Environmental Science and Policy 118 (2021) 71–85

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Effects of national affiliations and international collaboration on scientific findings: The case of transboundary air pollution in Northeast Asia

Matthew A. Shapiro [a,*], Masaru Yarime [b]

[a] Illinois Institute of Technology, United States
[b] Hong Kong University of Science and Technology, Hong Kong

ARTICLE INFO

Keywords:
Atmospheric science
Air pollution
Politicization of science
Northeast Asia
Environmental policy

ABSTRACT

In Northeast Asia, the debate among key policy actors regarding air pollution attribution is influenced by the issue's political sensitivity, but it could also be the result of variance in the scientific research. For example, we know that the springtime winds carry desert-originating dust laden with contaminants from industry and energy production out of China eastward to the Korean peninsula and Japan, but domestic contribution from South Korea and Japan must also be recognized. Science would be politicized when scientific findings are handpicked and argued over by politicians, advocacy groups, and pundits, leading key actors, including the general public, to prioritize particular results over others. In this paper we examine whether the atmospheric science literature produces research that varies depending upon funding source and international research collaboration. We survey 174 published atmospheric science studies and use scientometric methods to show that researchers based in both Japan and South Korea focus significantly more on China as the source of transboundary air pollution. China's researchers neither highlight China's air pollution contributions nor minimize them.

1. Introduction

Transboundary air pollution in Northeast Asia occurs periodically throughout the year, but there remains a debate over its origin, its effects by origin, or its precise impact (e.g., deposition, exposure). This partly reflects the challenges faced by atmospheric scientists to trace pollution back to its source given uncertainty about complex atmospheric processes. It may also reflect the fact that individual countries in the region, China in particular, are unwilling to acknowledge their role in producing pollution that flows abroad (Brettell and Kawashima, 1998; Shapiro, 2017; Tsunekawa, 2005). This scenario invokes the *politicization of science*, focusing on the debate over scientific findings by the non-science community – i.e. policy makers, interest groups, market actors, etc. – as they emphasize research findings that are in consistent with their preferences and biases. The result is the absence of a clear policy to address air pollution in the region where political rivalries and complexities preclude the establishment of an international scheme. This is very unlike other regions such as Europe, where the existence of a collection of scientists and researchers, also known as an *epistemic community*, has contributed to creating an international collaboration to address transboundary air pollution. In Northeast Asia, though, the lack of an epistemic community and sufficient collaboration among scientists and policy makers to provide a unified voice with regard to the sources of transboundary air pollution may be central to the lack of a clear path forward, and we investigate here the nature of research activities in this region to determine the extent of the political influence on science on air pollution.

It should be noted that politicization makes it very difficult for the general public to understand and respond to the air pollution problem. In this way, the transboundary air pollution in Northeast Asia could be compared to the politicization of climate science in the United States. Just as scientific consensus shapes public support for policy action with regard to climate change (Ding et al., 2011; van der Linden et al., 2015), the lack of certainty among the scientific community has led to the South Korean public's apathy or opposition to policy action with regard to Northeast Asian air pollution (Kim et al., 2015; Shapiro, 2016; Shapiro and Bolsen, 2019).

This paper examines the exact nature of the extant atmospheric science research on Northeast Asian air pollution to determine whether there is systematic influence within the scientific community. Specifically, we examine if there is variance between research that attributes Northeast Asian air pollution to a particular country and that which also

* Corresponding author.
E-mail address: shapiro@iit.edu (M.A. Shapiro).

https://doi.org/10.1016/j.envsci.2021.01.005
Received 20 July 2020; Received in revised form 6 January 2021; Accepted 8 January 2021
Available online 10 February 2021
1462-9011/

accounts for domestic contributions. There are a host of factors that could have contributed to each country's science orientation, including Japan's and South Korea's longer temporal focus on emissions reductions relative to China. However, we focus our attention here on the period starting from the late 1990s, when domestic air pollution became a shared concern across the Northeast Asia region, setting the foundation for environmental regionalism through institutions such as the Northeast Asian Conference on Environmental Cooperation (Shapiro, 2014). For the last 10–15 years, all of the key players have been working in parallel tracks to mitigate air pollution, although there are imbalances in terms of research emphasis and funding to address the transboundary air pollution problem, which we show later in the paper. That said, the field of transboundary air pollution in Northeast Asia is a well-established sub-field of atmospheric science and modeling, and China, Japan, and South Korea all play central and balanced roles.

Particular attention is given here to the researchers themselves as they are the starting point of the pipeline of research that, when addressing salient policy issues, ends with the general public. We survey the relevant science on Northeast Asian air pollution to identify the relationship between how air pollution is attributed to different countries in the region – primarily China but also accounting for domestic pollution in Japan and South Korea – and the source of research funding. We also examine the relationship between how air pollution is attributed and the logistics of the research enterprise, particularly whether or not there is collaboration across countries in the Northeast Asian region. In this way, this study is consistent with other scientometrics-oriented research focusing on international research collaborations, such as Park and Leydesdorff (2009) and Wagner and Leydesdorff (2005).

Our broader task is to identify the relevant science policy-related solutions. Cross-national efforts to address the problem have not been very robust, reflecting the aforementioned concerns regarding attribution of blame and related difficulties to foster a Northeast Asian version of the Convention on Long-Range Transboundary Air Pollution, including an acknowledgement of causality in the long-range transport of air pollution.[1] There are also enormous costs that countries in Northeast Asia would incur in order to significantly reduce air pollution. While subscribing to the view that formal, state-level channels of communication among the Northeast Asian countries are necessary, resulting in unified calls for action such as the Northeast Asia Clean Air Partnership in October 2018 (Lee, 2018) as well as the Science Panel of a new UN-back initiative, the Asia-Pacific Clean Air Partnership (UNEP, 2019), we are especially interested in the prospects for epistemic community building through research collaborations among researchers. To this end, China signed an agreement of science and technology cooperation with Japan in 1980, which provided a basis to make an agreement on bilateral environmental cooperation with Japan in 1994 (Otsuka, 2018). Since the 1990s, Japan's official development aid (ODA) to China had focused on environmental issues in response to mounting environmental problems in China, making Japan a top donor for China in terms of contract-based amounts of environmental ODA. Government officials as well as researchers in environmental sciences and technologies in China visited Japan to learn from the country's experience of developing technological measures and introducing environmental regulations to tackle air pollution. South Korea and China have opened the Korea-China Environmental Cooperation Center, which will monitor two technology-related initiatives relevant for air pollution: the Korea-China Air Quality Joint Research Team and the Korea-China Environmental Technology Demonstration Center (Ministry of the Environment of Korea, 2018). There are also a number of international initiatives for research collaboration in the region, notably, the Acid Deposition Monitoring Network in East Asia (EANET), Long-Range Transboundary Pollution of China, Japan and Korea (LTP), and the North-East Asian Subregional Programme for Environmental Cooperation (NEASPEC) (Shapiro, 2014; Yarime and Li, 2018). Since the late 1990s, scientists in Japan, South Korea, China, and beyond have been collaborating to analyze chemical transport models (CTMs), which represent the fate of atmospheric pollutants from emissions, transport, chemical reactions, and deposition. The Model Inter-Comparison Study for Asia (MICS-Asia) phase I was conducted in 1998–2000, phase II in 2003–2008, and phase III in 2010 (Carmichael et al., 2002, 2008; Itahashi et al., 2020). While this science and technology-related focus is would be essential for effective and efficient reductions in air pollution, we have not yet seen an international scheme to control transboundary air pollution firmly established in Northeast Asia.

2. Political influence on science & epistemic communities

Previous research examining the lack of a robust international scheme to address transboundary air pollution in Northeast Asia has concluded that political rivalries and a lack of trust among countries are the principal reasons for this institutional failure (Kim, 2007; Otsuka, 2018; Shim, 2017; Yoshimatsu, 2016). There is virtually no research assessing whether Northeast Asian air pollution research could be politically influenced.

In contrast to the European case, scientists in Northeast Asia might have difficulties in making collaboration given different levels of development across China, Japan, and South Korea or varying degrees of independent funding to pursue air pollution-related research. The institutional infrastructure is in place for scientists to coordinate across borders (Shapiro, 2014, 2017), but those who work on transboundary air pollution exhibited a certain degree of fragmentation (Yarime and Li, 2018). And, this occurs in spite of the fact that, every spring season, when the air pollution is particularly bad in Northeast Asia, there is plenty of media-based highlighting Chinese leaders' references to the naturally occurring yellow dust as opposed to attributing at least some transboundary air pollution to China's manufacturing and energy sectors. There is also plenty of media-based coverage of South Korean and Japanese leaders alluding to the pollution's apparent Chinese origins. In countries where pollution deposition occurs, politicians have largely avoided the issue when campaigning for office, the exception being the May 2017 presidential election in South Korea when candidates explicitly discussed the need for international coordination (Bae, 2017), and we do not know how this has impacted the relevant scientific pursuits surrounding transboundary air pollution research.[2]

We can invoke theories of the politicization of science in light of the tensions that exist among Northeast Asian leaders with regard to the attribution of regional air pollution. Politicization of science refers to a communication strategy where actors may focus on scientific uncertainty as a means of casting doubt on the existence of scientific consensus around an issue (Bolsen and Druckman, 2015). This effectively limits the flow of credible scientific information and generates general distrust in scientific evidence when used as part of a political argument (Bolsen et al., 2014). Like the case of climate science in the United States (Ding et al., 2011; van der Linden et al., 2015), political influence on the science of Northeast Asian air pollution can be more easily countered when the research community itself holds a consensus view. Conversely, a divided science community provides fuel for key policy actors who are prone to influence the science, again consistent with how climate change science has been politicized in the United States (Oreskes and Conway, 2010; Pielke, 2007).

