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Field-specific gold open access dynamics in the Chinese mainland: Overviews, disparities, and strategic insights

Xinyi Chen,* and Zhiqiang Liu


Xinyi Chen


Zhiqiang Liu

Periodicals Agency of Shanghai University, Shanghai University, Shanghai, 200444, China

ORCID:
X. Chen: 0000-0003-2654-4308

***Corresponding author:** Xinyi Chen, Periodicals Agency of Shanghai University, Shanghai University, Shanghai 200444, China.
E-mail: shirleychen@i.shu.edu.cn

Abstract: Gold Open Access (OA) journals are crucial for scholarly communication, highlighting the need for a thorough evaluation of their academic influence on different research fields. This study leverages the InCites platform to examine article-level characteristics relating to 22 Essential Science Indicators (ESI) research fields, with a focus on the dynamics of gold OA articles, including gold OA uptake in the Chinese mainland and gold OA adoption in the domestic English-language academic journal publishing of the Chinese mainland. The findings reveal that disparities in gold OA adoption across 22 ESI fields are more pronounced in the Chinese mainland compared with the world scenario. In the Chinese mainland, there is a significant polarization in gold OA publishing volumes across different ESI fields, particularly in Chemistry, Clinical Medicine, and Engineering. This study builds on the understanding of OA citation advantage (OACA) by incorporating gold OA publishing volume into a two-dimensional framework, resulting in the development of a "distance" metric. It further categorizes gold OA citation effects into four quadrants: positive citation effects (quadrants A and B) and negative citation effects (quadrants C and D), based on category normalized citation impact (CNCI) and journal normalized citation impact (JNCI) indicators from the InCites database. The findings underscore the importance of developing tailored strategies to address field-specific challenges and promote gold OA dynamics in the Chinese mainland; while prioritizing high-quality gold OA journals is essential for fostering gold OA development in the rest of the world.

Keywords: academic influence, citation advantage, citation impact, Essential Science Indicators, OA dynamics, OA uptake, open access

INTRODUCTION

Open access (OA) scientific journal publishing stands out as a transformative force in the global academic landscape. By offering free access to scholarly literature, OA holds the potential to expedite scientific progress, nurture collaboration, and spur innovation across diverse disciplines.

Brief introduction of global OA dynamics

Large-scale bibliometric studies comparing uptake (Hobert et al., 2021; Simard, Ghiasi, et al., 2022), usage (Basson et al., 2021), and citations (Maddi & Sapinho, 2022) between OA and traditional publishing, or between different OA models, reveal substantial variations across disciplines (Demeter et al., 2021; Maddi, 2020). Severin et al. (2018) argued that the implementation of OA in certain disciplines faces barriers due to deep-rooted research cultures, while Liu and Li (2018) advocated for targeted and sophisticated approaches to tackle differences in natural and social sciences.

The uptake of gold (or article processing charge [APC]-funded) OA is argued to be significantly influenced by authors' sensitivity to the costs associated with APCs. This sensitivity is particularly pronounced when authors are required to cover these costs as "allowable project costs" by their funding sources (Björk & Solomon, 2014). This dynamic may result in the gold OA market being less influenced by the academic impact of journal content, which could explain why editors of APC-funded journals have argued for the abolition or reduction of APCs (Alperin, 2022; Liverpool, 2023), notably leading to the resignation of entire editorial boards of two neuroimaging journals in protest against high APCs (Sanderson, 2023a, 2023b).

On the other hand, in recent years, numerous studies have delved into the potential of OA to bolster equality within and between communities (Arunachalam, 2017; Koutras, 2020; Nwagwu & Ahmed, 2009; Veletsianos & Kimmons, 2012) and bridge the global North–South research divide (Adcock & Fottrell, 2008). However, concerns about potential widening of the digital divide due to inequities in OA resources are also prevalent (Bezuidenhout et al., 2017; Siriwardhana, 2015).

Besides the paradoxical economic and societal impacts of OA, its academic influences raise questions (Brembs et al., 2013; Chang, 2017; Wang et al., 2015). Specifically, concerning the OA citation advantage (OACA) for OA articles over closed access (CA) articles, while most evidence supports an OACA (Piwowar & Vision, 2013; Sotudeh et al., 2015), it is claimed to be primarily driven by "Green" and "Hybrid" OA, with "Gold" OA articles showing citation disadvantages compared to CA articles (Piwowar et al., 2018). Davis (2011) assessed the effects of OACA within 3 years through a randomized controlled trial. However, the influence of OA on citations remains unclear (Langham-Putrow et al., 2021). Therefore, Ross-Hellauer et al. (2022) emphasized the critical need to address potential negative effects on equity during the transition to open science, rather than focusing solely on affirming or challenging the presence of OACA.

