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Dubious cross-national affiliations obscure the assessment of international research collaboration

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ABSTRACT

Assessing international research collaboration through cross-national papers is a common practice but may be compromised by dubious affiliations lacking clear evidence of substantial collaboration. In this study, we analyze cross-national papers indexed in SCIE, SSCI, and A&HCI databases, published between 2012 and 2021, and affiliated respectively with pairs of four nations: the US, China, the United Kingdom, and Australia. Our findings reveal that at least 27 % of them exhibit dubious affiliations, with the proportion potentially rising above 60 % in SCIE papers between the United Kingdom and Australia. This underscores the need to address the potential impact of these papers. We also find that academic practice, cultural proximity, and geopolitical tension have affected the prevalence of different types of dubious affiliations across disciplinary categories and nation pairs. Moreover, papers with dubious affiliations are more prevalent in collaborations among Western nations compared to those involving China. A particular type of dubious affiliations, known as Solo Show, is especially pronounced between the US and China, highlighting the distinctive nature of their pattern of collaboration.

1. Introduction

Research collaboration is vital for the advancement of science, and international research collaboration (IRC) further expands the exchange of ideas, expertise, and resources beyond national boundaries (Collaborations Across the Globe, 2022). IRC, however, seems to decline in recent years due to the impact of global pandemics and geopolitical tensions, prompting hand-wringing among research communities over the future of IRC. Reports indicate that scholarly migration, research collaboration, and talent mobility all undergo noticeable drop, especially between the US and China, the two largest economies and technology leaders of the world (Wang, Tang, Cao & Zhou, 2020; Van Noorden, 2022; Wagner & Cai, 2022).

To assess IRC, scholars primarily rely on multinational papers—research articles co-authored by individuals affiliated with institutions in two or more nations (Han et al., 2014; Wagner, Bornmann & Leydesdorff, 2015; Hu, Wang & Deng, 2020; Matveeva, Sterligov & Lovakov, 2022; Chang & Huang, 2023). These papers are considered indicators of collaborative efforts between nations. Therefore, to investigate the current state of IRC between nations, multinational papers involving these nations are gathered and

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evaluated.

Using co-authorship as a measure of collaboration can be ambiguous, as co-authorship does not necessarily indicate true collaboration, and genuine collaboration may not always result in co-authored papers (Katz & Martin, 1997). While it is generally accepted that the number of co-authored papers can be a useful indicator of collaboration (Han et al., 2014; Wagner, Bornmann & Leydesdorff, 2015; Bonaccorsi, Belingheri, & Secondi, 2021; Liu & Hu, 2022), extending this idea to equating multinational papers to IRC can introduce even greater uncertainty, potentially hindering accurate assessments of IRC between nations. This ambiguity in measurement has significant implications, as it may affect policy decisions and funding allocations within the academic communities.

The lack of a precise definition for multinational papers contributes to the increased uncertainty in assessing IRC. Prior studies on IRC often did not explicitly specify whether the author affiliations of these papers were exclusively with specific nations or included additional nations. For instance, to investigate the collaboration between the United States and China, multinational papers drafted by authors affiliated with US- and China-based institutions are gathered. However, the prior studies were not clear whether these papers also involve some additional nations (cf. He, 2009; Liu, Liu & Ye, 2010; Tang & Shapira, 2011; Sun & Jiang, 2014; Wagner, Bornmann & Leydesdorff, 2015).

In addition, a lack of control over how multinational papers are collected from scholarly databases is another factor causing the uncertainty in IRC assessment. While it is intuitive to assume that multinational papers involve at least two authors, scholarly databases such as Scopus and Web of Science do not provide control over the number of authors involved or the distribution of their affiliated nations when these papers are retrieved. This lack of control over the data presents a challenge for accurately assessing IRC using multinational papers. To address these issues, a precise definition of multinational papers is needed, along with a rigorous process for scrutinizing retrieved papers. However, this may not always be feasible when dealing with large datasets.

This study, therefore, aims to shed light on the influence of the ambiguity surrounding the assessment of IRC using multinational papers. To achieve this goal, we first identify the potential sources of multinational papers that may not reflect substantial collaboration. We then observe the potential impact from these papers, ultimately contributing to more accurate IRC assessments in the future.

This study is organized as follows: In the next section, we provide a literature review where we explain two related concepts causing uncertainty in IRC analysis, namely multi-institutional and multinational affiliations, and examine related works. Additionally, we address previous IRC research, specifically focusing on their lack of clarity in defining cross-national papers. The third section, Methodology, defines two types of dubious cross-national affiliations and offers formal definitions and examples for them. In the fourth section, Empirical Data, we describe the dataset employed for analysis and provide some overall statistics. The fifth section, Analysis Results, reports how the different types of dubious affiliations are distributed across disciplinary categories among various nation pairs and their trends over a 10-year period. Finally, in the concluding section, we summarize the findings and their implications, and outline future research directions.

2. Literature review

The measurement of research collaboration activities utilizing papers with multiple authors or multiple affiliated addresses are generally referred to as multi-authorship or co-authorship analysis (Katz & Martin, 1997). The co-authorship analysis can be conducted at different aggregation levels such as nation, region, institution, field, author, etc.

The co-authorship analysis conducted at the institution- or nation-level is complicated by a specific type of authorship called multi-institutional authorship or multi-institutional affiliation (MIA), a phenomenon pertaining to authors who concurrently hold affiliations with two or more institutions, a trend that has gained increasing prominence in today's academic landscape (Hottenrott, Rose & Lawson, 2021). When these multiply affiliated institutions are situated in two or more nations, this specific form of MIA can be further categorized as multinational authorship or multinational affiliation (MNA). While an MIA author may or may not be an MNA author, an MNA author must also be an MIA author.

In addition to the lack of precise definition and, therefore, a clear criterion for multinational papers, the presence of MNA authors is another major factor further causing ambiguity in these papers and uncertainty in IRC analysis, as papers involving MNA authors may be inadequately categorized in specific multinational paper categories.

While there are numerous co-authorship studies conducted at various levels to explore various forms of research collaborations, the phenomena of MIA and MNA receive only moderate attention. Hottenrott and Lawson (2017) is probably the first work that systematically investigated MIA authors. Their study, which analyzed papers from three major science and technology nations (Germany, Japan, and the UK) across three fields (biology, chemistry, and engineering), revealed a significant increase in the number of MIA authors over the years, particularly on high-impact papers, implying an increased possibility of the uncertainty in IRC analysis.

Huang and Chang (2018) explored the academic impact of papers by MIA authors in the fields of genetics and high-energy physics between 2008 and 2013. This study also reported that there is an increasing trend in the annual percentages of MIA authors and their papers, and the papers' academic impact is also greater than that of other papers. Sanfilippo, Hewitt and Mackey (2018) reported that, when a paper includes 6 to 9 MIA authors, and the average number of affiliated institutions per author is 2, the average number of citations for the paper increases by 11.8 times. If a paper has more than 9 MIA authors, the average number of citations increases by 20.8 times, based on 27,612 papers published in four multi-disciplinary science journals between 2010 and 2014. These few works all confirmed the benefits of having MIA authors, but none has addressed the potential impact of MIA authors on IRC analysis.

