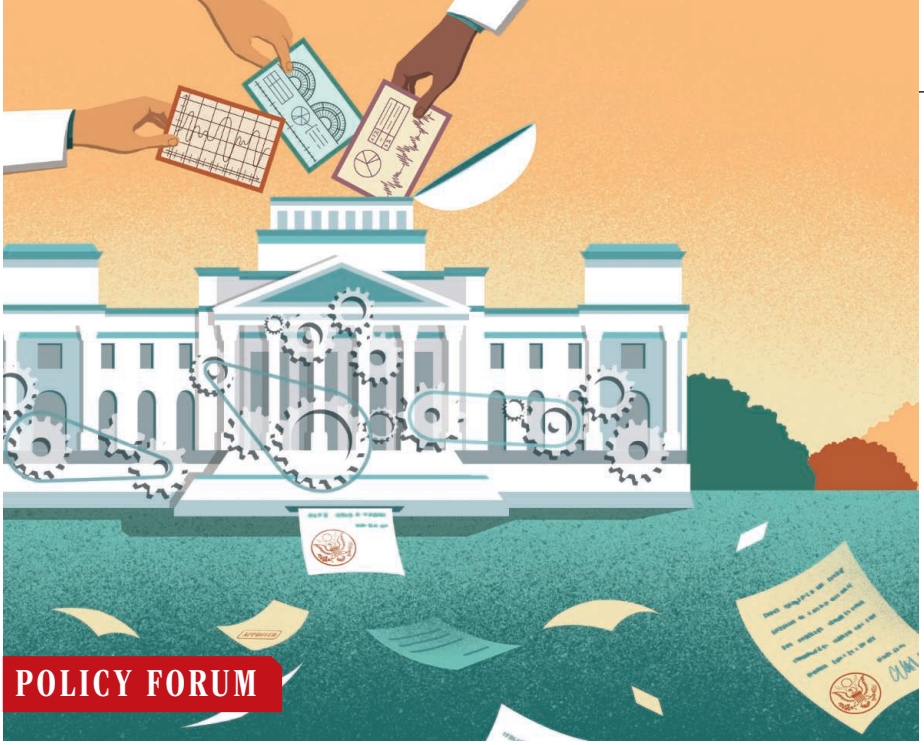

POLICY FORUM

SCIENCE FOR POLICY: COVID-19

Coevolution of policy and science during the pandemic

Recent, high-quality science is being heard, but unevenly

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Disconnects between science and policy, in which important scientific insights may be missed by policymakers and bad scientific advice may infect decision-making, are a long-standing concern (*1*–*7*). Yet, our systematic understanding of the use of science in policy remains limited (*1*, *4*–*6*), partly because of the difficulty in reliably tracing the coevolution of policy and science at a large, global scale (*3*). Today, the world faces a common emergency in the COVID-19 pandemic, which presents a dynamic, uncertain, yet extraordinarily consequential policy environment across the globe. We combined two large-scale databases that capture policy and science and their interactions, allowing us to examine the coevolution of policy and science during the pandemic. Our analysis suggests that many policy documents in the COVID-19 pandemic substantially access recent, peer-reviewed, and high-impact science. And policy documents that cite science are especially highly cited within the policy domain. At the same time, there is a heterogeneity in the use of science across policy-making institutions. The tendency for policy documents to cite science appears mostly concentrated within intergovernmental organizations (IGOs), such as the World Health Organization (WHO), and much less so in national governments, which consume science largely indirectly through the IGOs. This close coevolution between policy and science offers a useful indication that a key link is operating, but it has not been a sufficient condition for effectiveness in containing the pandemic.

The rapid production of new science during COVID-19 raises key questions about its use in policy during the pandemic. There is long-standing skepticism over connections between science and policy, which are often thought to be highly disconnected spheres. For example, the "two communities" theory in knowledge utilization (*7*) highlights a substantial gap between scientists and policy-makers, disconnecting research from the policy process. Related viewpoints suggest that policy-makers may not be able to distinguish relatively robust scientific ideas from less established ones (*2*). Particularly in the pandemic setting, there is substantial concern that policy may take up nonvetted and potentially incorrect scientific results. For example, preprint servers have played an outsized role in disseminating COVID-19–related research (*8*). Although open science greatly facilitates the sharing of data and research (*8*) and allows the wider community to check and interrogate the results and claims, publicly releasing science before it passes peer review may undermine the rigor of scientific evidence accessible to the public (*9*). In the age of misinformation, this may create enduring harms if the evidence presented turns out to be less robust. Such concerns are further heightened by examples of widely reported and then retracted results regarding COVID-19 (*10*).