The involvement of a diverse range of stakeholders in OA publishing industries adds complexity to evidence-based discussions on OACA (Asai, 2023; Butler et al., 2023). Shadow libraries can affect researchers' citation practices by cancelling the positive effects of OA publishing (Maddi & Sapinho, 2023). APCs stratify OA publishing and transmission, prompting calls for alternative models like Diamond OA (Klebel & Ross-Hellauer, 2023). The development of transformative agreements has further blurred the lines between subscription and OA publication, insofar as the OA element of such agreements can be summarized as "subscribe to open" (S2O). Beyond the real-world factors previously mentioned, polarized viewpoints on OA from research communities add another layer of complexity (Craig et al., 2007; Tennant et al., 2016). It is recommended that studies on OACA focus on continuous qualitative tracking and reviews, rather than relying on meta-analysis (Langham-Putrow et al., 2021).

Key points

- Disparities in gold OA adoption across fields in the Chinese mainland are more pronounced compared to the global landscape, such as Chemistry, Clinical Medicine, and Engineering.
- Fields such as Microbiology, Molecular Biology & Genetics, and Neuroscience & Behaviour exhibit a greater academic influence of gold OA in the Chinese mainland compared to the rest of the world.
- It is important for the Chinese mainland to address disciplines with unfavorable academic influence of gold OA, such as Agricultural Sciences, Multidisciplinary, and Social Sciences.
- Developing tailored strategies to address field-specific challenges and promote gold OA dynamics in the Chinese mainland is crucial.
- Prioritizing high-quality gold OA journals is essential for advancing gold OA development globally.

Why has the Chinese mainland been chosen for regional analysis of gold OA dynamics?

According to the InCites database, the Chinese mainland has led the world in gold OA scientific output by its authors since the mid-2010s, and this presents a strong case for analysing regional gold OA uptake and its influences on citations in the Chinese mainland. Moreover, China's OA landscape is multifaceted, with notable field-specific variations. Significant funding and policy support has resulted in a notable increase in gold OA scientific output by Chinese authors, especially in disciplines such as the biomedical sciences (Schiermeier, 2018). Moreover, the economic burden of APCs poses a significant challenge for Chinese researchers across all fields. China is estimated to pay the highest APCs by region to the 12 major international journal publishers (Kwon, 2022; Maddi & Sapinho, 2022; Smith et al., 2021; Zhang et al., 2022).

However, many academic journals in the Chinese mainland adopt a "free to read" OA model, known as the "bronze OA type," but lack clear creative commons (CC) licensing (CAST & STM, 2022; Maddi, 2020; Simard, Basson, & Larivière, 2022). Therefore, it is crucial to address deficiencies in China's academic publishing volume and enhance consistency and best practices in the publishing industry (CAST, 2023; Hu et al., 2012; Ren et al., 2023; Wen & Ning, 2023). This necessitates research into field-specific OA dynamics within the Chinese mainland to foster equitable OA across all disciplines.

Against this backdrop, this study employs a data-driven approach, using the Essential Science Indicators' (ESI) schema of 22 research fields. It examines field-specific gold OA dynamics both globally and within the Chinese mainland through in-depth scientometric analyses. The aim is to elucidate the mechanisms driving the growth of gold OA publishing output as influenced by field-specific academic factors. It seeks to address a significant gap in the literature and ultimately enhance the efficiency and balance of gold OA publishing.

DATA AND PROCESSING

For an in-depth analysis of field-specific gold OA publishing volume and academic influence, the InCites database of Clarivate™ was utilized. The methodology involved categorizing journals indexed in the ESI dataset of the InCites database, that is, the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI), into 22 fields. The citation counts for each of the 22 ESI fields were derived from citing sources that include the SCIE, SSCI, and Arts & Humanities Citation Index (AHCI).

Articles are classified by OA type in the InCites database. It is noteworthy that the OA type is determined through Clarivate™ in collaboration with OurResearch. There are five types of articles: gold, gold-hybrid, free to read (aka bronze), green and non-OA (https://webofscience.help.clarivate.com/en-us/Content/open-access.html).

This study focused on gold OA articles from 22 ESI research fields in 2023, using non-OA articles from the same fields and year as the control group. Article-level metrics offered by the InCites database served as the foundation for scientometric analysis within individual research fields. Moreover, the InCites database provides robust field-normalized and article-specific indicators like category normalized citation impact (CNCI) and journal normalized citation impact (JNCI) for assessing academic impact within and across fields. These features make InCites a more suitable database for article-level analysis compared with other well-known databases like Dimensions and Scopus.

Three definitions require clarification. (1) Gold OA uptake (Hobert et al., 2021) in the Chinese mainland refers to the percentage of total scientific output by Chinese authors that is made available via the gold OA model. (2) Gold OA adoption (Björk & Korkeamäki, 2020; Simard, Ghiasi, et al., 2022) in the domestic English-language academic journal publishing of the Chinese mainland encompasses two key indicators: the proportion of gold OA articles in English-language academic journals of the Chinese mainland as well as that of citations these articles receive. (3) Gold OA dynamics (Ross-Hellauer et al., 2022) in the Chinese mainland encompasses both gold OA uptake and gold OA adoption, as outlined in the abstract.