In this research, we examine the possibility that the science of air pollution in Northeast Asia could be influenced by political

[1] The Convention on Long-Range Transboundary Air Pollution engages countries in Europe and North America and explicitly outlines in the Gothenburg Protocol the connections between source and deposition of air pollution.

[2] Concerns about pollution deposition now extend beyond "acid rain" but account for particulates, ozone, and heavy metals, all of which have negative health implications.

considerations. We hypothesize that the roots of political influence on science rest in the source of the research funding. Referring again to the climate change issue, there is evidence that funding source has been correlated with ideological polarization of the climate change issue (Farrell, 2016), ultimately threatening the integrity of the science community (Guston, 2000). Given the international nature of the Northeast Asian air pollution problem, the funding differences that are most relevant here are expected to be those that are distinguished by their country-level affiliations. To clarify, we expect that funding from a particular country will lead to differentiated levels of attribution regarding Northeast Asian air pollution's source and propose the following two hypotheses:

H1. Research funding from a specific country is negatively associated with research that attributes transboundary pollution to that country

H2. Research funding from a specific country is positively associated with research that attributes transboundary pollution inflows to other countries.

Funding sources may identify research targets explicitly, implicitly, or not at all. We leave open the exact nature of how funding sources identify their targets with regard to each country's air pollution problem in the context of potential transboundary air pollution in Northeast Asia.

We also hypothesize that a proxy for the impact of funding may simply be the country-level affiliation of the researchers themselves. For example, China-based researchers may be expected to focus less on research that attributes South Korean and Japanese pollution to Chinese sources, while South Korean and Japanese researchers may be expected to focus more on identifying the source or nature of their air pollution inflows. We propose the following two hypotheses that are parallel with H1 and H2:

H3. Research with members from a specific country is negatively associated with research that attributes transboundary pollution to that country

H4. Research with members from a specific country is positively associated with research that attributes transboundary pollution to other countries.

Countering the potential for political influence on science with regard to transboundary air pollution, we invoke the notion of epistemic communities. Interdependence across states increases cooperation among countries (Keohane and Nye, 1989), and technology-based relationships between countries are connected to cross-national attempts to address environmental concerns (Young, 1990). With regard to Northeast Asia specifically, it has been shown that ecologists within and between countries avoid politicization while advancing environmentally-oriented technologies (Shapiro, 2014). In other words, international research collaborations are already occurring within the region to address problems analogous to air pollution: renewable energy production, electric vehicles, reduction in fossil fuel use, etc. However, there has not yet been clear evidence of the presence of an epistemic community in the region with regard to air pollution-related research, and there are indications that, in Northeast Asia, there was an increasing fragmentation of epistemic communities of scientists who are working on transboundary air pollution (Yarime and Li, 2018).

Assuming that the presence of an epistemic community around air pollution-related science is present and manages to remain relatively free of political concerns, we hypothesize that collaborations between countries will produce research findings that are distinct from non-collaborative research. That is, research teams that are comprised of individuals based in multiple countries are less likely to generate research findings that attribute transboundary pollution to a specific country. Scientists involved in these international collaborations might attempt to avoid stirring political outcomes or implications and instead focus on basic research, perhaps on the mechanisms rather than the sources, of air pollution. At an exploratory level, we also test for whether these same multi-country research collaborations are unique from individual-country efforts in terms of the nature of the research itself, producing more basic research. This would arguably lay a deeper foundation for the fields of atmospheric and pollution transport sciences. To be clear, we hypothesize the following:

H5. Research teams that are comprised of individuals based in multiple countries are less likely to generate research findings that attribute transboundary air pollution to a single country.

H6. Research teams that are comprised of individuals based in multiple countries are more likely to produce research that is general/basic in nature with regard to air pollution than research teams that are comprised of individuals based in a single country.

We currently have virtually no understanding of how attribution-related claims are associated with the corpus of atmospheric science research. If certain aspects of an article's research focus predict specific findings regarding pollution attribution, we will make this clear below. Thus, in anticipation of other aspects of Northeast Asian transboundary air pollution-related research not covered by the aforementioned hypotheses, particularly those connected to the extent to which an article attributes pollution, we propose the following exploratory research question:

RQ: What is the relationship between the content of an article and its likelihood that it will attribute pollution to a particular country/countries?

3. Sample construction

The corpus of Northeast Asian transboundary air pollution research upon which we focus is indexed in the Web of Science (WoS; Clarivate Analytics) database. WoS is internationally renowned and a frequent population from which samples are drawn for scientometric analysis (Wagner and Leydesdorff, 2005). One might argue that the English-only population of articles listed in the WoS would create some sort of bias among researchers in the Northeast Asian region. Analysis of scientific output using WoS-based data based shows that China is one of the most research-producing countries in the world (Zhou and Leydesdorff, 2006).

Focusing our attention on those articles that are most relevant for transboundary air pollution-related science, we initially limited our search of the WoS database to those articles, reviews, proceedings papers, etc. that have the topics of "air pollution" and either "Asia" or "East Asia". Based on these parameters, a sample of 2136 articles was downloaded from the WoS website in mid-2019.[3] Two additional steps were taken to identify the most relevant articles. First, to focus on transboundary air pollution-related articles, the original sample of 2136 articles was limited to 783 based on the requirement that abstracts contain one or more of the following keywords: "transport" (363 articles), "source" (331 articles), "regional" (244 articles), "origin" (120 articles), "trans-boundary" or "transboundary" (36 articles), and "international" (31 articles). Second, to narrow the focus on China and the propensity for eastward transboundary air pollution in Northeast Asia, articles were limited to those with abstracts containing the terms "China" or "Asian continent" (717 articles) as well as articles with abstracts containing "Korea" (199 articles) or "Japan" (161 articles). Any reference to areas outside of Northeast Asia, such as Southeast Asia (7 articles), represented overlapping content with Northeast Asia. With these restrictions in place, our WoS-derived sample of articles with abstracts containing both the transboundary air pollution and Northeast Asian geographic

[3] The data were downloaded on May 25, 2019.

Table 1
Share of total publications by institution.

	Institution (country) / %
1	Natl Inst Environm Studies (Japan) / 4.76
2	Chinese Acad Sci (China) / 3.64
3	Seoul Natl Univ (South Korea) / 2.94
4	Kyushu Univ (Japan) / 2.52
5	Natl Inst Environm Res (South Korea) / 1.96
6	Univ Iowa (USA) / 1.82
7	Japan Agcy Marine Earth Sci & Technol (Japan) / 1.54
8	Argonne Natl Lab (USA) / 1.26
9	Cent Res Inst Elect Power Ind (Japan) / 1.26
10	NASA (USA) / 1.26
11	NOAA (USA) / 1.26
12	Fukuoka Inst Hlth & Environm Sci (Japan) / 1.12
13	Tokyo Univ Agr & Technol (Japan) / 1.12
14	Korea Ctr Atmospher Environm Res (South Korea) / 0.98
15	Kyoto Univ (Japan) / 0.98
16	Nagoya Univ (Japan) / 0.98
17	Nanjing Univ (China) / 0.98
18	Ewha Womans Univ (South Korea) / 0.84
19	GIST (South Korea) / 0.84
20	Nagasaki Univ (Japan) / 0.84
21	Natl Taiwan Univ (Taiwan) / 0.84
22	Yonsei Univ (South Korea) / 0.84
23	Hankuk Univ Foreign Studies (South Korea) / 0.70
24	Harvard Univ (USA) / 0.70
25	Japan Meteorol Agcy (Japan) / 0.70

foci consisted of 198 articles.[4]

Additional information is automatically provided by the WoS, including each article's entire abstract, the authors' names, and the authors' affiliations. Based on counts of authorship by institutions, the top twenty-five most-prolific article producers are presented in Table 1,[5] and a more complete list of the top-100 institutions is included in the appendix. Among those institutions engaged in the generation of publications in line with transboundary air pollution in Northeast Asia, Chinese institutions are less likely to be involved, the exceptions being the Chinese Academy of Sciences and Nanjing University.[6]

Information is also provided in the WoS database regarding WoS-based research categories. To determine the co-occurrence of research categories, we calculated the network statistics for these research categories. Given our focus on the atmospheric sciences, the most central (i.e. co-occurring) research categories of our sample are "environmental sciences," "meteorology and atmospheric sciences," "water resources," and "engineering, environmental". The WoS also provides an automatically-generated keyword list via its KeyWords Plus feature, which produces a maximum of ten keywords per article that are based on phrases frequently appearing in the titles of an article's references but not in the title of the article itself. This is especially helpful when author-generated keywords are few or entirely missing, although we acknowledge that KeyWord Plus-based keywords by themselves do not provide the most accurate representation of the article content itself. Presented in Fig. 1 is the network structure (Fruchterman-Reingold algorithm-derived) of how these keywords co-occur – i.e. appear together – in the titles of an article's references (but not in the title of the article itself) across the population of articles.[7] For reasons of clarity, we label only the top 50 most commonly appearing keywords in Fig. 1, indicating that the primary focus of these articles is transboundary air pollution in Northeast Asia. Table 2 presents the degree and betweenness centrality for the top 25 most central (i.e. co-occurring) terms among the KeyWords Plus keywords.