To explore COVID-19 science and policy, we harnessed a large-scale database, Overton, which records policy documents sourced globally from government agencies, think tanks, and IGOs. For each policy document, we then matched scientific references to our second dataset, Dimensions, a large-scale publication and citation database, offering a distinct opportunity to examine the role of science in the global policy response to COVID-19. Further details on all data collection, integration, and analyses (including examples of policy documents and the scientific papers they reference, systematic comparisons with alternative data sources, and external validations on the overall coverage of our datasets) are provided in the supplementary materials (SM).

POLICY, SYNCHRONY, SHIFTS

Our Overton dataset captures 37,725 policy documents published by government agencies and think tanks from 114 countries and 55 IGOs, from 2 January to 26 May 2020. Policy documents are defined by Overton as "research, briefs, reviews, or reports written with the goal of influencing or changing policy," and scientific and policy references are demarcated within each document. The data includes all major economies and large population centers, with a notable exception of mainland China. Together, our data cover 66.3% of the world population, 79.3% of total gross domestic product, and 95.6% of confirmed deaths worldwide due to COVID-19 (as of 30 May 2020). Within this corpus, we identified COVID-19–related policy documents through keyword filtering (7730 documents in total), which allowed us to compare COVID-19 policy documents with all other policy documents published in 2020 (see SM for data description and validation).

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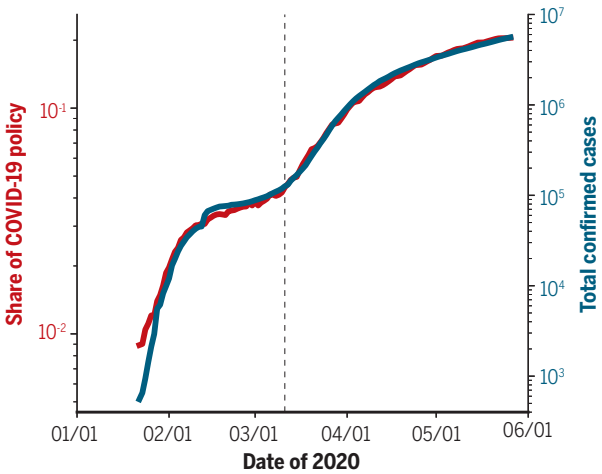
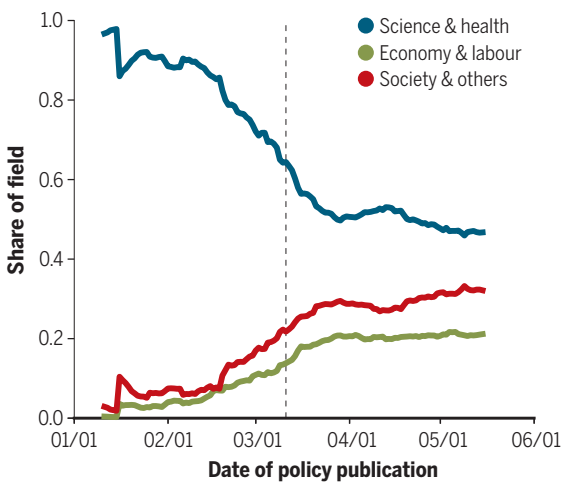
As a first look at the policy data and its practical relevance, we examined how the evolution of COVID-19 policy documents corresponds to facts on the ground. The policy documents mirror the case dynamics (see the first figure), showing a synchrony between the share of COVID-19 policy documents among all policy documents and the number of total confirmed cases (see SM for fit statistics).

We further examined the content of the COVID-19 policy documents, breaking them down by field (see the first figure) and topic (fig. S7). Both analyses show substantial shifts in policy attention related to the pandemic. In the early stage of the outbreak (January and February 2020), about 90% of COVID-19 policy documents belong to the health and science category, showing a clear, initial focus on medical and public health issues. The policy priorities show a visible shift, however, since WHO declared COVID-19 a pandemic on 11 March 2020, with a rise in attention to issues around the economy and society, suggesting a growing policy balance between health and socioeconomic implications of the pandemic. These shifts are observed in COVID-19 policy documents only; we repeated the analyses for other policy documents published in the same period, finding that the distributions of fields and topics remained relatively stable during this period (see SM).