Data collection

The InCites dataset utilized in this study was updated on 31 May 2024, and included Web of Science (WoS) content indexed through 30 April 2024. The data collected for analysis included datasets for the Chinese mainland and the rest of the world, respectively, incorporating the following:

1. Gold OA articles indexed in ESI from international English-language journals in the Chinese mainland in 2023 (referred to as CP_{OA2023}).
2. Gold OA articles indexed in ESI from international English-language journals outside the Chinese mainland in 2023 (referred to as W_{OA2023}).
3. Non-OA articles indexed in ESI from international English-language journals in the Chinese mainland in 2023 (referred to as $CP_{non\text{-}OA2023}$).
4. Non-OA articles indexed in ESI from international English-language journals outside the Chinese mainland in 2023 (referred to as $W_{non\text{-}OA2023}$).
5. Articles indexed in ESI from international English-language journals outside the Chinese mainland in 2023, with no authors located in the Chinese mainland (referred to as W_{2023}).
6. Articles indexed in ESI in 2023 with at least one author located in the Chinese mainland (referred to as C_{2023}).
7. Gold OA articles indexed in ESI in 2023 with at least one author located in the Chinese mainland (referred to as C_{OA2023}).
8. Articles indexed in ESI from international English-language journals in the Chinese mainland in 2023 (referred to as CP_{2023}).

The mutual filters and indicators for all the above eight datasets were as follows:

- Dataset: InCites Dataset+ESCI.
- Schema: Essential Science Indicators.
- Time Period: [2023, 2023].
- Include Early Access documents: true.
- Funding Data Source: All Sources.
- Source Type: [Journals].
- Domestic/International Collaboration: All.
- Indicators: Web of Science Documents; Times Cited; Journal Normalized Citation Impact; Category Normalized Citation Impact.

Moreover, for each dataset the added filters were set as shown in the following Table 1.

Each data point from Figs. 3 to 7 corresponds to one of the 22 ESI fields, represented by the following indices: 1, Agricultural Sciences; 2, Biology & Biochemistry; 3, Chemistry; 4, Clinical Medicine; 5, Computer Science; 6, Economics & Business; 7, Engineering; 8, Environment/Ecology; 9, Geosciences; 10, Immunology; 11, Materials Science; 12, Mathematics; 13, Microbiology; 14, Molecular Biology & Genetics; 15, Multidisciplinary; 16, Neuroscience & Behaviour; 17, Pharmacology & Toxicology; 18, Physics; 19, Plant & Animal Science; 20, Psychiatry/Psychology; 21, Social Sciences, general; 22, Space Science.

Data processing

To assess data distributions for normality, OriginPro 2018 (OriginLab Corporation, Northampton, MA, USA) was used. Excel

TABLE 1 Filters set specifically for the eight datasets.

	Location	Open access	Publication source country/region
CP_{OA2023}	-	[Gold]	[CHINA MAINLAND]
W_{OA2023}	-	[Gold]	NOT [CHINA MAINLAND]
$CP_{non\text{-}OA2023}$	-	[Non-Open Access]	[CHINA MAINLAND]
$W_{non\text{-}OA2023}$	-	[Non-Open Access]	NOT [CHINA MAINLAND]
W_{2023}	NOT [CHINA MAINLAND]	-	NOT [CHINA MAINLAND]
C_{2023}	[CHINA MAINLAND]	-	-
C_{OA2023}	[CHINA MAINLAND]	[Gold]	-
CP_{2023}	-	-	[CHINA MAINLAND]

computer spreadsheets (Microsoft, Seattle, WA, USA) were the primary tool for conducting calculations in this study. A *p*-value less than 0.05 was considered statistically significant.

RESULTS

Overview of gold OA publishing volume in the Chinese mainland

As shown in Fig. 1, authors from the Chinese mainland produced 255,539 gold OA articles in 2023, accounting for 33.13% of the global total of gold OA articles. This substantial share positions the Chinese mainland as the leading contributor among all countries and regions. In contrast, only 21,566 gold OA articles were published in the Chinese mainland in the same year, representing just 2.796% of the global total. Additionally, 4640 of these articles, or 21.515%, were authored exclusively by researchers from outside the Chinese mainland. This striking disparity between the high volume of gold OA articles authored by Chinese researchers and the comparatively limited gold OA publishing volume in the Chinese mainland highlights the substantial potential for further development of gold OA publishing in China. Indeed, the global share of gold OA articles authored by Chinese researchers is almost an astonishing 12-times greater than the global share of gold OA articles published by Chinese publishers. Furthermore, given the limited volume of gold OA publishing by Chinese publishers, it is reasonable to use gold OA adoption in the English-language academic journal publishing of the rest of the world as a representation of the world scenario.