4. Variable identification

It was necessary to confirm that each article was in fact discussing transboundary air pollution in Northeast Asia. To this end, we conducted a content analysis of each article's abstract, in line with Krippendorff (2019) and a host of research that uses article abstracts to for content analysis in health communication (Beck et al., 2004; Manganello and Blake, 2010), industrial organization (Scarbrough et al., 2005), and information technology (Raub and Rüling, 2001). In spite of the strict conditions employed when curating our sample of articles from the WoS database, our content analysis revealed a number of articles that were off-topic. These included articles that strictly focused on the epidemiological aspects of air pollution, mentioning China as a potential source but with no substantiation. Other disqualified articles focused on geographic areas unrelated to our Northeast Asian focus or on ocean pollution. In total, 24 articles were deemed off-topic, reducing the sample to 174 articles.

We also used content analysis of article abstracts to identify the dependent variables of our hypotheses.[8] Our content analysis of the 174 articles focused first on whether China's pollution was referenced in the context of transboundary air pollution flows to Japan (74 articles) or to South Korea (74 articles). We also documented whether a pollution source other than China was referenced in the abstract. These other sources referred to domestic contributions from within Japan or South Korea, to a source outside of the East Asian region, or to an international source, such as a body of water. To be clear, our coding scheme was based on whether a source was clearly attributed as a source of pollution. Thus, in an article abstract, if pollution was not attributed explicitly to China, Japan, South Korea, etc., one could assume that it was not a sufficiently relevant and reportable scientific finding. Among this sample of 174 articles focusing on Chinese pollution in some form, 40 refer to domestic pollution in Japan, 16 refer to domestic pollution in South Korea, and 17 refer to a source of pollution beyond China, Japan, or South Korea. These efforts produced the dependent variables for our first five hypotheses (H1-H5) as well as for our exploratory research question (RQ).

We also note here our efforts to identify research focusing on basic and/or general research on air pollution, which typically took the form of mentions of advancements in atmospheric modeling simulation or data collection and analysis. Based on our survey of the literature, research that simply conveyed pollution levels was excluded from this general research category, as it did not advance research on air pollution modeling and assessment. In this way, general research is foundational in terms its scientific contributions as well as how it advances the corpus of research with specific focus on air pollution transport within Northeast Asia. This produced the dependent variable for our sixth hypothesis (H6). The presence of this sort of content in an abstract did not preclude specific attribution of air pollution to one or more countries; among the 49 article abstracts that contained this content, 18 also mentioned air pollution attribution in specific terms, i.e. with regarding to either China, Japan, or South Korea.

Our explanatory variable for H1 and H2 is the source of funding, and we focus on the funding agencies' country affiliations. The WoS

[4] The journals from which these articles are drawn, and the frequency with which they appear in each journal, are presented in the appendix.

[5] Articles with authorships based in multiple institutions were counted more than once, as the denominator for Table 1 is the total number of authoring institutions for the entire sample of articles.

[6] Only five articles are represented by Hong Kong affiliations, and only two of those articles were authored without participation of mainland Chinese institutions. Thus, we opted to not exclude Hong Kong affiliated institutions from the "China" category.

[7] This figure was generated using NodeXL (Smith et al., 2010).

[8] All coding exercises described here involved both authors being simultaneously present. No intercoder reliability statistics are provided (or necessary) because there was complete agreement.

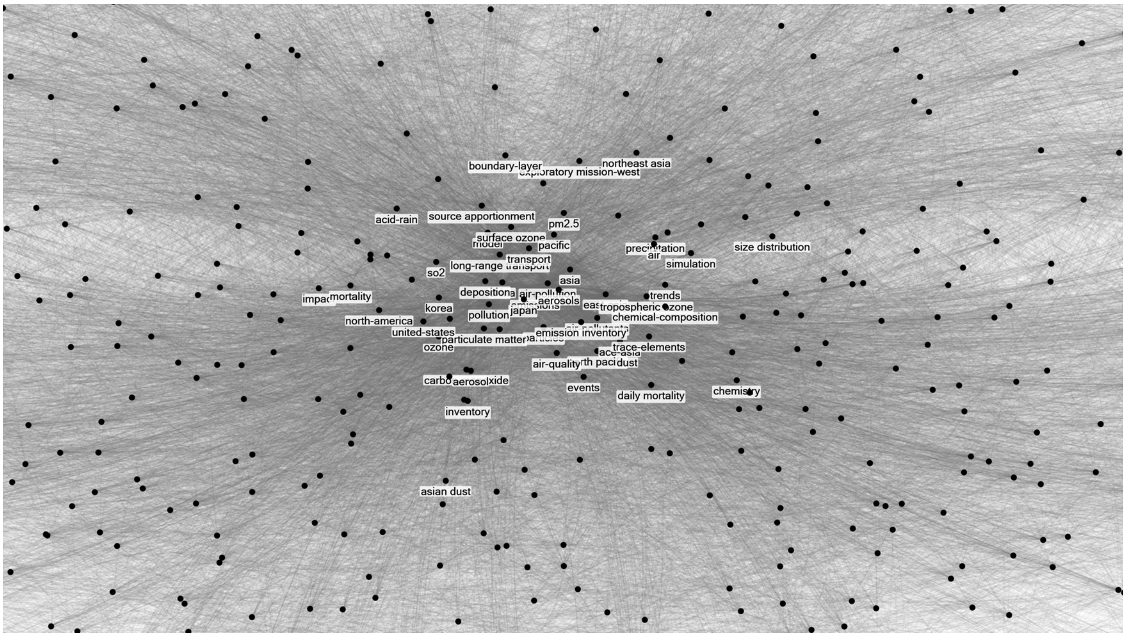

Fig. 1. Co-occurrence network of KeyWords Plus keywords.

Table 2
Statistics for KeyWords Plus keywords network.

	Degree	Betweenness centrality
air-pollution	523	18659.121
long-range transport	483	15884.305
east-asia	449	13132.143
china	444	13665.439
pollution	417	11565.813
emissions	402	10485.164
transport	321	6509.936
particulate matter	299	5608.285
model	287	5208.898
air-quality	275	4711.949
united-states	259	4286.463
particles	260	4102.288
source apportionment	251	3802.885
surface ozone	238	3339.308
ozone	216	2838.092
japan	211	2841.794
deposition	201	2389.792
aerosol	195	2165.002
asia	192	2112.898
pm2.5	186	2002.486
tropospheric ozone	174	1779.178
korea	172	1829.261
north-america	170	1759.543
emission inventory	161	1591.341
carbon-monoxide	160	1587.843

Table 3
Share of total publications by funding source.

	Funding source (country) / %
1	Japan Ministry of Environment (Japan) / 13.38
2	Korea National Research Foundation (NRF) (South Korea) / 12.27
3	Japan Min. of Education, Culture, Sports, Science and Tech. (Japan) / 10.03
4	Japan Society for the Promotion of Science (Japan) / 6.69
5	Korea Meteorological Administration (South Korea) / 5.94
6	Korea Ministry of Environment (MOE) (South Korea) / 5.57
7	China National Natural Science Foundation (China) / 4.08
8	Chinese Academy of Sciences (China) / 3.71
9	NASA (USA) / 3.71
10	U.S. Department of Energy (DOE) (USA) / 2.23
11	Korea Ministry of Education (South Korea) / 1.85
12	China National Basic Research Program (China) / 1.48
13	European Union (EU) / 1.48
14	Japan Ministry of Health, Labour, and Welfare (Japan) / 1.48
15	Korea National Institute of Environment Research (South Korea) / 1.48
16	Japan Science and Technology Agency (Japan) / 1.11
17	Korea Institute of Science and Technology (KIST) (South Korea) / 1.11
18	Kyushu University (Japan) / 1.11
19	NSERC (Nat. Sciences and Engin. Res. Council of Canada) (Canada) / 1.11
20	Aeris (CNES) (France) / 0.74
21	China Ministry of Science and Technology (MOST) (China) / 0.74
22	Hankuk University of Foreign Studies (South Korea) / 0.74
23	Otsuka Toshimi Scholarship Foundation (Japan) / 0.74
24	Seoul National University (South Korea) / 0.74
25	Steel Industry Foundation (Japan) / 0.74

database began collecting grant information in 2008, and only 121 of the 174 articles were published after 2007. The top twenty-five most-prolific funding sources of articles is presented in Table 3,[9] and a more complete list of the entire list of funding sources is included in the appendix. The basis for our explanatory variables for H3-H6 is the country-level affiliations of authors. For the 174 articles under analysis, 46 are authored by researchers with institutional affiliations in China, 85 are authored by institutional affiliations in Japan, 70 are authors by researchers with institutional affiliations in South Korea, and 65 are authored by researchers with institutional affiliations based in countries other than China, Japan, or South Korea. Fifteen articles have coauthors from both China and South Korea, 26 have coauthors from both China and Japan, and twelve have coauthors from both Japan and South Korea. Eight have coauthors from all three countries.

With regard to the explanatory variables for our exploratory research question, we automatically coded content via the KeyWords Plus feature of the WoS database. A survey of the most prolific concepts and issues presented in these articles – the 85 keywords comprising the top 50 percent of total keywords represented among our sample of articles (783 keywords total) – revealed several that are in line with our focus on transboundary air pollution in Northeast Asia. These categories include atmospheric modeling, the country-level focus, the source of pollution, pollution transport, pollution deposition, the seasonality of pollution,

[9] Articles with multiple sources of funding were counted more than once, as the denominator for Table 3 is the total number of funding sources for the entire sample of articles.

and natural sources of pollution, such as the Asian dust. Identifying these categories within the KeyWord Plus-generated list of keywords required us to identify root, non-delimited keywords as a basis for searching among the entire list of keywords. For example, “model,” the ninth most common KeyWord Plus-identified keyword from the list of 783 keywords (see appendix for an abbreviated list), is also an element of other keywords on the long list, including “climate model”, “earth system model”, and “model description”. Presented in Table 4 are the root keywords and frequency of use among the 174 articles of our sample.

