the dependent variable. In Columns (4) to (6) only citations from a patent that has at least one inventor located in the same country as at least one of the authors of the focal paper are used in constructing the dependent variable. In Columns (1) and (4), the sample includes all papers. In Columns (2) and (5), the sample is restricted to only include neglected disease papers. In Columns (3) and (6), the sample is restricted to only include non-neglected disease papers. Control variables are included as per the notes to Table B.2. Observations are weighted in each stack according to the share of treated units in the full sample that are in that stack. Standard errors are clustered by paper. ***p<0.001, **p<0.01, *p<0.5, $^{+}$p<0.1.