Field-specific gold OA uptake and publishing volume

Table 2 illustrates the distributions of CP_{OA2023}/C_{OA2023}, CP_{OA2023}/CP_{2023}, C_{OA2023}/C_{2023} and W_{OA2023}/W_{2023} among 22 ESI fields. It should be noted that the distributions of CP_{OA2023}/CP_{2023} (i.e., the proportion of gold OA articles in English-language academic journals of the Chinese mainland), C_{OA2023}/C_{2023} (i.e., gold OA uptake in the Chinese mainland) and W_{OA2023}/W_{2023} cannot reject normality in the Shapiro–Wilk test at a significance level of 5%, which is suitable for testing normality of data sizes less than 50, indicating there is no inherent inequity in gold OA uptake and publishing volume by different research fields in both cases of the Chinese mainland and the rest of the world. However, the distribution of CP_{OA2023}/C_{OA2023} exhibited non-normality at a significance level of 10%, implying a clear mismatch between gold OA publishing volume in the Chinese mainland and the gold OA scientific output by Chinese authors among the 22 fields.

Distribution and rug plots in Fig. 2 can better illustrate the mismatch among the datasets. Fig. 2 clearly shows the non-normality of CP_{OA2023}/C_{OA2023}, and also shows that in most fields, CP_{OA2023}/C_{OA2023} is less than 20% and substantially less than the other three datasets, to the extent that there is limited overlapping between CP_{OA2023}/C_{OA2023} and the other three. Furthermore, while the distribution of CP_{OA2023}/CP_{2023} exhibited normality, it showed a significantly wider dispersion compared to W_{OA2023}/W_{2023}. This indicates greater polarization among research fields in terms of gold OA publishing volumes in the Chinese mainland compared with the world scenario. Journal practitioners in China should consider this disparity if they aim to foster a more balanced publishing landscape that aligns with the aims of the Sustainable Development Goals Publishers Compact, both in terms of field-specific focus and geographical representation.

Summary statistics for the comparison of these four datasets are presented in Table 3, utilizing median and interquartile range (IQR) due to the non-normal distribution of the CP_{OA2023}/C_{OA2023} dataset, alongside mean and standard deviation (SD). Notably, CP_{OA2023}/CP_{2023} exhibits the widest dispersion among the four datasets as depicted in Fig. 2, statistically supported by the largest IQR of 41.797%. Furthermore, CP_{OA2023}/CP_{2023} and C_{OA2023}/C_{2023} share a similar median with W_{OA2023}/W_{2023}, approximately 40%, indicating that domestic gold OA uptakes and gold OA adoptions in the publishing sector of the Chinese mainland are largely influenced by the world scenario.

Moreover, it is helpful to explore the correlation between four distributions (CP_{OA2023}, C_{OA2023}, CP_{2023}, C_{2023}) among the 22 fields to reveal research fields with significant mismatch. Spearman correlation coefficients, suitable for non-normally distributed datasets, were employed as shown in Fig. 3, and all

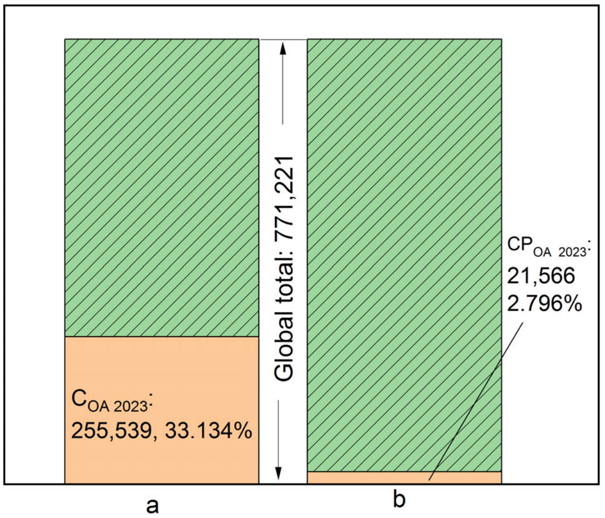

FIGURE 1 Bar charts depicting gold OA articles from (a) authors from the Chinese mainland and (b) international English-language journals in the Chinese mainland in 2023, with global percentages.

coefficients were found to be significant at a 0.05 level, signifying the effectiveness of this analysis. Fig. 3 highlights a statistically significant mismatch between CP_{OA2023} and C_{OA2023}, as well as between CP_{2023} and C_{OA2023} in field 4 (Clinical Medicine). Moreover, significant disparities between CP_{OA2023} and CP_{2023} are observed in fields 3 (Chemistry) and 4 (Clinical Medicine), signalling uneven development of gold OA adoption across fields. Besides, the mismatch in field 7 (Engineering) between C_{2023} and the other three indicators is most significant among 22 ESI fields.