The evolution of policy during the pandemic



The share of COVID-19 policy documents among all policy documents published up to a given day (red line) versus the global confirmed case count (blue line), as traced by the Johns Hopkins COVID-19 tracking map (*15*).



The share of three broad subject categories within the COVID-19 policy documents (21-day moving average).

POLICY FRONTIER ROOTED IN SCIENCE

Much like the global policy frontier, the scientific understanding of COVID-19 also evolved rapidly, as exemplified by the strong response from the global research enterprise. According to Dimensions data, more than 40,000 papers on coronavirus research were published from 1 January through 30 May 2020. Our findings reveal close connections between the evolving COVID-19 policy frontier and the evolving scientific frontier.

The fraction of COVID-19 policy documents that cite at least one scientific paper fluctuates in early 2020 but then features a steady increase with time, especially after WHO's pandemic declaration (fig. S12A). Also, COVID-19 policies are disproportionately centered on the latest scientific frontier (see the second figure). Out of all scientific references drawn on by COVID-19 policy documents, 19.9% of the scientific papers were published in 2020. This rate of using the newest science is highly unusual, more than 10 times greater than seen for other policy documents. Predictably, the latest science cited is primarily related to COVID-19 (88.4%).

The close connection between science and policy is also reflected in the fields of science that COVID-19 policy documents cite (see SM), showing a clear shift from drawing primarily on the biomedical literature to citing economics, society, and other fields of study, which is consistent with overall shifts in policy focus (see the first figure). Together, these results suggest that despite the extremely recent development in COVID-19–related research, new scientific work has rapidly found its way into policy documents, prompting us to next examine the quality of scientific evidence that informs policy.

We examined the quality of science that appears in policy documents along two dimensions. First, we separated COVID-19–related papers into two groups on the basis of whether or not they are referenced by COVID-19 policy documents, and we measured each paper's scientific impact within the science community, approximated by the number of citations the paper received from other scientific papers. We found a large difference between the two groups (see the second figure): Papers referenced in policy documents garner on average 40 times more citations than those not referenced in policy documents (average citations, 67.72 versus 1.67). Overall, this result shows that the coronavirus research used by policy-makers aligns with what scientists heavily engage with themselves.

Further, we broke down the policy coverage of COVID-19 research according to publication venues (see the second figure). We found that different venues differ widely in publication volume, with preprint servers such as medRxiv, bioRxiv, and SSRN publishing an order of magnitude more COVID-19–related papers than did peer-reviewed journals. Yet despite the volume of preprints, their impact in policy is rather limited because these preprint servers show consistently fewer policy citations than average. By contrast, COVID-19 policy documents disproportionately reference peer-reviewed insights, drawing especially heavily on top medical journals, both general (such as *Lancet*) and specialized (such as *Clinical Infectious Diseases*). Although peer review does not necessarily guarantee high-quality science (*9*), amid growing concerns over the quality and abundance of coronavirus research posted on preprint servers, these results nevertheless show that during this crisis, peer-reviewed journals continue to remain a crucial institution in supplying scientific evidence for policy-making.

Overall, the COVID-19 policy frontier appears to be deeply grounded in extremely recent, peer-reviewed scientific insights, and science directly drawn on by this policy frontier appears to be especially impactful within the research community itself. Moreover, policy documents that are grounded in the scientific frontier also tend to garner substantially more ci-

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tations within the global policy network. Specifically, separating COVID-19 policy documents by whether they cite science or not, we found that COVID-19 policy documents that cite at least one scientific paper are associated with more than twice the number of citations from other policy documents (see fig. S12B). To test whether this difference in use can be explained by other covariates, we further used a regression model (see SM) to control for the policy document's source, date, number of scientific references, and self-citations, arriving at the same conclusions.

Together, these results show that despite the rapidly evolving nature of the pandemic, the policy and scientific frontier of COVID-19 are closely interlinked, with documents and articles that are directly along the policy-science interface (policy documents that cite science and the cited science itself) being more impactful within their own domains. But what policy institutions contribute most strongly to the policy-science interface? Our final analysis examines the policy institutions that cite science, comparing national governments, think tanks, and intergovernmental organizations. We found that although government agencies produced the most COVID-19 policy documents among the three types of institutions (fig. S13), they are the least likely to cite science (fig S14).