Given limitations of using KeyWord Plus-related data for our analysis, particularly the fact that only references and not article titles are used to construct keywords, we constructed unique measures for the explanatory variables of our exploratory research question. These updated measures are based on whether the keywords presented in Table 4 are presented in article abstracts. We present the updated frequencies of these keywords in Table 5, and we use these new measures when attempting to answer the exploratory research question regarding article abstract content and the extent to which pollution is attributed to a particular country.

5. Methods of analysis

Our first hypothesis (H1) states that there will be a negative association between research funding from a specific country and research attributing transboundary pollution to that country. Because China is the primary origin of transboundary air pollution in Northeast Asia based on the parameters of our sample selection, we test H1 by determining whether research funding from China is negatively associated with research that attributes transboundary air pollution to China. In contrast, our second hypothesis (H2) states that research funding from a specific country is positively associated with research findings attributing pollution inflows to other countries. Given that the Northeast Asian case is focused on inflows of transboundary air pollution from China, we test H2 specifically for whether research funding from Japan or South Korea is positively associated with research attributing inflows of air pollution to China. We note again that funding-related indexing in the WoS database did not begin until sometime in 2008, requiring us to truncate our sample when testing H1 and H2.

Our third and fourth hypotheses (H3, H4) focus on the relationship between pollution attribution and the characteristics of the researchers themselves, specifically whether they are based in China, Japan, or South Korea. H3 states that research produced by researchers in a specific country will be negatively associated with findings attributing air pollution to that country, while H4 states that research produced by researchers in a specific country will be positively associated with findings attributing air pollution to other countries. We test these two hypotheses by examining whether Chinese, Japanese, or South Korean institutional affiliations relate to (1) research that attributes regional transboundary air pollution to China, (2) research that attributes Japan’s air pollution inflows to China, (3) research that attributes South Korea’s air pollution inflows to China, (4) research that accounts for Japan’s domestic contributions, and (5) research that accounts for South Korea’s domestic contributions.

Table 4
Article content categories and keyword count based on KeyWord Plus feature.

Category	Keywords	Frequency
atmospheric modeling	model*, simulat*, parameter*	51 articles
pollution source	source*,	26 articles
pollution transport	transport*, outflow*	79 articles
pollution deposition	deposition*	30 articles
seasonal focus	season*, spring, summer, winter	10 articles
sand/dust focus	dust, sand	38 articles

Note: * indicates a non-delimited keyword; ** indicates hyphenated in KeyWord Plus.

Table 5
Article content categories and keywords based on article abstracts.

Category	Keywords	Frequency
atmospheric modeling	model*, simulat*, parameter*	79 articles
pollution source	source*,	74 articles
pollution transport	transport*, outflow*	127 articles
pollution deposition	deposition*	25 articles
seasonal focus	season*, spring, summer, winter	96 articles
sand/dust focus	dust, sand	63 articles

Note: * indicates a non-delimited keyword.

Turning now to the epistemic community-related theories and the potential for researchers from China, Japan, and South Korea to work together to address the transboundary air pollution problem in Northeast Asia, we note that our fifth hypothesis (H5) states that multiple-country research teams will produce research different from individual country-based research efforts. To test H5, we examine research attributing Northeast Asian air pollution to China as well as the bilateral relationships that exist among the China-Japan and China-Korea research communities with regard to research attributing regional air pollution to China. We first look for significant effects of solely Chinese research, solely Japanese research, and China-Japan partnered research. Separately, we look for significant effects of solely Chinese research, solely South Korean research, and China-Korea partnered research. We will test our sixth hypothesis (H6) by running the same series of regressions but replacing the dependent variable – research attributing Northeast Asian air pollution to China – with research that is general/basic in nature.

To answer the exploratory research question (RQ), we conduct a series of logistic regressions where the different forms of air pollution attribution are regressed on the abstract-related content. In this way, we can understand the relationship between article content and its likelihood that it will attribute pollution to a particular country or countries. The following are the specific areas of article content under consideration: model-related content, source-related content, transport-related content, deposit-related content, dust-related content, and seasonal-related content. The dependent variables used in pursuit of RQ are Northeast Asian air pollution attributed to China, Japanese pollution attributed to China, South Korean pollution attributed to China, Japanese pollution attributed to Japan, and South Korean pollution attributed to South Korea.

All of our analysis is conducted with expectations that research foci have shifted over time as models become more robust and data availability increases. This might explain the recent increase in articles published with regard to specific types of air pollution attribution, shown in Fig. 2. Year of article publication, which ranges from 1995 to

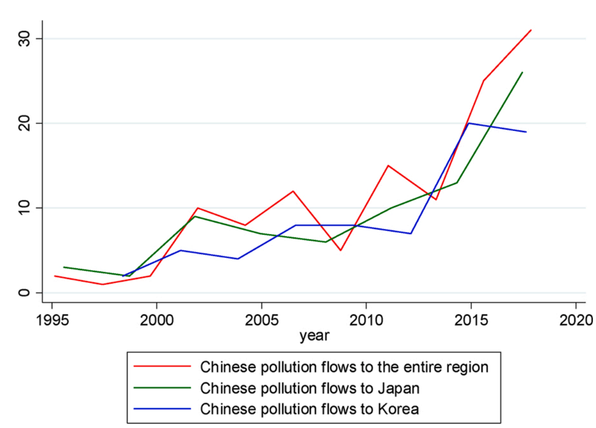

Fig. 2. Frequency of article publication with specific attribution type.
Note: 2019 data are based on publications reported in WoS database as of May 2019.

2019, is thus included as a control variable for all statistical tests.

6. Results

Presented in Table 6 are the descriptive statistics for pollution attribution, type of research, research involvement based on institutional affiliation and source of funding, and abstract content based on the nature of the article abstracts. We observe that Chinese pollution flows to the entire Northeast Asian region are mentioned in approximately 69 percent of the articles, a sub-group of which references Chinese pollution flows to Japan (42.5 percent of articles) and to South Korea (42.5 percent of articles). Twenty-three percent of articles mentioned Japanese domestic pollution explicitly, and 9.2 percent of articles reference South Korea's domestic pollution. As was mentioned earlier, features of WoS database-derived articles covering Northeast Asian transboundary air pollution are a function of our qualitative coding process, which also accounts for our identification of research that was general/basic in nature, representing 28.2 percent of all article abstracts' content.

Regarding the mean values for institutional involvement from each country, including those outside of the Northeast Asian region, 26.4 percent have researchers affiliated with Chinese institutions, 48.9 percent have researchers from Japan, 40.2 percent have researchers from South Korea, and 37.4 percent have researchers from elsewhere. Regarding funding, we truncate the sample to account for the fact that the WoS began collecting funding-related information in 2008. Among the qualifying 121 articles, 11.6 percent received funding from China, 27.3 percent received funding from Japan, 31.4 percent received funding from South Korea, and 17.4 percent received funding from elsewhere. These country-level differences could be attributed to the greater research infrastructure present in Japan and South Korea relative to China; yet, we do not expect that these differences will persist, as the funding and research presence of China has increased steadily over time. Focusing on the time period from 2015 through mid-2019, representing 79 publications (45.4 percent of our sample), 40.0 percent have researchers affiliated with Chinese institutions, 46.7 percent have researchers from Japan, and 40.0 percent have researchers from South Korea. Regarding funding, 40.0 percent received funding from China, 46.7 percent received funding from Japan, and 40.0 percent received funding from South Korea. We can expect that this gap between China and Japan/South Korea will continue to shrink.

Finally, Table 6 presents the mean and standard deviation for each of the research attributes identified with regard to transboundary air pollution. Among our sample of 174 articles, abstracts mentioned "model" content 45.4 percent of the time, "source" content was mentioned 42.5 percent of the time, and "transport" content was mentioned with the greatest prevalence, 73 percent of the time. "Deposit" content was mentioned only 14.4 percent of the time, while "dust" content was mentioned in abstracts 36.2 percent of the time, and "seasonal" content was mentioned 55.2 percent of the time.

Our statistical results are presented as logistic regressions expressed as odds ratios.[10] Based on column (1) of Table 7, we reject H1 given that the presence of Chinese funding does not negatively relate to research findings that attribute Northeast Asian air pollution to Chinese sources. However, and shown in columns (2) and (3) of Table 7, we accept H2 given that research funding from Japan and South Korea are both positively associated with research attributing pollution inflows to both countries from China. We observe that the presence of Japanese funding increases the probability of an article attributing Japanese air pollution to China by more than 11 times and that the presence of South Korean funding increases the probability of an article attributing South Korean air pollution to China by nearly 20 times.

Two sets of findings are available for our test of H3. Shown in column (4) of Table 7, we observe that the presence of researchers from Chinese institutions decreases the probability of an article presenting findings that attribute Northeast Asian air pollution to China by approximately 77 percent. On this point we accept H3. However, in column (5) of Table 7, we reject H3 given that the presence of researchers from Japanese institutions increases the probability of an article presenting findings that attribute Japanese air pollution to Japanese sources by 6.18 times. Column (6) of Table 7 shows that researchers from South Korean institutions have no effect on whether an article attributes South Korean air pollution to South Korean sources. To recapitulate, we accept H3 for the Chinese case and reject H3 with regard to the Japanese and South Korean cases.