Qualitative research on field-specific impacts of gold OA compared with non-OA articles

Additional statistical analyses comparing citation metrics among research fields are necessary. To evaluate the differences in the distributions of articles and citations across 22 research fields in gold OA publishing contexts, both in the Chinese mainland and globally, we established eight distinct datasets. These include: the ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$, the citation ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$, the ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, and the citation ratio of W_{OA2023} to $W_{non\text{-}OA2023}$; additionally, the

TABLE 2 Ratio of CP_{OA2023} relative to C_{OA2023}, CP_{2023}, and C_{2023}, and that of W_{OA2023} relative to W_{2023}, respectively indexed in 22 ESI research fields in 2023.

	CP_{OA2023}/C_{OA2023} (%)	CP_{OA2023}/CP_{2023} (%)	C_{OA2023}/C_{2023} (%)	W_{OA2023}/W_{2023} (%)
1. Agricultural Sciences	15.456	93.488	38.278	64.220
2. Biology & Biochemistry	8.240	52.945	37.439	51.850
3. Chemistry	0.808	2.263	24.493	50.367
4. Clinical Medicine	13.260	83.391	57.846	39.439
5. Computer Science	10.555	28.582	11.753	20.729
6. Economics & Business	11.623	47.154	9.737	9.268
7. Engineering	7.111	44.116	21.691	46.752
8. Environment/Ecology	2.150	22.719	41.426	65.329
9. Geosciences	9.691	41.045	45.501	67.424
10. Immunology	2.009	44.128	67.959	63.224
11. Materials Science	12.275	31.172	21.008	45.929
12. Mathematics	0.000	0.000	34.082	40.761
13. Microbiology	0.138	7.200	71.946	91.480
14. Molecular Biology & Genetics	12.448	75.305	56.456	68.546
15. Multidisciplinary	4.779	64.516	84.121	39.050
16. Neuroscience & Behavior	12.222	76.389	45.535	34.852
17. Pharmacology & Toxicology	13.164	66.280	36.495	44.169
18. Physics	14.004	25.644	26.948	33.960
19. Plant & Animal Science	7.523	56.818	53.245	51.959
20. Psychiatry/Psychology	0.920	28.358	44.221	26.002
21. Social Sciences, general	0.047	4.110	35.806	20.130
22. Space Science	0.325	1.379	35.453	34.469
Sum (in percentage)	8.439	41.820	33.887	42.993

reciprocals of these four datasets were included for comparison, which are the ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023}, the citation ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023}, the ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}, and the citation ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}.

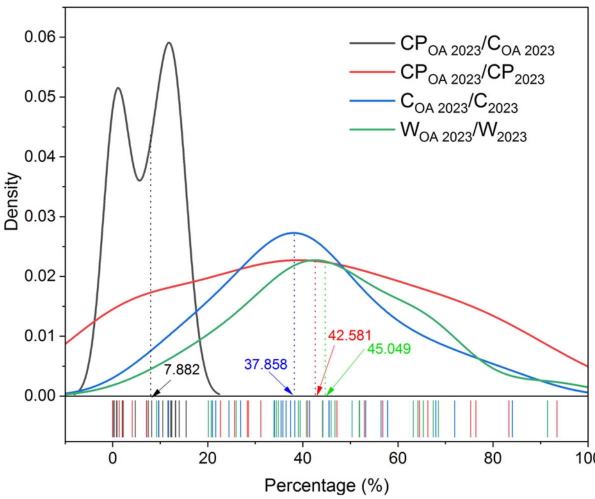

FIGURE 2 Distributions and rug plots for CP_{OA2023}/C_{OA2023}, CP_{OA2023}/CP_{2023}, C_{OA2023}/C_{2023} and W_{OA2023}/W_{2023} among 22 ESI fields. Medians of these four datasets are displayed.

TABLE 3 Means, medians, SDs and IQRs for CP_{OA2023}/C_{OA2023}, CP_{OA2023}/CP_{2023}, C_{OA2023}/C_{2023} and W_{OA2023}/W_{2023} among 22 ESI fields.

	Mean	Median	SD	IQR
CP_{OA2023}/C_{OA2023} (%)	7.216	7.882	5.530	11.355
CP_{OA2023}/CP_{2023} (%)	40.773	42.581	28.333	41.797
C_{OA2023}/C_{2023} (%)	40.974	37.858	18.884	26.297
W_{OA2023}/W_{2023} (%)	45.905	45.049	19.159	28.754

Shapiro–Wilk tests revealed that the eight distributions by 22 fields are not significantly drawn from a normally distributed population. Consequently, the paired sample Wilcoxon signed-rank test, specifically designed for differences that may not be normally distributed, was conducted to qualitatively compare the variable citation influences imposed by gold OA upon the Chinese mainland and the rest of the world. Moreover, the median and IQR were used as indicators in summary statistics, as shown in Fig. 4.