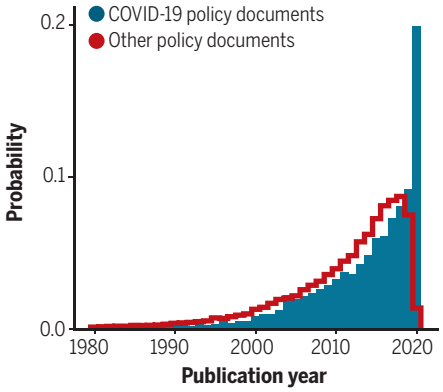
By contrast, policy documents that are grounded in science are disproportionately produced by IGOs, especially by WHO (fig. S14). These differences in the use of science persist when we compare the indirect use of science (citing other policy documents that cite science), showing that IGOs again draw disproportionately more on the policy-science interface (fig. S14, inset). Many have argued that nations work best together through international institutions, especially in a crisis such as COVID-19 (*11*). These results suggest a key role of WHO and other IGOs in the global policy response to COVID-19, acting as central conduits that link policy to science.

SCIENCE IS BEING HEARD

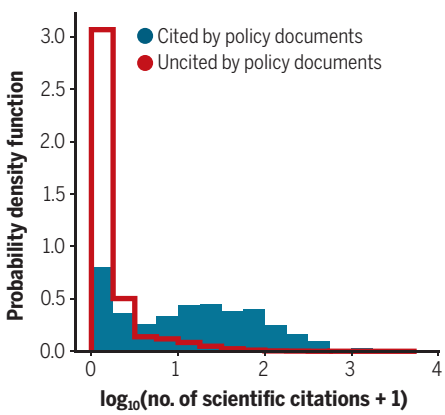
Taken together, our results show that policy documents in the COVID-19 pandemic substantially access recent, peer-reviewed, and high-impact science. At the same time, our reference-based measures are but a proxy for the uses of science in policy (*1*), and policies may cite science for different reasons (*6*). Policy-relevant science may be interpreted differently depending on one's specific interests (*4*) and may even be distorted during the dissemination process (*5*). Further, although our data captures among the largest collection of policy documents, there could be potential biases in data sample and coverage that future research may help to further elucidate. Also, our data capture science-policy interactions up to 26 May 2020, and the observed patterns may continue to evolve as the pandemic unfolds worldwide. Nevertheless, our results suggest that COVID-19 policy documents appear neither isolated from scientific advances nor reliant on dubious science. These findings appear encouraging for the scientific community as scientists, journals, and funders work expeditiously to advance and validate new research, with the hope that their work might affect the course of the pandemic.

Ultimately, although scientific advances provide a global public good, and IGOs can help coordinate global action, national policy approaches and death rates have varied greatly (*12*). Although some countries have been quite successful in containing the outbreak (*13*), some have been actively antagonistic to IGOs and scientific advice (*11*, *14*). In the current picture, science is breaking through, and scientific results are being heard, but they are not being heard everywhere. ■

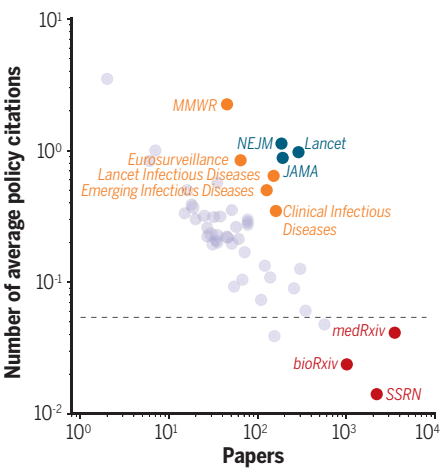
Science use in policy documents



Distribution of publication years of scientific papers (published from 1980 to 2020) cited by policy documents. The unusual spike in citing papers published in 2020 indicates that COVID-19 policy documents draw heavily on recent scientific evidence.



COVID-19 scientific papers that are cited by policy documents have greater citation impact within science.



For different journals and preprint servers, we measured the number of COVID-19 related papers (*x* axis) and the average number of citations from COVID-19 policy documents to these papers (*y* axis) in 2020. Shown here are the top 50 publication outlets based on the total number of citations from COVID-19 policy documents. The black dashed line indicates the average number of citations measured on all COVID-19 papers. *MMWR, Morbidity and Mortality Weekly Report; NEJM, The New England Journal of Medicine; JAMA, The Journal of the American Medical Association*

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SUPPLEMENTARY MATERIALS

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