Turning to H4, column (4) of Table 7 shows that the presence of researchers from Japan and South Korea increase the probability of an article presenting research that attributes Northeast Asian air pollution to China by, respectively, 2.78 and 4.47 times. We also accept H4 when looking specifically at research focusing on air pollution flows from China to Japan, shown in column (7), where the presence of Japanese institutions increases the probability of such findings 7.52 times. The same is true for South Korea, shown in column (8), where we note that a South Korean institution working on a research project attributing South Korean pollution to China increases such findings by 9.56 times.

Regarding H5 and H6, the epistemic community-related hypotheses, we first focus on the case of Japan, presented in column (1) of Table 8. With regard to China-originating pollution to the region, we observe that publications based on the efforts of Chinese institutions alone decrease the probability of an article presenting findings that attribute Northeast Asian air pollution to China by 93 percent. Publications based on the efforts of Japanese institutions alone have no significant impact on the probability of an article presenting the same findings, but collaboration between Chinese and Japanese institutions decreases the probability of these findings being reported by nearly 59 percent. This might suggest that, given the influence of Chinese contributions to the

Table 6
Descriptive statistics of variables.

Content of article	Number of obs.	Mean	Std. dev.	Min.	Max.
Pollution attribution characteristic (Source: qualitative content analysis of WoS article abstracts)					
Chinese pollution to region	174	0.701	0.459	0	1
Chinese pollution to Japan	174	0.437	0.497	0	1
Chinese pollution to S. Korea	174	0.420	0.495	0	1
Japanese domestic pollution	174	0.230	0.422	0	1
S.Korean domestic pollution	174	0.115	0.320	0	1
Type of research (Source: qualitative content analysis of WoS article abstracts)					
General/basic research prod.	174	0.276	0.448	0	1
Research involvement at country level (Source: WoS data)					
Chinese institution	174	0.264	0.442	0	1
Japanese institution	174	0.489	0.501	0	1
South Korean institution	174	0.402	0.492	0	1
Another country's instit.	174	0.374	0.485	0	1
Chinese funding	121	0.116	0.321	0	1
Japanese funding	121	0.273	0.447	0	1
South Korean funding	121	0.314	0.466	0	1
Another country's funding	121	0.174	0.380	0	1
Abstract content by research attribute (Source: quantitative content analysis of WoS article abstracts)					
"Model" content	174	0.454	0.499	0	1
"Source" content	174	0.425	0.496	0	1
"Transport" content	174	0.730	0.445	0	1
"Deposit" content	174	0.144	0.352	0	1
"Dust" content	174	0.362	0.482	0	1
"Seasonal" content	174	0.552	0.499	0	1

[10] Odds ratios show the multiple-times likelihood that a specific variable predicts the dependent variable. Odds ratios less than 1 decrease the probability, while odds ratios greater than 1 indicate an increased probability.

Table 7
Logistic regressions (odds ratios) for research findings attributing pollution on funding and institutional affiliation.

	(1) Chinese pollution to the region	(2) Chinese pollution to Japan	(3) Chinese pollution to South Korea	(4) Chinese pollution to the region	(5) Japanese domestic pollution	(6) South Korean domestic pollution	(7) Chinese pollution to Japan	(8) Chinese pollution to South Korea
Chinese funding	0.435 (0.260)							
Japanese funding		11.621** (5.960)						
South Korean funding			19.547** (10.611)					
Chinese institutions				0.227** (0.091)	0.806 (0.362)	0.675 (0.405)	0.595 (0.249)	0.415+ (0.198)
Japanese institutions				2.780* (1.158)	6.179** (3.185)	0.825 (0.483)	7.520** (3.058)	0.168** (0.073)
South Korean institutions				4.465** (2.003)	0.527 (0.279)	1.303 (0.756)	0.334* (0.143)	9.555** (4.192)
Year	1.048 (0.069)	0.963 (0.064)	0.988 (0.070)	1.040 (0.030)	1.056 (0.035)	1.025 (0.043)	1.017 (0.031)	1.002 (0.034)
Constant	0.000 (0.000)	0.000 (0.000)	0.000 (0.030)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
N	121	121	121	174	174	174	174	174
Chi2	2.10	29.34**	42.88**	29.95**	29.16**	0.78	59.69**	90.65**
R2	0.015	0.178	0.258	0.141	0.155	0.014	0.250	0.383

Note: +,*, and ** represent $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

Table 8
Logistic regressions (odds ratios) for research findings attributing pollution on research type and institutional affiliation.

	(1) Chinese pollution to the region	(2) Chinese pollution to Japan	(3) Chinese pollution to the region	(4) Chinese pollution to South Korea	(5) General/basic research	(6) General/basic research
Chinese instit. alone	0.070* (0.079)	0.603 (0.676)	0.090* (0.100)	0.485 (0.541)	1.087 (0.978)	1.155 (1.030)
Japanese instit. alone	1.637 (0.725)	12.227** (5.401)			0.287* (0.143)	
Chinese/Japanese instit.	0.412+ (0.190)	3.522** (1.619)			1.158 (0.547)	
Korean instit. alone			7.263** (5.492)	39.100** (29.605)		0.223* (0.142)
Chinese/Korean instit.			0.521 (0.290)	1.633 (0.925)		1.524 (0.863)
Year	1.040 (0.029)	0.994 (0.028)	1.024 (0.028)	1.021 (0.030)	0.956 (0.027)	0.973 (0.026)
Constant	0.000 (0.000)	62224.26 (3,582,616)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
N	174	174	174	174	174	175
Chi2	15.27**	43.73**	22.55**	54.03**	9.91	10.33*
R2	0.072	0.183	0.106	0.228	0.048	0.050

Note: +,*, and ** represent $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

research collaboration, China-Japan collaborations effect a political dynamic in which researchers from both sides avoid research topics that would generate results attributing air pollution to China.

There are differences, however, when we examine research findings that focus on Chinese-originating pollution in Japan. Shown in column (2) of Table 8, we observe that Japanese institutions alone increase the probability of an article presenting these findings by 12.23 times, while we also observe that China-Japan collaborations increase the probability of these findings being presented in an article by 3.52 times. Avoiding potentially politically charged findings does not seem to be the case for Japanese researchers alone or for Japanese researchers working in conjunction with Chinese researchers when focusing on Japanese pollution that has its origins in China. This same political dynamic appears to be present for China-Korean research collaborations, shown in columns (3) and (4) of Table 8. South Korean researchers working alone increase the probability of an article presenting findings that attribute Northeast Asian air pollution to China by 7.26 times (column [3]), and the probability of an article presenting findings that attribute Chinese-originating air pollution in South Korea increases by 39 times for South Korean institutions alone (column [4]). However, we find no evidence that collaborations between Chinese and South Korean institutions significantly predicts a decrease in the probability that research findings attribute air pollution to the Northeast Asian region (column [3]) or to South Korea specifically (column [4]).

Regarding H6 and the potential for multinational research teams to produce basic, more general research than single-country-based research efforts, we see no clear evidence that collaborations matter in this regard for both the Japanese or South Korean cases, presented respectively in columns (5) and (6) of Table 8. We do note, however, that Japanese institutions working alone on air pollution-related research as well as South Korean institutions working alone are significantly less likely to produce research findings that are general/basic in nature. The

Table 9
Summary of hypothesis tests by country/country combinations.

Single-country analysis	China	Japan	South Korea
H1: no self-attribution (funding)	n.s.	—	—
H2: attribution to others (funding)	—	Accept	Accept
H3: no self-attribution (institutes)	Accept[a]	Reject	Reject
H4: attribution to others (institutes)	—	Accept	Accept
Country-pair analysis		**China-Japan**	**China-Korea**
H5: no single-country attribution with cross-national teams		Mixed results	Reject
H6: more general research cross-national teams		Reject	Reject

Note: "n.s." indicates "not significant".
[a] We accept H3 with regard to research attributing Chinese pollution to the region (Table 7, column [4]) and to Korea (Table 7, column [8]) but not to Japan (Table 7, column [7]), the results of which are in the right direction but not significant.

Table 10
Logistic regressions (odds ratios) for research findings attributing pollution on article content.

	(1) Chinese pollution to the region	(2) Chinese pollution to Japan	(3) Chinese pollution to South Korea	(4) Japanese domestic pollution	(5) South Korean domestic pollution
"Model" content	0.358**	1.351	0.525+	0.880	2.035
	(0.141)	(0.454)	(0.181)	(0.342)	(1.030)
"Source" content	0.924	1.096	1.140	0.993	1.239
	(0.362)	(0.369)	(0.387)	(0.381)	(0.614)
"Transport" content	5.660**	2.653*	2.628*	4.412*	1.359
	(2.441)	(1.069)	(1.064)	(2.555)	(0.833)
"Deposit" content	0.978	2.700*	0.985	1.292	0.641
	(0.484)	(1.307)	(0.477)	(0.753)	(0.519)
"Dust" content	3.650**	1.788+	2.082*	1.357	1.361
	(1.614)	(0.624)	(0.722)	(0.543)	(0.694)
"Seasonal" content	1.045	2.227*	0.487*	1.869	1.152
	(0.401)	(0.753)	(0.164)	(0.737)	(0.574)
Year	1.060+	0.982	1.052+	1.035	1.019
	(0.032)	(0.027)	(0.029)	(0.033)	(0.042)
Constant	0.000	1.49e+15	0.000	0.000	0.000
	(0.000)	(8.13e+16)	(0.000)	(0.000)	(0.000)
N	174	174	174	174	174
Chi2	34.48**	18.80**	21.36**	13.12	3.78
R2	0.163	0.079	0.090	0.070	0.030

Note: +,*, and ** represent $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

results for this hypothesis as well as the previous five hypotheses are summarized in Table 9.