The results depicted in Fig. 4a reveal that, at a 95% confidence level, the distribution pair of the CP_{OA2023} to $CP_{non\text{-}OA2023}$ ratio and its corresponding citation ratio, as well as that of W_{OA2023} to $W_{non\text{-}OA2023}$, shows significant differences across the 22 research fields ($p = 0.024$ and $p = 0.003$, respectively). Consequently, the Wilcoxon signed-rank tests make it evident that gold OA publishing practices significantly alters traditional citation behaviour across different research fields both inside and outside the Chinese mainland. Conversely, Fig. 4b suggests that the global effect of non-OA on gold OA is statistically similar for different research fields at a 95% confidence level; in other words, non-OA publishing practices do not bring about significant changes in gold OA adoptions in the world scenario. However, this is not the case for the Chinese mainland, where there is differentiation among research fields concerning the altering effects of non-OA on gold OA adoptions that is statistically significant ($p < 0.001$).

In summary, the Chinese mainland displays statistically distinct distributions between gold OA publishing volume and citation behaviours across different research fields, compared with the world scenario.

Quantification of field-specific impacts of gold OA compared with non-OA articles

To further quantify the impact of gold OA publishing practices, we conducted ordinary least squares (OLS) regression of the

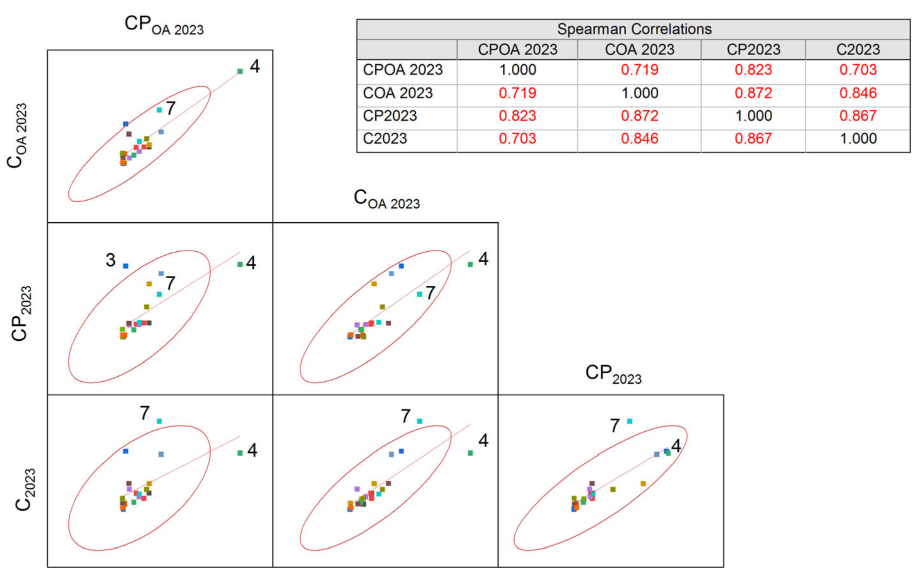

FIGURE 3 Scatter plots illustrating Spearman correlations among C_{2023}, CP_{2023}, C_{OA2023}, and CP_{OA2023}. The ellipses represent a 95% confidence level. The coefficients of Spearman correlations are provided as well with significant correlations at a level of 0.05 in red.