On the other hand, the MNA phenomenon was mentioned as early as Katz and Martin (1997). This study investigated the difference between research collaboration and co-authorship, and identified papers by a single author affiliated with two different institutions, respectively located in different countries, as one of four scenarios that do not necessarily indicate substantial collaboration. Abt (2007) defined multinational papers as those in which the authors reside in two or more different nations. Abt then explored the factors

Fig. 1. A US–CN cross-national paper with Solo-Show affiliation.

that promote domestic and international collaboration based on the authors' affiliations in the multinational papers. In Abt's study, a single-author paper, whether MNA or not, was considered not as a multinational paper. As a result, the single-author papers were excluded from the dataset of multinational papers in Abt's study. This processing is necessary to prevent the inadvertent classification of papers with sole MNA authors as multinational papers.

Iribarren-Maestro, Lascurain-Sánchez and Sanz-Casado (2009) investigated whether multi-institutional and multinational papers contribute to higher citation counts and enhance the quality of journal citations. Their study was based on research output from ten departments at Carlos III University of Madrid, Spain, spanning from 1997 to 2003, along with the number of citations received from 1997 to 2004. However, unlike Abt (2007), this work did not explicitly clarify whether its definition of multinational papers required the involvement of two or more authors. Furthermore, it left open the question of whether papers with a single MNA author were included in the category of multinational papers. This omission is a common drawback that can be found in many IRC analytical works.

Hottenrott, Rose and Lawson (2021) studied both MIA and MNA authors in a large scale. Based on more than 15 million authors and 22 million articles from 40 countries, their study found that the share of MIA authors increased from around 10 % to 16 % since 1996, and MIA is prevalent in all fields and it is stronger in high impact journals. In addition, their study noted that MNA authors accounts for about a quarter of MIA authors, most often involve institutions from the United States, China, Germany and the United Kingdom. Their work confirmed that, just like MIA authors, MNA authors are also gaining popularity in recent years, again stressing the increased possibility of the uncertainty in IRC analysis.

IRC analysis is a form of national-level co-authorship analysis based on multinational papers. Numerous IRC studies have assessed the productivity and academic impact of nations involved in multinational papers, especially between pairs of nations. These multinational papers are hereinafter referred to the two nations' cross-national papers.

The previous IRC works usually conducted their observations based on cross-national papers indexed in SCI (or SCIE), SSCI, or A&HCI databases. They were often quite loose about what papers are counted as cross-national papers between two nations. Conditions like whether there are MNA authors, whether other nations are affiliated, and how many authors are from the two specific nations were commonly left unspecified. Furthermore, the previous IRC works cited below all adopted whole counting without considering author ranks and roles, and they often included in their datasets some papers with dubious cross-national affiliations that should have been excluded or required further justification.

Arunachalam and Doss (2000) investigated and compared eleven Asian nations' international collaboration and this work considered that a cross-national paper is collaborated by two nations if both nations appear in the paper's affiliated addresses. He (2009) explored China's collaboration with G7 nations and classified cross-national papers similar to Arunachalam and Doss (2000). He (2009), however, was explicit about that, if a paper is signed with China (CN) and several G7 nations, this paper is respectively counted as the cross-national paper by each pair of involved nations. Liu, Liu and Ye (2010), Tang and Shapira (2011), Wagner, Bornmann and Leydesdorff (2015) all focused their study on cross-national papers from the United States (US) and China, but were not clear whether a sole MNA author affiliated with US and CN is included or excluded, and whether other nations may be affiliated or not. Sun and Jiang (2014) was a rare exception in that, in investigating collaboration between CN and South Korea (KR), this work specifically limited their data to CN-KR cross-national papers with "all of the authors with an address in Korea or China." Wagner and Cai (2022), when examining the IRC between CN, US, and the European Union (EU), didn't provide their criteria about how a paper is counted as, for example, a CN-US cross-national paper. These works highlight the inconsistency in the methods used and reinforce the need for a more precise and standardized criterion for cross-national papers.

3. Methodology

3.1. Identification of dubious cross-national papers

In the present study, we identify two distinct types of dubious cross-national affiliations that may exist in the datasets for IRC analysis. In the following description of the dubious affiliations, we use US–CN cross-national papers as examples for simplicity's sake.

It should be stressed that the term 'dubious affiliations' is not intended to imply doubt about the affiliations themselves. Instead, it signifies that the use of papers with these affiliations in IRC analysis is 'dubious,' as they do not seem to reflect genuine collaborations.

The first type, referred to as "Solo Show," is characterized by the involvement of an MNA author as a paper's sole author or one of

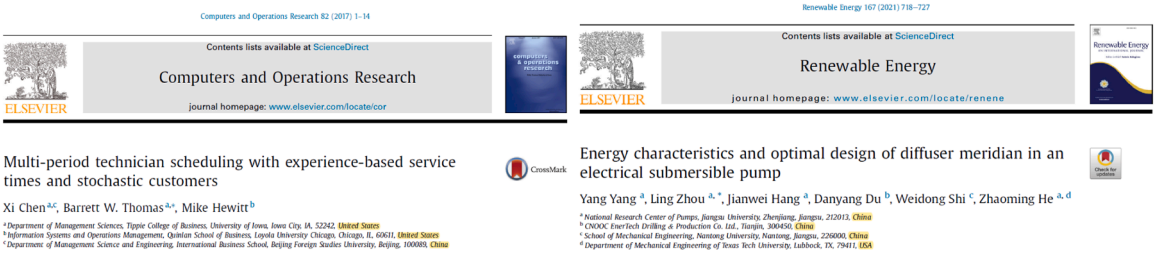

Fig. 2. Other US–CN cross-national papers with Solo-Show affiliations.

Fig. 3. US–CN cross-national papers with Insufficient affiliation.

the paper's authors. The dubiety of these Solo-Show papers lies in that the nations assumed to be collaborative are concentrated on a single person, thereby lacking a clear evidence of substantial collaboration between these nations. A formal definition to the Solo-Show affiliations will be provided later.

US–CN cross-national papers with Solo-Show affiliations can manifest in three scenarios. The first scenario involves papers with a sole author simultaneously affiliated with both US and CN. Take, for instance, Chang (2021), a sole-authored US–CN cross-national paper, whose title page is partially shown in Fig. 1. If US–CN cross-national papers are identified only based on the US and CN nationalities appearing in the affiliated addresses, without further considering the number of authors, the inappropriate inclusion of papers with dubious Solo-Show affiliations like Chang (2021) is inevitable.

The second scenario of US–CN Solo-Show papers is similar to the first scenario, except that it occurs from papers with multiple authors. For US–CN Solo-Show papers following this scenario, they involve only one author affiliated with US and CN while the other authors are affiliated with neither US nor CN. This scenario indicates that the author count alone cannot avoid papers with this type of dubious affiliations. How the affiliated nations are distributed among the authors should be further scrutinized.

Both the foregoing two scenarios involve a single MNA author affiliated with US and CN. Please note that, when this MNA author is affiliated with additional nations besides the US and CN, these papers still are mistakenly categorized as a US–CN cross-national paper. In addition, the second scenario can also involve one or more MNA authors, as long as they are not affiliated with US and CN, indicating the complexity of identifying papers with these dubious affiliations.

The third Solo-Show scenario also arises from papers having multiple authors and an MNA author affiliated with US and CN. However, unlike the second scenario, the remaining authors are all affiliated only with US or CN or some additional nations. Chen, Thomas and Hewitt (2017) and Yang et al. (2021), whose title pages are partially shown in Fig. 2, are US–CN papers according to this scenario. For Chen, Thomas and Hewitt (2017) (left), all three authors are affiliated with the US, and one of them is also affiliated with CN. Similarly, all authors of Yang et al. (2021) (right) are affiliated with the CN, and one of them is also affiliated with the US.