Logistic regressions of the different forms of air pollution attribution as predicted by article content are presented in Table 10 as odds ratios. Beginning with research findings attributing Northeast Asian air pollution to China, presented in column (1) of Table 10, we note that these findings decrease by more than 64 percent when an article focuses on atmospheric modeling; however, they increase with mention of pollution transport (5.66 times) and dust (3.65 times). A subset of this attribution, i.e. findings that attribute Japanese air pollution to China, is presented in column (2) of Table 10. Pollution transport-related content, deposition-related content, dust-related content, and seasonal-related content all increase this attribution focus by, respectively, 2.65 times, 2.70 times, 1.79 times, and 2.23 times. This is also largely true for research findings attributing South Korean pollution to China, shown in column (3) of Table 10: transportation-related content and dust-related content, respectively, increase the probability of this form of attribution by 2.63 and 2.08 times. However, atmospheric modeling content and seasonal content decreases the probability of South Korean pollution being attributed to China by, respectively, 4.75 percent and 51.3 percent. This was unexpected given the fact that South Korea's inflows of air pollution from China are often attributed to meteorological shifts based on seasonal changes, particularly the severe pollution during the spring and winter months in South Korea. If seasonality is not being emphasized in the scientific literature, there is less of a focus on the most severe air pollution events relative to air pollution trends over different/longer periods of time. Perhaps this reflects a general tendency to focus on annual pollution trends rather than peak events during the spring and winter seasons.

7. Conclusion

On their own, Chinese researchers are less likely to emphasize findings that attribute transboundary air pollution to China, while the individual efforts of Japanese and South Korean researchers focus especially on findings that do attribute air pollution in the Northeast Asian region to China. This paper also assesses whether Chinese research attributing transboundary air pollution to China is impacted by research collaborations between Chinese and Japanese researchers or collaborations between Chinese and South Korean researchers. We observe that international collaborations between Chinese and Japanese researchers do not always avoid research activities that would produce findings attributing transboundary air pollution to China. We also observe that collaborations between Chinese and South Korean researchers do tend to avoid research activities that would result in research findings attributing transboundary air pollution to China, implying that China-Korea collaborations may be avoiding research activities that would result in attributing transboundary air pollution to China, probably because the scientists might not want to make it clear which country is responsible for the transboundary air pollution. There is no evidence that a focus on basic or general research when identifying the source of transboundary air pollution is promoted or diminished with cross-national collaborations in the Northeast Asian region.

There is no coherent international policy scheme to address seasonal air pollution in Northeast Asia. This may be the result of the issue's complexity, namely that it results from a combination of domestic, transboundary, anthropogenic, and natural causes. The frames that have emerged in public discourse on air pollution in the Northeast Asian countries ultimately determine the considerations that are available, accessible, and applicable when individuals think about aspects of the issue. They are simultaneously strategic devices that communicators employ to influence or persuade audiences to think about a problem in a particular way. Our research intends to examine the potential political influence on science on air pollution in Northeast Asia. Our results show that Japan and South Korea focus on Chinese pollution first and foremost, and that this is significantly determined by whether, respectively, Japanese and South Korean funding is present. Japanese research also focuses on domestic contributions, but our findings indicate that South Korean research pays little attention to domestic contributions. Japan and South Korea thus seem to approach the issue of transboundary air pollution in different ways, and there may be serious implications if, as we have shown, basic research efforts are undercut when South Koreans work in isolation.

Given the evidence that research efforts from Japan and South Korea are generating research highlighting China as the source of pollution, a more defined arrangement is necessary that addresses differences in the scientific motivations between the European and Northeast Asian cases. Given the importance of research collaborations between the countries in the region on this issue, and given the role of funding, we recommend that the countries all pool their research funding to open up collaborative research opportunities for researchers in the region (the United States, Europe, etc. would of course be welcome to participate if they are willing to commit to a research focus on the Northeast Asian region's air pollution). More importantly, this pool of research funding would target international collaborations in order to institutionalize the building of an epistemic community surrounding this issue. Further, by identifying scientific enterprise that reduces potential political influence, we can have more confidence in the findings themselves, and this will likely be done in conjunction with a more transparent dialogue within the region, modeled on the Asia Pacific Clean Air Partnership (APCAP), initiated by the United Nations Environmental Programme, particularly an APCAP Science Panel to address the challenges of political influence on science to facilitate effective policy making on this issue in the Asia-Pacific region (UNEP, 2019). To end, we would encourage future research to engage in a comparative analysis of the APCAP and European/North American cases, i.e. CLRTAP. This may show how the science motivations in these two regions might be driven by distinct forms of political influence as well as other relevant factors such as funding levels.

Future research can also expand upon these findings by tracking precisely which types of researchers, institutions, and sources of funding are related to the impact of a particular article. For example, who would be more likely to cite articles that are providing compelling evidence that China is a primary source of transboundary air pollution in Japan or South Korea? An answer to such a question would help establish whether selected articles serve as the foundation for subsequent research that either reinforces or rejects such a claim. Further, in line with the current tendency to automate content identification for large datasets, future research can use the data generated from our content analysis to build a classifier to identify and hopefully predict potentially influenced research in related subject areas and geographic regions.

Author statement

Authors divided up tasks evenly.

Declaration of Competing Interest

The authors report no declarations of interest.

Appendix A

A1. Frequency of article appearance by journal

	Journal / frequency
1	ATMOSPHERIC ENVIRONMENT / 41
2	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOS.. / 25
3	ATMOSPHERIC CHEMISTRY AND PHYSICS / 21
4	AEROSOL AND AIR QUALITY RESEARCH / 12
5	SCIENCE OF THE TOTAL ENVIRONMENT / 9
6	ENVIRONMENTAL POLLUTION / 7
7	WATER AIR AND SOIL POLLUTION / 7
8	AIR QUALITY ATMOSPHERE AND HEALTH / 6
9	ASIA-PACIFIC JOURNAL OF ATMOSPHERIC S.. / 4
10	ENVIRONMENTAL SCIENCE & TECHNOLOGY / 4
11	JOURNAL OF THE AIR & WASTE MANAGEMENT.. / 3
12	JOURNAL OF THE METEOROLOGICAL SOCIETY.. / 3
13	ATMOSPHERIC RESEARCH / 2
14	BIOLOGICAL & PHARMACEUTICAL BULLETIN / 2
15	ENVIRONMENT INTERNATIONAL / 2
16	ENVIRONMENTAL MONITORING AND ASSESSMENT / 2
17	GEOSCIENTIFIC MODEL DEVELOPMENT / 2
18	JOURNAL OF ENVIRONMENTAL MANAGEMENT / 2
19	JOURNAL OF ENVIRONMENTAL SCIENCES / 2
20	SOLA / 2
21	AMBIO / 1
22	ATMOSPHERE / 1
23	ATMOSPHERIC POLLUTION RESEARCH / 1
24	AURIS NASUS LARYNX / 1
25	BULLETIN OF THE KOREAN CHEMICAL SOCIETY / 1
26	BUNSEKI KAGAKU / 1
27	CHEMICAL & PHARMACEUTICAL BULLETIN / 1
28	CURRENT OPINION IN ENVIRONMENTAL SUST.. / 1
29	ENERGIES / 1
30	ENERGY / 1
31	ENVIRONMENTAL GEOCHEMISTRY AND HEALTH / 1
32	ENVIRONMENTAL HEALTH PERSPECTIVES / 1
33	ENVIRONMENTAL MODELLING & SOFTWARE / 1
34	ENVIRONMENTAL SCIENCE AND POLLUTION R.. / 1
35	ENVIRONMENTAL SCIENCE-PROCESSES & IMP.. / 1
36	FORESTS / 1
37	FRESENIUS ENVIRONMENTAL BULLETIN / 1
38	GEOCHEMICAL JOURNAL / 1
39	GEOPHYSICAL RESEARCH LETTERS / 1
40	HUMAN GENETICS / 1
41	INDIAN JOURNAL OF MEDICAL RESEARCH / 1
42	INHALATION TOXICOLOGY / 1
43	INTERNATIONAL JOURNAL OF ENVIRONMENTA.. / 1
44	INTERNATIONAL JOURNAL OF OCCUPATIONAL.. / 1
45	JOURNAL OF AGRICULTURAL METEOROLOGY / 1
46	JOURNAL OF ATMOSPHERIC CHEMISTRY / 1
47	JOURNAL OF CLEANER PRODUCTION / 1
48	JOURNAL OF ENVIRONMENTAL INFORMATICS / 1
49	JOURNAL OF EPIDEMIOLOGY / 1
50	JOURNAL OF HAZARDOUS MATERIALS / 1
51	JOURNAL OF HEALTH SCIENCE / 1
52	JOURNAL OF THE OPTICAL SOCIETY OF KOREA / 1
53	KAGAKU KOGAKU RONBUNSHU / 1
54	MARINE RESOURCE ECONOMICS / 1
55	METEOROLOGICAL APPLICATIONS / 1
56	NANO LETTERS / 1
57	OZONE-SCIENCE & ENGINEERING / 1
58	PLOS ONE / 1
59	RESOURCES CONSERVATION AND RECYCLING / 1
60	TOXICOLOGY AND INDUSTRIAL HEALTH / 1