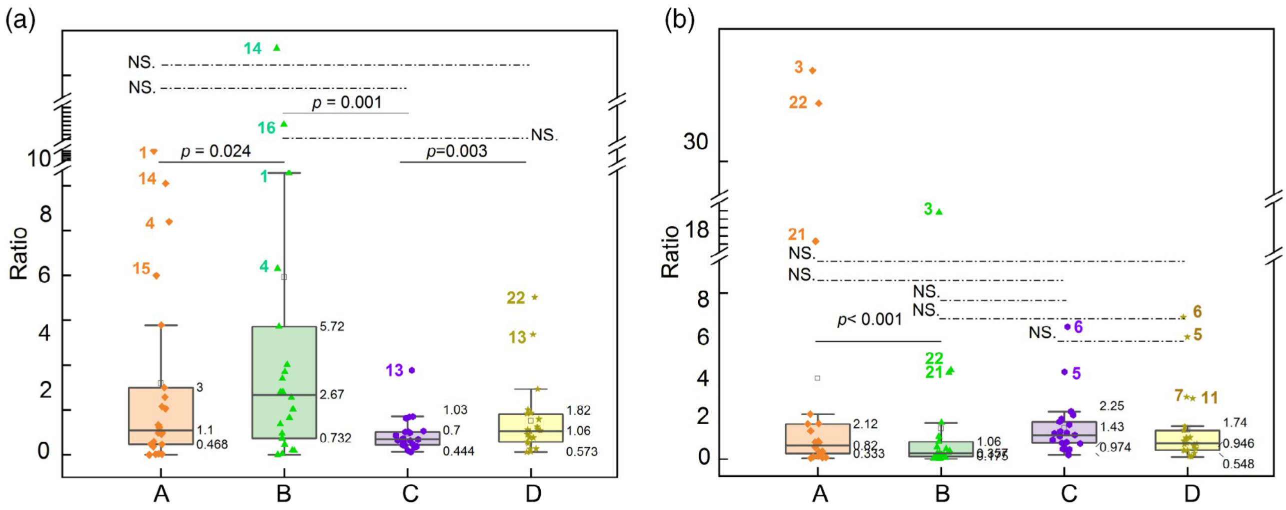

FIGURE 4 (a) Box plots depict (A) the ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$, (B) the citation ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$, (C) the ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, and (D) the citation ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, with respect to 22 research fields. (b) Box plots depict (A) the ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023}, (B) the citation ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023}, (C) the ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}, and (D) the citation ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}, with respect to 22 research fields. The box plots are accompanied by the results of paired sample Wilcoxon signed-rank tests for the 12 pairs of datasets. "NS" indicates that the two distributions are not significantly different at a 95% confidence level, while the displayed *p* values indicate statistical significance at a 95% confidence level. Additionally, the box ranges, whiskers, medians and indices of ESI fields are presented; whiskers indicate outliers (greater than Q3 + 1.5IQR and smaller than Q1 – 1.5IQR).

citation ratios of gold OA to non-OA on the respective article ratios of gold OA to non-OA for both the world and the Chinese mainland, and vice versa. Among the four relationships examined, only the OLS regression of the citation ratios of $W_{non\text{-}OA2023}$ to W_{OA2023} on the ratio of $W_{non\text{-}OA2023}$ to W_{OA2023} is statistically significant. The critical assumption that the residuals around the regressions are normally distributed is satisfied at the 0.05 significance level, indicating the effectiveness and goodness-of-fit of the fitted OLS model to the observed values. Additionally, the Q-Q plots of the regular residuals in the four cases are shown in Fig. 5, corroborating the results of OLS regression. The outcomes of the OLS regression with respect to Fig. 5d are presented in Table 4, where the confidence level for parameters is 95%.

Based on the parameters presented in Table 4, it is reasonable to infer that the interplay between gold OA and non-OA publishing practices has a less consistent and more variable effect on citation behaviours across different research fields for the Chinese mainland than for the rest of the world. This finding echoes the results of the paired sample Wilcoxon signed-rank test. The next step would be to quantify the field-specific impacts of gold OA publishing practices both in the Chinese mainland and the rest of the world with more powerful statistical tools.

Although the datasets for the Chinese mainland do not meet the criteria for conducting OLS regression, we employed a two-dimensional method for comprehensive evaluation by considering the ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$ and the ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, which were projected onto the *x*-axis of the two-dimensional rectangular coordinate system in Fig. 6, in tandem with the citation ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$ and the citation ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, which were projected onto the *y*-axis of the two-dimensional system in Fig. 6.

The line of equity denotes the position where gold OA publishing practices have no differential influence on citation behaviours compared with non-OA. In the world scenario, as evidenced by data points located around the line of equity, gold OA publishing practices did not conspicuously affect citation behaviours concerning the 22 fields in 2023. On the other hand, the data points of the Chinese mainland are more dispersed, and are divergently distributed as the *x*-axis increases, echoing the Q-Q plots of the regular residuals regarding the Chinese mainland (Fig. 5a,c) that clearly exhibit the steep S shape and non-normality.

The metrics "distance" in Fig. 6 are calculated by using the following equation: $(y - x)/\text{sqrt}(2)$. By delving into the two-dimensional diagram, we can quantitatively study the field-specific effect of the gold OA model both in the Chinese mainland and the rest of the world. Unlike the data points for the rest of the world, the data points for the Chinese mainland show an uneven distribution. Specifically, 17 data points lie above the line of equity with positive distances from the line as opposed to four data points (1, Agricultural Sciences; 4, Clinical Medicine; 15, Multidisciplinary; 18, Physics) below it. These distances from the line can be interpreted as the increasing or decreasing coefficients of the effects of the gold OA model on citation behaviours compared with non-OA.

In Table 5, we present all the distances of data points and the average distance, which unveil room for improvement and distinct implications with respect to different disciplines inside and outside the Chinese mainland. Moreover, the