Papers according to the third scenario are arguably less controversial than those of the first two scenarios. Their affiliations are considered as dubious ones as the appearance of collaboration between two nations is still manifested by a single author, while none of the other authors can offer further collaboration evidence between the two nations.

As mentioned in Hottenrott and Lawson (2022), MIA, as well as MNA, is sometimes adopted by institutions to boost their prestige by recruiting external talent. Therefore, for papers like Chen, Thomas and Hewitt (2017) and Yang et al. (2021), further clarification about where the single US–CN author are truly or mainly based should be conducted, in addition to taking author ranks or roles into consideration.

The second type of dubious cross-national affiliations, referred to as "Insufficient Affiliation," concerns those that may be affiliated more frequently with one or more additional nations. Therefore, considering these papers as collaboration between two nations exhibiting fewer affiliations seems too stretched. A formal definition to this type of dubious affiliations will be provided later.

For instance, Park et al. (2020) and Ying et al. (2021) are examples of this type of US–CN papers, whose title pages are partially and respectively shown to the left and right in Fig. 3. For Park et al. (2020) (left), the paper has six authors where four of them are exclusively affiliated with KR, while the other two are respectively affiliated with US and CN. On the other hand, among the authors of Ying et al. (2021) (right), four have affiliation with Australia (AU), two with US, one with New Zealand, and one with CN. Even though

both papers' affiliated addresses involve US and CN, categorizing them as a US–CN cross-national paper seems strained, as US and CN do not appear to have representative shares.

To avoid papers with this type of dubious affiliations, not only the author ranks and roles, but also the counting method should be considered in justifying the inclusion or exclusion of this type of papers as legitimate US–CN cross-national papers.

While Solo-Show papers seem to be more controversial than Insufficient-Affiliation ones, these two types of dubious cross-national affiliations both introduce uncertainty to the assessment of IRC. Even though they do not necessarily imply the absence of collaboration, it is important to recognize that both types of papers raise doubts about their legitimacy and should not be included in the assessment of IRC without justification or further clarification. A more accurate and reliable assessment of IRC then can be ensured.

The aim of this study, therefore, is to answer questions like how common are these types of cross-national papers, how are they distributed across disciplinary categories, are some nation pairs more prone to these dubious affiliations, and whether they are emerging problems or long-term phenomena?

3.2. Definitions of dubious cross-national papers

To establish the foundation for the methodology in this study, we require clear definitions for conventional cross-national papers and those with dubious affiliations. Let's consider a paper P with N authors ($A_1, A_2, \ldots, A_N$). Each author is affiliated with one or more institutions in one or more nations. We can represent the set of nations affiliated with author A_i as $C(A_i)$. Then, the set of nations affiliated with the paper P is $C(P)$, which is the union of the sets $C(A_i)$ from all authors A_i (i.e., $C(P) = \cup_{\forall i} C(A_i)$).

According to conventional definitions, if the US is one of the nations in $C(P)$ (i.e., US $\in C(P)$), the paper is considered as a US paper. If both the US and CN are in $C(P)$ (i.e., {US, CN} $\subset C(P)$), then it is considered as a US–CN cross-national paper. For examples, when we list the authors' affiliated nations sequentially as ($C(A_1)$, $C(A_2)$, …, $C(A_N)$), papers with the following lists of affiliated nations all fit the above definition of US–CN cross-national papers:

P_1: ({US, CN}),
P_2: ({US, CN}, {AU}),
P_3: ({US, CN}, {US}, {JP}), and
P_4: ({US, CN, KR}, {CN}, {CN}).

However, in the above examples, P_2 can also be counted as a US–AU or CN–AU cross-national paper, P_3 as a US–JP or CN–JP cross-national paper, and P_4 as a US–KR or CN–KR cross-national paper, demonstrating the ambiguity of the conventional definition and emphasizing the necessity for more accurate criteria.

The US–CN cross-national papers with Solo-Show affiliations can be formally defined as follows. The notation $CC(A_i,\ K)$ indicates if the author A_i is affiliated with the nation K, which equals 1 if $K \in C(A_i)$, and 0 otherwise. The notation $CC(P,\ K)$, then, counts the number of authors of the paper P affiliated with the nation K (i.e., $CC(P,\ K) = \sum_{\forall i} CC(A_i, K)$). The paper P is a US–CN cross-national paper with Solo-Show affiliation if

(1) there exists exactly one author A_j affiliated with both US and CN (i.e., $\exists! j\ s.t.\ \{\text{US},\ \text{CN}\} \subset C(A_j)$), and
(2) the number of authors affiliated with either US or CN can only be one (i.e., $CC(P,\ \text{US}) = 1$ or $CC(P,\ \text{CN}) = 1$).

Then, all four exemplary papers $P_1 \sim P_4$ conform to the above definition of US–CN cross-national papers with Solo-Show affiliations. Please also note that P_1 fits the first scenario, P_2 fits the second scenario, and P_3 and P_4 fit the third scenario of Solo-Show affiliations.

A US–CN cross-national paper with Insufficient Affiliation, as conceptually described in the previous section, is one where the authors are more frequently affiliated with at least a third nation other than the US and CN, making it unclear whether it should be considered a US–CN collaboration. For example, papers with the following lists of affiliated nations are US–CN papers with Insufficient Affiliation, as they are more often affiliated with KR and including them as US–CN cross-national papers seem forced:

P_5: ({CN, KR}, {US}, {KR}),
P_6: ({CN}, {US, KR}, {KR}, {KR, JP}), and
P_7: ({US, CN}, {KR}, {KR}, {UK}).

Whether a paper qualifies as one with Insufficient Affiliation depends on the counting method used, as well as whether author ranks or roles are considered. As mentioned in the Literature Review section, most, if not all, IRC works adopted whole counting without considering author ranks and roles, we adopt the same approach in defining the papers with Insufficient Affiliation.

Formally, a US–CN cross-national paper with Insufficient Affiliation is one satisfying the following condition: $\exists K \in C(P)\ s.t. CC(P,\ \text{US}) < CC(P,K)$ or $CC(P,\text{CN}) < CC(P,K)$. In other words, for such papers, their number of authors affiliated with the third nation K is more than their number of authors affiliated with US or CN.

Furthermore, just like Solo-Show papers can occur on papers with a sole author or with multiple authors, Insufficient-Association papers can also occur on single-author or multi-author papers. It is also possible that a single- or multi-author paper may qualify both as one with Solo Show or Insufficient Affiliation. An example of such a paper is the paper P_7 above with the list of affiliated nations ({US, CN}, {KR}, {KR}, {UK}). For papers falling under both categories of dubiety, we always categorize them only as Solo-Show ones in the

Table 1
Distribution of SCIE, SSCI, and A&HCI papers.

Total	SCIE	SSCI	A&HCI
1,017,594	951,012	150,721	8354

Table 2
Distribution of cross-national papers.