A2. Share of total publications by institution, first 100 listed

	Institution / %
1	Natl Inst Environm Studies / 4.76
2	Chinese Acad Sci / 3.64
3	Seoul Natl Univ / 2.94
4	Kyushu Univ / 2.52
5	Natl Inst Environm Res / 1.96
6	Univ Iowa / 1.82
7	Japan Agcy Marine Earth Sci & Technol / 1.54
8	Argonne Natl Lab / 1.26
9	Cent Res Inst Elect Power Ind / 1.26
10	NASA / 1.26
11	NOAA / 1.26
12	Fukuoka Inst Hlth & Environm Sci / 1.12
13	Tokyo Univ Agr & Technol / 1.12
14	Korea Ctr Atmospher Environm Res / 0.98
15	Kyoto Univ / 0.98
16	Nagoya Univ / 0.98
17	Nanjing Univ / 0.98
18	Ewha Womans Univ / 0.84
19	GIST / 0.84
20	Nagasaki Univ / 0.84
21	Natl Taiwan Univ / 0.84
22	Yonsei Univ / 0.84
23	Hankuk Univ Foreign Studies / 0.70
24	Harvard Univ / 0.70
25	Japan Meteorol Agcy / 0.70
26	Jeju Natl Univ / 0.70
27	Keio Univ / 0.70
28	Konkuk Univ / 0.70
29	Korea Inst Sci & Technol / 0.70
30	Meteorol Res Inst / 0.70
31	Peking Univ / 0.70
32	Asia Ctr Air Pollut Res / 0.56
33	Ctr Environm Sci Saitama / 0.56
34	Fudan Univ / 0.56
35	Georgia Inst Technol / 0.56
36	Hokkaido Univ / 0.56
37	Hong Kong Polytech Univ / 0.56
38	Kanazawa Univ / 0.56
39	Korea Univ / 0.56
40	Natl Cent Univ / 0.56
41	Natl Inst Adv Ind Sci & Technol / 0.56
42	Tsinghua Univ / 0.56
43	Univ Tokyo / 0.56
44	Univ Tsukuba / 0.56
45	Acad Sinica / 0.42
46	Beijing Normal Univ / 0.42
47	Chiba Univ / 0.42
48	Chinese Acad Meteorol Sci / 0.42
49	Chinese Res Inst Environm Sci / 0.42
50	Dalhousie Univ / 0.42
51	Gwangju Inst Sci & Technol / 0.42
52	Hanyang Univ / 0.42
53	Hosei Univ / 0.42
54	Int Inst Appl Syst Anal / 0.42
55	Korea Meteorol Adm / 0.42
56	Korea Natl Univ Educ / 0.42
57	Nagoya City Inst Environm Sci / 0.42
58	Natl Ctr Atmospher Res / 0.42
59	Osaka Prefecture Univ / 0.42
60	Osaka Univ / 0.42
61	Princeton Univ / 0.42
62	Pusan Natl Univ / 0.42
63	Sejong Univ / 0.42
64	Tokyo Metropolitan Univ / 0.42
65	Tottori Univ / 0.42
66	Toyama Univ / 0.42
67	Univ Space Res Assoc / 0.42
68	Univ Washington / 0.42
69	Acid Deposit & Oxidant Res Ctr / 0.28
70	Ajou Univ / 0.28
71	Australian Nucl Sci & Technol Org / 0.28
72	Cheju Natl Univ / 0.28
73	Chonnam Natl Univ / 0.28
74	City Univ Hong Kong / 0.28

(*continued on next page*)

(*continued*)

	Institution / %
75	Collaborat Innovat Ctr Reg Environm Q.. / 0.28
76	Emory Univ / 0.28
77	European Ctr Medium Range Weather For.. / 0.28
78	Fukuoka Univ / 0.28
79	Gachon Univ / 0.28
80	Geophys Fluid Dynam Lab / 0.28
81	Harvard Smithsonian Ctr Astrophys / 0.28
82	IIASA / 0.28
83	Inha Univ / 0.28
84	Inje Univ / 0.28
85	JAMSTEC / 0.28
86	KARI / 0.28
87	KMA / 0.28
88	Kobe Univ / 0.28
89	Korea Inst Ocean Sci & Technol / 0.28
90	Korea Res Inst Stand & Sci / 0.28
91	Kyoto Pharmaceut Univ / 0.28
92	Kyungpook Natl Univ / 0.28
93	Nagasaki Prefectural Environm Affairs.. / 0.28
94	Natl Chung Hsing Univ / 0.28
95	Natl Inst Agroenvironm Sci / 0.28
96	Natl Inst Polar Res / 0.28
97	Natl Univ Singapore / 0.28
98	Oregon State Univ / 0.28
99	Osaka City Inst Publ Hlth & Environm. . / 0.28
100	Sci Syst & Applicat Inc / 0.28

A3. Share of total publications by funding source

	Funding source / %
1	Japan Ministry of Environment / 13.38
2	Japan Ministry of Education, Culture, Sports, Science and Technology / 10.03
3	Korea National Research Foundation (NRF) / 12.27
4	Japan Society for the Promotion of Science / 6.69
5	Korea Meteorological Administration / 5.94
6	Korea Ministry of Environment (MOE) / 5.57
7	China National Natural Science Foundation / 4.08
8	Chinese Academy of Sciences / 3.71
9	NASA / 3.71
10	U.S. Department of Energy (DOE) / 2.23
11	Korea Ministry of Education / 1.85
12	China National Basic Research Program / 1.48
13	European Union / 1.48
14	Japan Ministry of Health, Labour, and Welfare / 1.48
15	Korea National Institute of Environment Research / 1.48
16	Japan Science and Technology Agency / 1.11
17	Korea Institute of Science and Technology (KIST) / 1.11
18	Kyushu University / 1.11
19	NSERC (Natural Sciences and Engineering Research Council of Canada) / 1.11
20	Aeris (CNES) / 0.74
21	China Ministry of Science and Technology (MOST) / 0.74
22	Hankuk University of Foreign Studies / 0.74
23	Otsuka Toshimi Scholarship Foundation / 0.74
24	Seoul National University / 0.74
25	Steel Industry Foundation / 0.74
26	United Nations Environmental Program / 0.74
27	Cater / 0.37
28	China National Key Technology RD Program / 0.37
29	China National Science and Technology Support Program / 0.37
30	China Scholarship Council / 0.37
31	China State Key Laboratory of Atmospheric Boundary Layer / 0.37
32	Copernicus Atmosphere Monitoring Service, European Union / 0.37
33	Dankook university / 0.37
34	European Commission / 0.37
35	French Space Agency - CNES / 0.37
36	GERF / 0.37
37	GIST Inst. International Environmental Res. Center (IERC), Korea / 0.37
38	Gwangju Green Environment Center / 0.37
39	Health Canada / 0.37
40	Hokkaido University / 0.37
41	INSU-CNRS (France) / 0.37
42	Izaak Walton Killiam Memorial Scholarship / 0.37
43	Japan Environmental Laboratories Association / 0.37
44	Japan Meteorological Research Institute / 0.37

(*continued on next page*)

(*continued*)

	Funding source / %
45	JAXA / 0.37
46	Julich Research Center (FZJ, Julich, Germany) / 0.37
47	Korea Ministry of Oceans and Fisheries / 0.37
48	Korea Ministry of Science, ICT, and Future Planning (MSIP) / 0.37
49	Korea National Leading Research Laboratory program / 0.37
50	Korea Polar Research Institute / 0.37
51	Korea Rural Development Administration / 0.37
52	Korean Environmental Industry and Technology Institute / 0.37
53	Korean Research Institute of Standards and Science (KRISS) / 0.37
54	Korea's Cooperative Research Program / 0.37
55	Meteo-France / 0.37
56	National Energy Research Scientific Computing Center (NERSC), U.S. / 0.37
57	National Science Council of the ROC (Taiwan) / 0.37
58	NCAR Advanced Study Program Postdoctoral Fellowship / 0.37
59	NIEHS NIH HHS / 0.37
60	Norwegian Research Council / 0.37
61	PANDA European Project (FP7) / 0.37
62	Texas Commission on Environmental Quality / 0.37
63	Tottori University / 0.37
64	Universite Paul Sabatier (Toulouse, France) / 0.37
65	Zhejiang Provincial Natural Science Foundation of China / 0.37
66	Zhejiang University Education Foundation Global Partnership Fund / 0.37

A4. Share of total keyword usage based on WoS KeyWords Plus, first 100 listed

	Keyword / %
1	air-pollution / 2.90
2	china / 2.56
3	east-asia / 2.45
4	long-range transport / 2.45
5	pollution / 2.33
6	emissions / 2.11
7	transport / 1.37
8	air-quality / 1.20
9	model / 1.20
10	particulate matter / 1.14
11	united-states / 1.14
12	particles / 1.08
13	source apportionment / 0.97
14	surface ozone / 0.91
15	aerosol / 0.80
16	japan / 0.80
17	deposition / 0.74
18	ozone / 0.74
19	asia / 0.68
20	tropospheric ozone / 0.68
21	korea / 0.63
22	north-america / 0.63
23	pm2.5 / 0.63
24	ace-asia / 0.57
25	aerosols / 0.51
26	air / 0.51
27	air-pollutants / 0.51
28	boundary-layer / 0.51
29	carbon-monoxide / 0.51
30	dust / 0.51
31	emission inventory / 0.51
32	north pacific / 0.51
33	so2 / 0.51
34	chemical-composition / 0.46
35	inventory / 0.46
36	asian dust / 0.40
37	chemistry / 0.40
38	daily mortality / 0.40
39	exploratory mission-west / 0.40
40	mortality / 0.40
41	seasonal-variations / 0.40
42	acid-rain / 0.34
43	events / 0.34
44	impact / 0.34
45	mineral dust / 0.34
46	pacific / 0.34
47	precipitation / 0.34
48	simulation / 0.34

(*continued on next page*)

(*continued*)