Total	US–CN	US–UK	US–AU	CN–UK	CN–AU	UK–AU
1,017,594	448,253	282,915	146,239	103,436	103,075	96,490

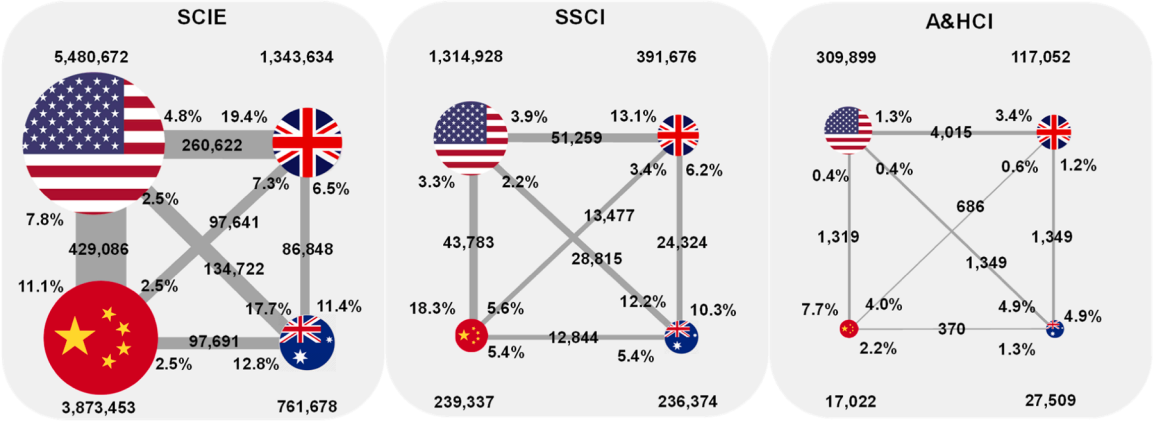

Fig. 4. Papers and cross-national papers of US, CN, UK, and AU indexed in SCIE, SSCI, and A&HCI.

subsequent analysis to avoid duplications.

4. Empirical data

In order to assess the impact of dubious cross-national papers, we chose to focus on the top three nations whose institutions are most frequently involved in MIA (He, 2009), namely the US, CN, and the UK. Therefore, cross-national papers between these nations are prone to include those with dubious affiliations, especially those with Solo-Show affiliations. For comparative purposes, we also included AU, whose institutions play a lesser role in terms of MIA.

Additionally, as research collaboration activities vary across disciplines (Franceschet & Costantini, 2010; Gazni, Sugimoto & Didegah, 2012) and may also change over time, we collected papers of the four nations and their cross-national papers, of all article types, from Web of Science's SCIE, SSCI, and A&HCI databases. In this way, papers from the three major disciplinary categories, namely natural science, social science, and arts and humanities, were included for analysis. The publication time of the collected papers was limited to between 2012 and 2021 to ensure a recent and comprehensive dataset. Overall, the dataset includes 1,017,594 papers,[1] and their distributions across disciplinary categories and among the six pairs of nations (i.e., US–CN, US–UK, US–AU, CN–UK, CN–AU, and UK–AU) are respectively provided in Tables 1 and 2.

Fig. 4 offers an overview of the numbers of papers and cross-national papers from and between US, CN, UK, and AU indexed in SCIE, SSCI, and A&HCI. The numbers above or below the nations' flags are the nations' total paper counts. The numbers along the lines connecting two nations' flags are the counts of cross-national papers affiliated with the two nations. It should be stressed again that these papers were categorized following the definitions outlined in the previous section. The flag sizes and line widths reflect paper counts. They are not drawn to scale but their relative magnitudes are generally preserved.

The percentage adjacent to a first nation and the nation's line to a second nation is the share of cross-national papers between the two nations to the first nation's papers. This percentage is similar to the collaboration ratio used in Wang et al. (2014) and reflects how much the first nation's cross-national paper with the second nation accounting for the first nation's total number of papers. Taking US and UK and their SCIE papers as examples, US and UK respectively have 5,480,672 and 1,343,634 papers and there are 260,622 US–UK

[1] The search command is "((CU = China and CU = USA) or (CU = China and CU = England) or (CU = China and CU = Australia)or (CU = USA and CU = England) or (CU = USA and CU = Australia)or (CU = England and CU = Australia)) AND PY = 2012–2021", and the search time is 2022/07/28.

Table 3
Distribution of cross-national papers with dubious affiliations.

		US-CN	US-UK	US-AU	CN-UK	CN-AU	UK-AU
SCIE	Total papers	429,086 (1)	260,622 (2)	134,722 (3)	97,641 (5)	97,691 (4)	86,848 (6)
	Papers with non-dubious affiliations	301,026 (1) (70.2%) (1)	135,274 (2) (51.9%) (4)	64,390 (3) (47.8%) (5)	54,324 (5) (55.6%) (3)	62,806 (4) (64.3%) (2)	32,741 (6) (37.7%) (6)
	Papers with dubious affiliations	128,060 (1) (29.8%)(6)	125,348 (2) (48.1%) (3)	70,332 (3) (52.2%) (2)	43,317 (5) (44.4%) (4)	34,885 (6) (35.7%) (5)	54,107 (4) (62.3%) (1)
SSCI	Total papers	43,783 (2)	51,259 (1)	28,815 (3)	13,477 (5)	12,844 (6)	24,324 (4)
	Papers with non-dubious affiliations	31,970 (1) (73.0%) (1)	29,353 (2) (57.3%) (4)	16,098 (3) (55.9%) (5)	7,929 (6) (58.8%) (3)	7,933 (5) (61.8%) (2)	12,431 (4) (51.1%) (6)
	Papers with dubious affiliations	11,813 (4) (27.0%) (6)	21,906(1) (42.7%) (3)	12,717(2) (44.1%) (2)	5,548(5) (41.2%) (4)	4,911(6) (38.2%) (5)	11,893(3) (48.9%) (1)
A&HCI	Total papers	1,319 (4)	4,015 (1)	1,349 (2)	686 (5)	370 (6)	1,349 (2)
	Papers with non-dubious affiliations	741 (2) (56.2%) (3)	1,845 (1) (46.0%) (5)	666 (3) (49.4%) (4)	400 (5) (58.3%) (1)	213 (6) (57.6%) (2)	599 (4) (44.4%) (6)
	Papers with dubious affiliations	578 (4) (43.8%) (4)	2,170 (1) (54.0%) (2)	683 (3) (50.6%) (3)	286 (5) (41.7%) (6)	157 (6) (42.4%) (5)	750 (2) (55.6%) (1)

cross-national papers. The same set of 260,622 papers accounts for only 4.8 % of US paper, but takes up a more significant 19.4 % share of UK papers, revealing that UK collaborates more frequently with US than the other way around in terms of SCIE papers.

Fig. 4 effectively highlights the overwhelming volume of SCIE papers compared to SSCI and A&HCI papers. It also confirms the previous findings that the US and CN have the highest number of cross-national papers, particularly in SCIE papers. However, Fig. 4 also reveals that, for both SSCI and A&HCI papers, it is the US and UK that lead in terms of numerous cross-national papers. This difference across disciplinary categories emphasizes the importance of considering cross-national papers within separate categories.

Fig. 4 further reveals that collaboration patterns can vary significantly between the four nations across the three categories of disciplines. Specifically, the four nations have distinct preferences for collaboration partners. For CN and UK, US is their primary collaborator across all three categories of papers, as US–CN and US–UK cross-national papers always take up the highest shares respectively among CN and UK papers. US and AU reveal different preferences in different disciplinary categories. For US, UK is its preferred partner for both SSCI and A&HCI papers but, for SCIE papers, CN is its main partner. As to AU, the US is its primary collaborator for both SCIE and SSCI papers, while, for A&HCI papers, both the US and UK are AU's primary partners. These observations suggest that some form of cultural proximity is at play here as, in disciplines outside the natural sciences (i.e., those of SSCI and A&HCI), Western nations (i.e., the US, UK, and AU) tend to have more frequent collaborations between them, possibly due to their relatively closer cultural backgrounds.

Another not-so-obvious pattern manifested in Fig. 4 is that, for Western nations, their shares of cross-national papers consistently decrease from SCIE to SSCI to A&HCI papers. For example, the shares of US–UK cross-national papers relative to US papers drops from 4.8 % in SCIE to 3.9 % in SSCI, and then 1.3 % in A&HCI. Similarly, for UK, its shares of US–UK cross-national papers drops from 19.4 % in SCIE to 13.1 % in SSCI to 3.4 % in A&HCI. These observations suggest that this pattern may be influenced by academic practice, with researchers in the natural sciences tending to collaborate in teams, while those in arts and humanities often work individually.

Interestingly, CN exhibits a rather different pattern compared to the Western nations. In SSCI papers, CN has the highest shares of cross-national collaborations with Western nations (18.3 % with the US, 5.6 % with the UK, and 5.4 % with AU, totaling 29.3 %), surpassing its shares in SCIE (totaling 16.1 %) and A&HCI (totaling 13.9 %) papers. This suggests that CN tends to engage in international collaborations more frequently in the fields of social sciences.

5. Analysis results

5.1. Impacts of dubious cross-national papers

To assess the impact of cross-national papers with dubious affiliations on IRC analysis, the distributions of papers with dubious affiliations within the six sets of cross-national papers are observed. Our findings are summarized in Table 3, which includes total paper counts, counts of cross-national papers with dubious affiliations (combining both types), and counts of papers after the exclusion of those with dubious affiliations. Percentages relative to each set and category's total papers are also included. Three columns of figures

Table 4
Shares of cross-national papers with dubious affiliations in SCIE, SSCI, and A&HCI averaged across the six nation pairs.

	SCIE	SSCI	A&HCI
Papers with dubious affiliations	45.4 %	40.4 %	48.0 %
Solo Show	14.4 %	16.2 %	35.9 %
Insufficient affiliation	31.1 %	24.2 %	12.1 %

Table 5
Distribution of papers with the two types' dubious affiliations.

		US–CN	US–UK	US–AU	CN–UK	CN–AU	UK–AU
SCIE	Solo Show	77,338 (18.0 %)	24,237 (9.3 %)	15,270 (11.3 %)	14,316 (14.7 %)	15,315 (15.7 %)	14,850 (17.1 %)
	Insufficient Affiliation	50,722 (11.8 %)	101,111 (38.8 %)	55,062 (40.9 %)	29,001 (29.7 %)	19,570 (20.0 %)	39,257 (45.2 %)
SSCI	Solo Show	6312 (14.4 %)	7422 (14.5 %)	4403 (15.3 %)	2178 (16.2 %)	1877 (14.6 %)	5418 (22.3 %)
	Insufficient Affiliation	5501 (12.6 %)	14,484 (28.3 %)	8314 (28.9 %)	3370 (25.0 %)	3034 (23.6 %)	6475 (26.6 %)
A&HCI	Solo Show	487 (36.9 %)	1714 (42.7 %)	464 (34.4 %)	217 (31.6 %)	103 (27.8 %)	569 (42.2 %)
	Insufficient Affiliation	91 (6.9 %)	456 (11.4 %)	219 (16.2 %)	69 (10.1 %)	54 (14.6 %)	181 (13.4 %)

in Table 3 are shaded to highlight the cross-national papers involving CN (i.e., US–CN, CN–UK, and CN–AU) for emphasis. In addition, ranks of the paper counts and percentages in descending order are indicated in red within parentheses.

Table 3 illustrates the significant influence of including cross-national papers with dubious affiliations on IRC analysis. Firstly, these papers consistently account for a significant portion, ranging from 27.0 % (in SSCI cross-national papers between the US and CN) to as high as 62.3 % (in SCIE cross-national papers between the UK and AU) across all three disciplinary categories and the six sets of cross-national papers. When considering the three disciplinary categories collectively, the average shares of cross-national papers with dubious affiliations across the six sets consistently exceed 40 %, with shares of 45.4 % for SCIE, 40.4 % for SSCI, and 48.0 % for A&HCI (see Table 4).

Secondly, the impact of these papers on the IRC analysis is evident when comparing the rankings of the six sets of cross-national papers before and after excluding those with dubious affiliations. Table 3 reveals that the rankings for SSCI and A&HCI papers undergo notable changes, affecting at least three sets, after the removal of papers with dubious affiliations. For instance, in SSCI cross-national papers, US–UK ranks first when papers with dubious and non-dubious affiliations are considered together. However, its rank drops to the second place when considering only those with non-dubious affiliations. Similarly, the ranks for CN–UK and CN–AU both shift by one place when considering only those with non-dubious affiliations. However, the ranking for SCIE papers remained the same regardless of the inclusion or exclusion of papers with dubious affiliations. These findings suggest that papers with dubious affiliations may exert a more pronounced influence on IRC analysis based on SSCI and A&HCI than on SCIE papers.

Table 3 also unveils intriguing and unexpected patterns when comparing the six sets of cross-national papers. Firstly, UK–AU cross-national papers consistently exhibit the highest percentages of those with dubious affiliations across all three disciplinary categories (62.3 % in SCIE, 48.9 % in SSCI, and 55.6 % in A&HCI). This observation is noteworthy because, as previously mentioned in the Empirical Data section, both the UK and AU generally collaborate most frequently with the US. However, the fact that UK–AU cross-national papers consistently have the highest percentages of dubious affiliations across all disciplinary categories suggests that a higher number of cross-national papers does not necessarily translate into a higher proportion of dubious affiliations.

In addition, despite concerns about questionable paper practices in China's rush to become the leader in scientific development (Mallapaty, 2020), Table 3 demonstrates that, for the six sets of cross-national papers, those involving CN consistently exhibit lower shares of dubious affiliations compared to cross-national papers between Western nations. Specifically, the sets US–CN, CN–UK, and CN–AU, as highlighted in grey columns, always rank among the last three places in terms of the shares of dubious affiliations. Notably, US–CN has the not only lowest but also notably smaller shares of papers with dubious affiliations both in SCIE (29.8 %) and SSCI (27.0 %), while CN–UK also has the lowest share in A&HCI (41.7 %).

5.2. Prevalence of papers with the two types' dubious affiliations across disciplinary categories

The above observations are based on results without differentiating the two types of dubious cross-national affiliations. In the following, whether the two types of dubious affiliations would distribute differently across disciplinary categories and the six pairs of nations are examined.

Firstly, as mentioned in the previous Methodology section, Solo-Show papers are the more controversial ones, as their evidence of collaboration is restricted to a single person. If we ignore the less controversial ones with Insufficient Affiliation, papers with Solo-Show affiliations alone still make up a sizable portion of cross-national papers. As shown in Table 4, papers with dubious Solo-Show affiliations, on average, take up more than 14 % for the six sets' SCIE, SSCI, and A&HCI papers, again demonstrating an impact that cannot be easily ignored.