	Keyword / %
49	size distribution / 0.34
50	trends / 0.34
51	climate / 0.28
52	gases / 0.28
53	nitrate / 0.28
54	northeast asia / 0.28
55	optical-properties / 0.28
56	polycyclic aromatic-hydrocarbons / 0.28
57	trace-elements / 0.28
58	urban / 0.28
59	variability / 0.28
60	ambient air / 0.23
61	asian emissions / 0.23
62	atmosphere / 0.23
63	atmospheric aerosols / 0.23
64	black carbon / 0.23
65	continental outflow / 0.23
66	dioxide emissions / 0.23
67	dry deposition / 0.23
68	elemental carbon / 0.23
69	exposure / 0.23
70	fine particulate matter / 0.23
71	hong-kong / 0.23
72	identification / 0.23
73	intercontinental transport / 0.23
74	marine boundary-layer / 0.23
75	modis / 0.23
76	parameterization / 0.23
77	satellite / 0.23
78	storm events / 0.23
79	sulfur deposition / 0.23
80	tropospheric chemistry / 0.23
81	wet deposition / 0.23
82	aerosol composition / 0.17
83	aerosol optical depth / 0.17
84	air-pollution sources / 0.17
85	airborne particulate matter / 0.17
86	anthropogenic emissions / 0.17
87	asian dust events / 0.17
88	association / 0.17
89	asthma / 0.17
90	cheju island / 0.17
91	chemical-characterization / 0.17
92	climate model / 0.17
93	components / 0.17
94	data assimilation / 0.17
95	dioxide / 0.17
96	direct sensitivity-analysis / 0.17
97	earth system model / 0.17
98	elemental mercury / 0.17
99	evaluating intercontinental transport / 0.17
100	gaseous dry deposition / 0.17

References

Bae, J., 2017. Minjoo Party Candidate Moon Promises to Cut 50% of Fine Dust Emissions. April 14. The Korea Economic Daily. http://english.hankyung.com/i/2017/04/14/0753191/minjoo-party-candidate-moon-promises-to-cut-50-of-fine-dust-emissions.

Beck, C.S., Benitez, J.L., Edwards, A., Olson, A., Pai, A., Torres, M.B., 2004. Enacting" health communication": the field of health communication as constructed through publication in scholarly journals. Health Commun. 16 (4), 475–492.

Bolsen, T., Druckman, J.N., 2015. Counteracting the politicization of science. J. Commun. 65 (5), 745–769.

Bolsen, T., Druckman, J.N., Cook, F.L., 2014. How frames can undermine support for scientific adaptations: politicization and the status-quo bias. Public Opin. Q. 78 (1), 1–26.

Brettell, A., Kawashima, Y., 1998. Sino-Japanese relations on acid rain. In: Schreurs, M. A., Pirages, D. (Eds.), Ecological Security in Northeast Asia. Yonsei University Press.

Carmichael, G.R., Calori, G., Hayami, H., Uno, I., Cho, S.Y., Engardt, M., Kim, S.-B., Ichikawa, Y., Ikeda, Y., Woo, J.-H., Ueda, H., Amann, M., 2002. The MICS-Asia study: model intercomparison of long-range transport and sulfur deposition in East Asia. Atmos. Environ. 36, 175–199.

Carmichael, G.R., Sakurai, T., Streets, D., Hozumi, Y., Ueda, H., Park, S.U., Funge, C., Han, Z., Kajino, M., Engardt, M., Bennet, C., Hayami, H., Sartelet, K., Holloway, T., Wang, Z., Kannari, A., Fu, J., Matsuda, K., Thongboonchoo, N., Amann, M., 2008. MICS-Asia II: the model intercomparison study for Asia Phase II methodology and overview of findings. Atmos. Environ. 42, 3468–3490.

Ding, D., Maibach, E.W., Zhao, X., Roser-Renouf, C., Leiserowitz, A., 2011. Support for climate policy and societal action are linked to perceptions about scientific agreement. Nat. Clim. Change 1 (9), 462–466.

Farrell, J., 2016. Corporate funding and ideological polarization about climate change. Proc. Natl. Acad. Sci. 113 (1), 92–97.

Guston, D., 2000. Between Politics and Science: Assuring the Integrity and Productivity of Research. Cambridge University Press.

Itahashi, S., Ge, B., Sato, K., Fu, J.S., Wang, X., Yamaji, K., Nagashima, T., Li, J., Kajino, M., Liao, H., Zhang, M., Wang, Z., Li, M., Kurokawa, J., Carmichael Gregory, R., Wang, Z., 2020. MICS-Asia III: overview of model intercomparison and evaluation of acid deposition over Asia. Atmos. Chem. 20 (5), 2667–2693.

Keohane, R.O., Nye, J.S., 1989. Power and Interdependence: World Politics in Transition. Little-Brown.

Kim, I., 2007. Environmental cooperation of Northeast Asia: transboundary air pollution. Int. Relat. Asia-Pacific 7 (3), 439–462.

Kim, Y., Lee, H., Lee, H., Jang, Y., 2015. A study of the public's perception and opinion formation on particulate matter risk [in Korean]. J. Korean Press Inf. Sci. [한국언론정보학보] 72, 52–91.

Krippendorff, K., 2019. Content Analysis: an Introduction to Its Methodology. Sage Publications.

Lee, K., 2018. Korea, China, Japan to Discuss Fine Dust. June 21. The Korea Times. http://m.koreatimes.co.kr/pages/article.asp?newsIdx=251078.

Manganello, J., Blake, N., 2010. A study of quantitative content anlaysis of health messages in U.S. media from 1985 to 2005. Health Commun. 25 (5), 387–396.
Ministry of the Environment of Korea, 2018. The 21st Tripartite Meeting to be Held in Japan in 2019. http://eng.me.go.kr/eng/web/board/read.do;jsessionid=U17XdlL1tdYgZkZqics1BG1eQztqDohHuWIFhjJiaOK4n8670qp34mEuansStUsu.meweb1vhost_servlet_engine3?pagerOffset=10&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=21&orgCd=&boardId=902770&board.
Oreskes, N., Conway, E.M., 2010. Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming. Bloomsbury Press.
Otsuka, K., 2018. Shift in China's commitment to regional environmental governance in Northeast Asia? J. Contemp. East Asia Stud. 7 (1), 16–34.
Park, H.W., Leydesdorff, L., 2009. Knowledge linkage structures in communication studies using citation analysis among communication journals. Scientometrics 81 (1), 157–175.
Pielke, R.A., 2007. The Honest Broker: Making Sense of Science in Policy and Politics. Cambridge University Press.
Raub, S., Rüling, C.-C., 2001. The knowledge management tussle–speech communities and rhetorical strategies in the development of knowledge management. J. Inf. Technol. 16 (2), 113–130.
Scarbrough, H., Robertson, M., Swan, J., 2005. Professional media and management fashion: the case of knowledge management. Scand. J. Manag. 21 (2), 197–208.
Shapiro, M.A., 2014. Regionalism's challenge to the pollution haven hypothesis: a study of Northeast Asia and China. Pacific Rev. 27 (1), 27–47.
Shapiro, M.A., 2016. Transboundary Air Pollution in Northeast Asia: The Political Economy of Yellow Dust, Particulate Matter, and PM2.5. http://www.keia.org/sites/default/files/publications/kei_aps_shapiro_160518_print.pdf.
Shapiro, M.A., 2017. China-based air pollution and epistemic community building in the Northeast Asian region. Crossing Borders: Governing Environmental Disasters in a Global Urban Age in Asia and the Pacific. https://doi.org/10.1007/978-981-10-6126-4_13.
Shapiro, M.A., Bolsen, T., 2019. Korean perceptions of transboundary air pollution and domestic coal development: two framing experiments. Energy Policy 126, 333–342.
Shim, C., 2017. Policy Measures for Mitigating Fine Particule Pollution in Korea and Suggestions for Expediting International Dialogue in East Asia. Working Paper No. 150. JICA Research Institute.
Smith, M., Milic-Frayling, N., Schneiderman, B., Mendes Rodrigues, E., Leskovec, J., Dunne, C., 2010. NodeXL: A Free and Open Network Overview, Discovery and Exploration Add-in for Excel 2007/2010. http://nodexl.codeplex.
Tsunekawa, K., 2005. Why so many maps there? Japan and regional cooperation. In: Pempel, T.J. (Ed.), Remapping East Asia: The Construction of a Region. Cornell University Press.
UNEP, 2019. Air Pollution in Asia and the Pacific: Science-based Solutions. UNEP. https://www.ccacoalition.org/en/resources/air-pollution-asia-and-pacific-science-based-solutions-summary-full-report.
van der Linden, S.L., Leiserowitz, A.A., Feinberg, G.D., Maibach, E.W., 2015. The scientific consensus on climate change as a gateway belief: experimental evidence. PLoS One 10 (2).
Wagner, C.S., Leydesdorff, L., 2005. Network structure, self-organization, and the growth of international collaboration in science. Res. Policy 34 (10), 1608–1618.
Yarime, M., Li, A., 2018. Facilitating international cooperation on air pollution in East Asia: fragmentation of the epistemic communities. Glob. Policy 9 (Supplement 3), 35–41.
Yoshimatsu, H., 2016. Developing Regional Governance in East Asia: A Case Study of Transboundary Air Pollution. PCAPS Working Paper Series 15002.
Young, O.R., 1990. Global environmental change and international governance. Millenn. - J. Int. Stud. 19 (3), 337–346.
Zhou, P., Leydesdorff, L., 2006. The emergence of China as a leading nation in science. Res. Policy 35 (1), 83–104.