On the other hand, the Insufficient-Affiliation type usually occurs on papers with multiple authors. Its distributions among the three disciplinary categories, therefore, are very different from those of the Solo-Show type. As shown in Table 4, the Insufficient-Affiliation type is more prevalent among SCIE and SSCI papers, where researchers engage more frequently in team works, whereas the

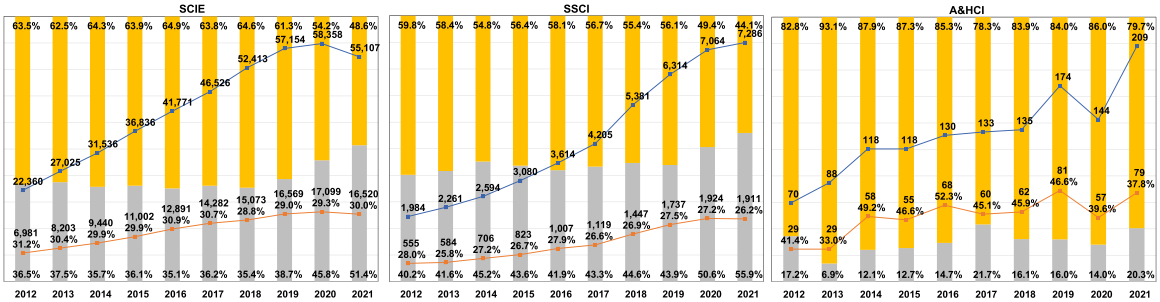

Fig. 5. Trend of US–CN papers.

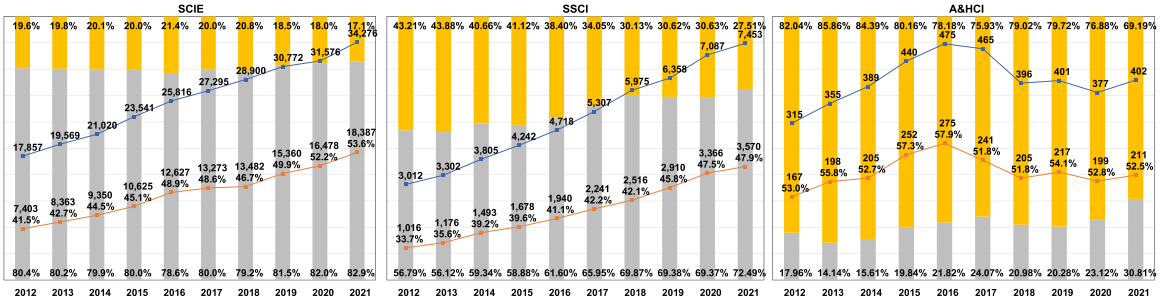

Fig. 6. Trend of US–UK apers.

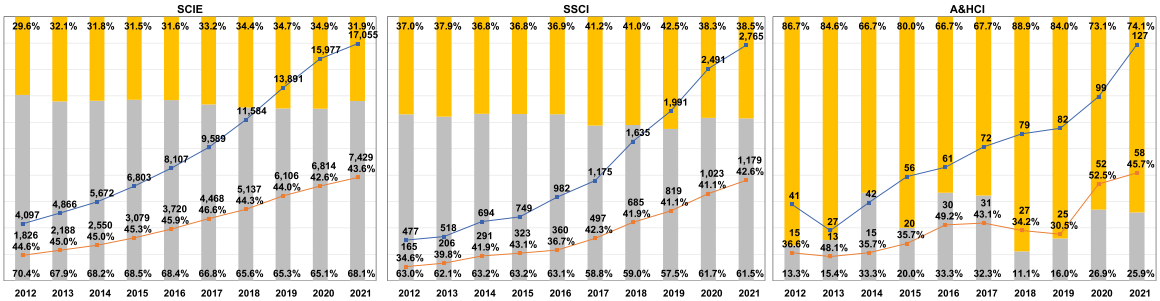

Fig. 7. Trend of CN–UK papers.

Insufficient-Affiliation type has the lowest average share among A&HCI papers, where researchers tend to work alone, reflecting the influence of academic practices in different disciplines.

5.3. Prevalence of papers with the two types' dubious affiliations across disciplinary categories and nation sets

Table 5 further breaks down the papers with dubious affiliations into those of Solo-Show type and those of the Insufficient-Affiliation type to demonstrate how the two types of dubious affiliations are distributed across the disciplinary categories and the six pairs of nations. Please note that the percentages shown are relative to the number of total papers of the corresponding nation set and disciplinary category.

Firstly, as previously shown in Table 4, the Solo-Show type is more prevalent among A&HCI papers. Table 5 also reveals that the six nation sets' cross-national papers indeed consistently show much stronger tendencies for the Solo-Show affiliations than for the Insufficient-Affiliation ones.

The Insufficient-Affiliation type, as also demonstrated in Table 4, is more prevalent among SCIE and SSCI papers. However, among the six nation sets, the US–CN papers uniquely exhibit a higher frequency of Solo-Show affiliations compared to their Insufficient-Affiliation ones. Specifically, there are respectively 18.0 % and 14.4 % papers with Solo-Show affiliations in US–CN SCIE and SSCI papers, both higher than the 11.8 % and 12.6 % of those with Insufficient-Affiliation. This observation highlights a distinctive nature of collaborations between the US and CN when compared to their collaborations with other nations.

Additionally, Table 5 shows that cross-national papers between Western nations consistently have a higher proportion of Insufficient-Affiliation papers compared to cross-national papers involving CN, particularly in the case of SCIE papers. For example, the

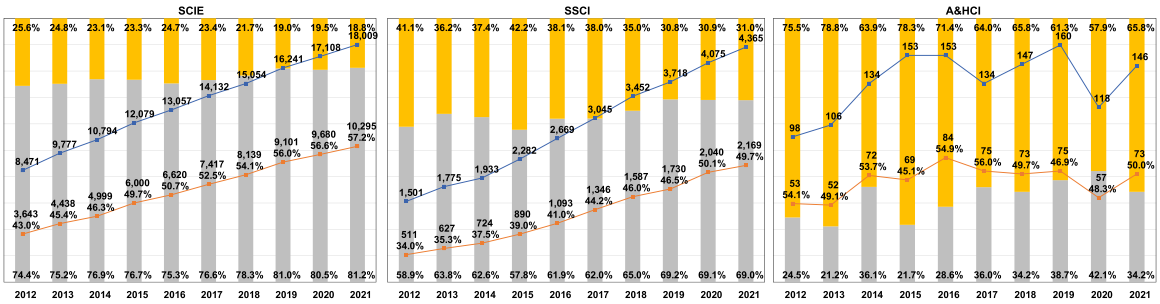

Fig. 8. Trend of US–AU papers.

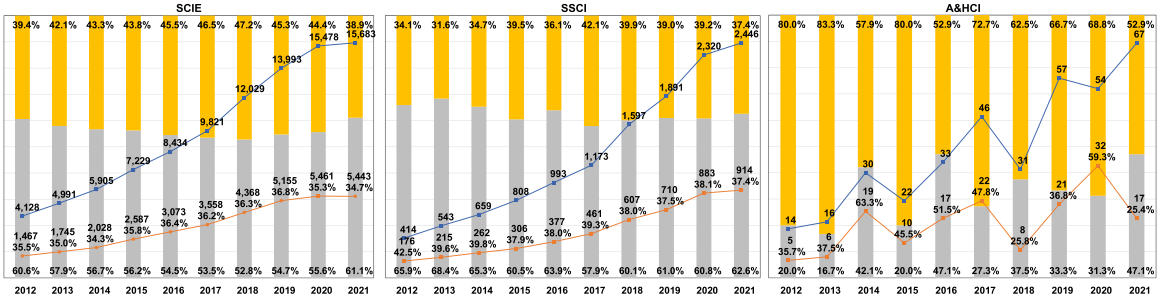

Fig. 9. Trend of CN–AU papers.

lowest proportion of Insufficient-Affiliation papers within SCIE papers among Western nations is 38.8 % between the US and UK, which is still notably higher than the highest proportion observed in SCIE cross-national papers involving CN, where the highest portion is 29.7 % between CN and UK. In contrast, the SCIE and SSCI Solo-Show papers do not present such a pattern.

5.4. Trends of dubious cross-national papers

The foregoing observations are conducted based on the cross-national papers collected over a ten-year period. To see whether the observed patterns have varied over the years, the six sets of cross-national papers, along with those with dubious affiliations, are depicted year by year in Figs. 5–10, respectively.

Within these figures, the blue and orange curves represent the trends of cross-national papers and those with dubious affiliations, respectively, from 2012 to 2021. The numbers of the papers with dubious affiliations are shown with their percentages relative to the total cross-national papers. In addition, for each year, the proportions of Solo-Show and Insufficient-Affiliation papers are represented by yellow and grey bars, respectively, with the percentages relative to the papers with dubious affiliations displayed along the top and bottom of the bars.

First, we can see from Figs. 5 to 10 that, for SCIE and SSCI papers, the six sets' cross-national papers and those with dubious affiliations generally follow a rising trends. As to A&HCI papers, due to their much smaller volumes, fluctuations and more prominent discrepancy can be observed between the trends of the six sets' cross-national papers and those with dubious affiliations. However, the noticeable presence of cross-national papers with dubious affiliations across all years, all sets, and all disciplinary categories indicate that these dubious affiliations are not some recent or sporadic phenomena.

For SCIE and SSCI papers, we can also see that cross-national papers involving CN seem to reveal stagnation since 2020 with even a downward turn in those between the US and CN for SCIE papers. We speculate that this may be attributed to the recent strained relationship between the two nations. It is worth noting that CN's recent stagnation can also be vaguely observed in its cross-national papers with the UK and AU, seemingly suggesting that geopolitical tension may have a spillover effect to other Western nations.

Furthermore, we can also observe that the increases in the numbers of papers with dubious affiliations in the SCIE and SSCI papers of the six nation sets are not as rapid as those of the total cross-national papers, as indicated by the smaller slopes of the orange curves representing the numbers of papers with dubious affiliations compared to the blue curves representing those of the total cross-national papers. Despite this, the significant portions of papers with dubious affiliations within the cross-national papers still suggest that they should not be overlooked for now and in the future.

It is also interesting to note that the shares of papers with dubious affiliations for SCIE and SSCI cross-national papers between the Western nations have consistently increased over the years. For example, the shares of US–UK SCIE papers with dubious affiliations have risen from 41.5 % in 2012 up to 53.6 % in 2021, and the shares of UK–AU SSCI papers with dubious affiliations rises from 37.3 % to 54.2 % between 2012 and 2021. In contrast, for SCIE and SSCI cross-national papers between CN and the Western nations, the shares of papers with dubious affiliations actually decrease across the years. For example, US–CN SCIE papers have 31.2 % papers with

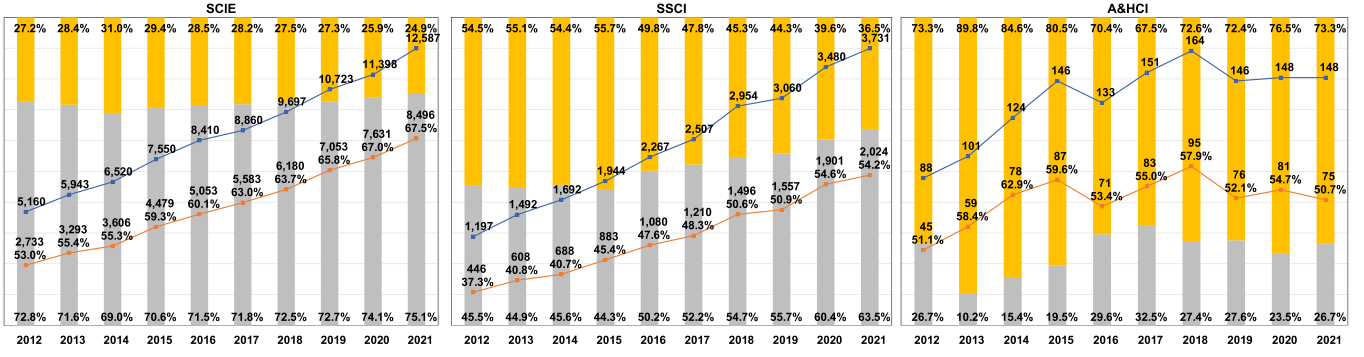

Fig. 10. Trend of UK–AU papers.

Table 6
The Solo-Show authors' roles in US–CN SCIE Solo-Show papers.

First author	Corr. author	First and corr. author	Other author
14,996 (19.4 %)	15,501 (20.0 %)	9406 (12.2 %)	37,435 (48.4 %)

dubious affiliations in 2012, and the percentage slightly drops to 30.0 % in 2021. Similarly, the shares of papers with dubious affiliations between CN–AU SSCI papers have dropped from 42.5 % in 2012 to 37.4 % in 2021. However, CN–UK SSCI papers exhibit an exception; their shares of papers with dubious affiliations actually rise from 34.6 % in 2012 to 42.6 % in 2021.

The patterns discovered from the previous section, such as the prevalence of papers with Solo-Show affiliations in the A&HCI cross-national papers, have remained consistent over the years, as revealed from the shares of Solo-Show and Insufficient-Affiliation papers depicted respectively by the orange and grey bars in Figs. 5–10. This suggests that these patterns have persisted over time, rather than being recent developments. However, a further examination to Figs. 5–10 provides some nuance findings.

Firstly, as mentioned in the previous section, the prominence of Solo-Show papers, which is uniquely more prominent among US–CN SCIE and SSCI cross-national papers, appears to be declining in recent years, possibly due to the contention between the US and CN. For example, in US–CN SCIE and SSCI papers with dubious affiliations, there were consistently more than 60 % and 50 % Solo-Show papers up to 2019, but these percentages dropped to 48.6 % and 44.1 % in 2021.

As also mentioned in the previous section, Insufficient-Affiliation papers consistently outnumber Solo-Show ones for SCIE and SSCI papers across the nation sets, except in the case of papers between the US and CN. This observation holds true for the other five nation sets over the years, except that, up to 2015, UK–AU papers had more Solo-Show papers than Insufficient-Affiliation papers, suggesting a shift in their collaboration pattern.

Furthermore, the prevalence of Insufficient-Affiliation papers in cross-national papers between Western nations seems to be increasing over the years, despite occasional fluctuations in specific years for certain nation sets. For example, the shares of Insufficient-Affiliation papers among US–UK SSCI cross-national papers grew from below 60 % to more than 70 %. Similarly, in the case of dubious affiliations in UK–AU SSCI papers, the shares of Insufficient-Affiliation ones increased from around 45 % to more than 60 %.

In contrast, SCIE and SSCI cross-national papers involving CN, such as those between CN and UK and between CN and AU, do not show similar signs of strengthening in the prevalence of Insufficient-Affiliation papers. For example, CN–UK SCIE papers exhibited relatively stable shares of Insufficient-Affiliation ones over the years, ranging between 65 % and 70 %. CN–AU SSCI papers, on the other hand, revealed fluctuations in the shares of Insufficient-Affiliation papers, hovering around 60 %.

6. Conclusion

In this study, we highlight the prevalence of cross-national papers with dubious affiliations, which may not accurately reflect substantial research collaborations, and its potential impact on the assessment of IRC. Our study, therefore, underscores the importance of caution when using cross-national papers as a measure of IRC and emphasizes the need for transparency and accuracy, as the global scientific community continues to collaborate and produce multinational papers.

We identify two types of dubious affiliations, namely Solo Show and Insufficient Affiliation, that may be present in the datasets used to assess IRC between nations. The papers with Solo-Show affiliations provide the appearance of collaboration falsified by a single person's affiliation with multiple nations. The Insufficient-Affiliation papers, on the other hand, lack the sufficient foundation to be considered as a result of collaboration between two nations.

Then, using papers and cross-national papers indexed in SCIE, SSCI, and A&HCI by and between US, CN, UK, and AU, we confirm that these papers with dubious affiliations are too numerous to ignore when conducting IRC analysis. There are on average at least 14 % of Solo-Show papers, and 40 % of both types of papers in the six sets of cross-national papers across the disciplinary categories.

We notice that cultural proximity seems to play a role in how papers with dubious affiliations are distributed between nations. Cross-national papers between Western nations (i.e., US, UK, and AU) always have higher shares of papers with dubious affiliations than those between Western nations and CN. It is surprising that US–CN has not only the lowest but also notably smaller shares of papers with dubious affiliations both in SCIE and SSCI.

We further find that academic practice affects how the two types of dubious affiliations are distributed across disciplinary categories. For A&HCI papers, where scholars tend to work independently, the Solo-Show papers are dominant among those with dubious affiliations. As to SCIE and SSCI papers, where scholars have higher preference to team works, the Insufficient-Affiliation papers are more prevalent than the Solo-Show ones. US–CN cross-national papers, however, exhibit a distinctive pattern that there are more Solo-Show papers than Insufficient-Affiliation ones, highlighting a different nature of collaboration between the US and CN.

Then, through examining cross-national papers and those with dubious affiliations from 2012 to 201, we further confirm that dubious affiliations are not sporadic or recent phenomena but follow a persistent development. By looking at the historical data, we also verify that the influences by academic practice and cultural proximity are generally preserved over the years. We also discover that geopolitical tension between the US and CN seems to exert noticeable influence on their cross-national papers. This phenomenon seems to have also permeated collaborations between CN and other Western nations.

There are several interesting directions for further exploration. First of all, verifying whether these papers with dubious affiliations are indeed collaborative works or not would be highly valuable, as this verification may help guaranteeing the accuracy of future IRC

Table 7
The Solo-Show corresponding authors' corresponding addresses in US–CN SCIE Solo-Show papers.

CN addresses	US addresses	Both CN and US addresses	Other addresses
9330 (37.5 %)	5945 (23.9 %)	9415 (37.8 %)	217 (0.9 %)

analysis. This task, however, seems more challenging than we imagine. Even for papers with Solo-Show affiliations that seem to lack collaboration evidence, they still involve varying degrees of dubiety.

We have performed some preliminary analysis on the 77,338 US–CN SCIE papers with Solo-Show affiliations to investigate the roles of these Solo-Show authors. Table 6 shows that almost half (48.4 %) of the Solo-Show authors have lesser contributions to their papers, casting further doubt on whether these papers should be included in IRC analysis as collaborative works. To truly verify these papers, consulting the author contributions of these papers would be most trustworthy. However, except some specific journals, most journals do not have author contributions as part of their papers' metadata.

In addition to author contributions, another piece of data that may be of use is the corresponding (or the so-call reprint) addresses specified by the corresponding authors. Then, for the 24,907 (=15,501 + 9406) papers whose Solo-Show authors are corresponding authors, the nations of their specified corresponding addresses are statisticized in Table 7. We can see from Table 7 that, even though these Solo-Show authors claims to be affiliated with both US and CN institutions, more than 60 % of them specify only US or CN corresponding addresses, suggesting a different degree of preference between US and CN from these authors. If the other authors are only affiliated with CN, for example, these papers probably cannot qualify as US–CN collaborations when their Solo-Show corresponding authors specify only CN addresses,[2] despite their higher contributive roles as corresponding authors.

Given time and resource constraints, we have not comprehensively investigated author ranks, roles, or counting methods for classifying papers with dubious affiliations beyond the preliminary results reported above. It is possible that, with the inclusion of these additional considerations, measures can be developed in future studies and implemented to ensure that cross-national papers genuinely and accurately reflect the contributions of all parties involved.

The presence of papers with dubious Solo-Show affiliations also raises questions about the motivations and incentives of institutions and researchers engaging in such practices, which worth further investigation. Another possible future study, therefore, is to examine how the Solo-Show papers are distributed among different scenarios, and what institutions and researchers are more frequently involved in these scenarios, would shed additional insight on why and how these dubious Solo-Show affiliations occur.

The findings of this study have significant implications for different stakeholders. For scientometricians and bibliometricians conducting IRC analysis, it is clear that they should explicitly spell out precise definitions of what counts as cross-national papers, and they ought to carry out rigorous data cleaning and filtering to mitigate the negative impact from papers with dubious affiliations. Even though creating a dataset of papers reflecting true collaborations may be costly, it is essential to provide at least some cautionary statements regarding the potential pitfalls that may result from papers with dubious affiliations.

On the other hand, as author affiliations are the foundation for the analyses of cross-institutional and cross-national collaborations, journal publishers may consider adopting and enforcing clearer guidelines for submitted papers in their specifications of institutional affiliations and addresses. For instance, perhaps only the institutions with which the authors have employment or contract agreements can be listed. Furthermore, journal publishers and scholarly databases should strive to make information about authors' contributions publicly available, so that the contributions of their affiliated institutions and nations can be more directly identified.

In addition, to scientific policy makers and research funding providers, the ambiguity reported by this study indicates that they should be cautious in measuring academic performance from their policy decisions and fund allocations, especially when international collaborations are involved. For instance, if international collaboration is a main goal for some policy or funding, a more in-depth investigation to the roles of the policy stakeholders and fund recipients in the international collaborations suggested by this study would ensure a more accurate evaluation to the effects of the policy or funding.

CRediT authorship contribution statement

Chung-Huei Kuan: Investigation, Visualization, Writing – original draft, Writing – review & editing. **Dar-Zen Chen:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing, Project administration, Supervision. **Mu-Hsuan Huang:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

Declaration of competing interest

Mu-Hsuan Huang is the Editor-in-Chief of Journal of Informetrics. The other authors declare that they have no conflict of interest.

[2] There is some inaccuracy in this observation as, before January 2016, only the first address is recorded by WoS even through multiple addresses are specified by the corresponding author. See https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-Core-Collection-Explanation-of-Reprint-Address?language=en_US.

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