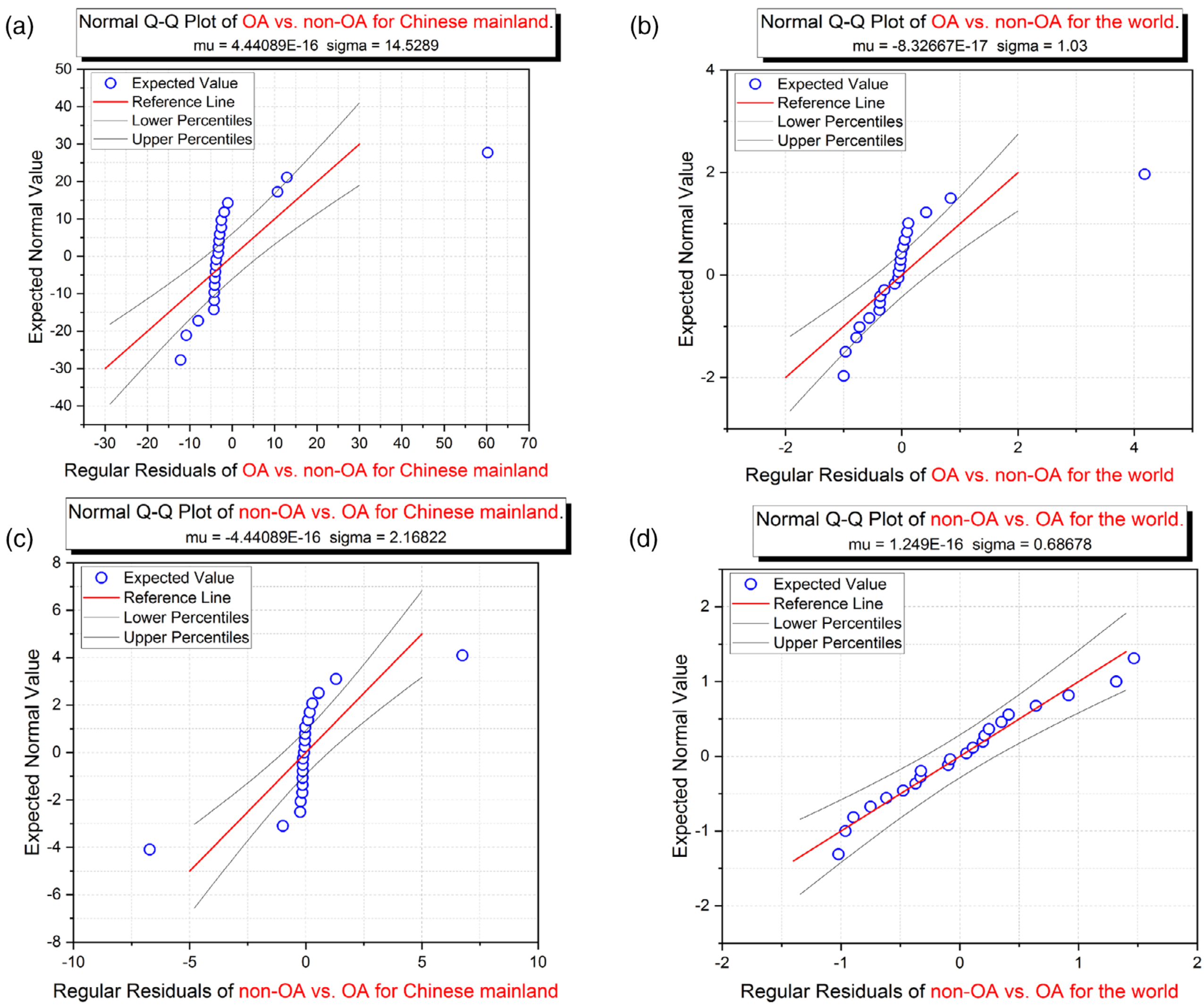

FIGURE 5 Normal Q-Q plots of the regular residuals for the OLS regression of (a) the citation ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$ on the ratio of CP_{OA2023} to $CP_{non\text{-}OA2023}$, (b) the citation ratio of W_{OA2023} to $W_{non\text{-}OA2023}$ on the ratio of W_{OA2023} to $W_{non\text{-}OA2023}$, (c) the citation ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023} on the ratio of $CP_{non\text{-}OA2023}$ to CP_{OA2023}, and (d) the citation ratio of $W_{non\text{-}OA2023}$ to W_{OA2023} on the ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}. The confidence bands for the Q-Q plots are set at the level of 95%.

TABLE 4 Outcomes of OLS regression of the citation ratio of $W_{non\text{-}OA2023}$ to W_{OA2023} on the ratio of $W_{non\text{-}OA2023}$ to W_{OA2023}.

Outcomes and statistics	Parameter
Intercept (β_0)	−0.487* (0.224)
Slope (β_1)	1.212*** (0.088)
R^2	0.904
Adj.-R^2	0.899
F-test value	188.158***

Note: Values in the brackets are standard errors; the significance levels are ***p < 0.001, and *p < 0.05.

average increasing coefficient of gold OA over non-OA for the Chinese mainland is 3.352, compared with 0.415 in the rest of the world.

It is important to note that the “distances” in Fig. 6 and Table 5 are field-normalized. This normalization is achieved by dividing the publishing volume and academic influence of gold OA articles by those of non-OA articles within each ESI field, thereby mitigating the influence of field classification on the two-dimensional analysis. However, since “distances” are not widely understood among bibliometricians, a relevant question emerges: how can we convert these distance metrics into conventional bibliometric indicators that are both easily understood and practically useful?

First, disparities in citation counts between gold OA and non-OA articles arise from the varied responses of different fields to the trend of OA publishing. This phenomenon can be quantified by utilizing the ratio of the JNCI for gold OA articles relative to that for non-OA articles. The JNCI reflects the impact of citation counts of articles on the journal to which they belong.

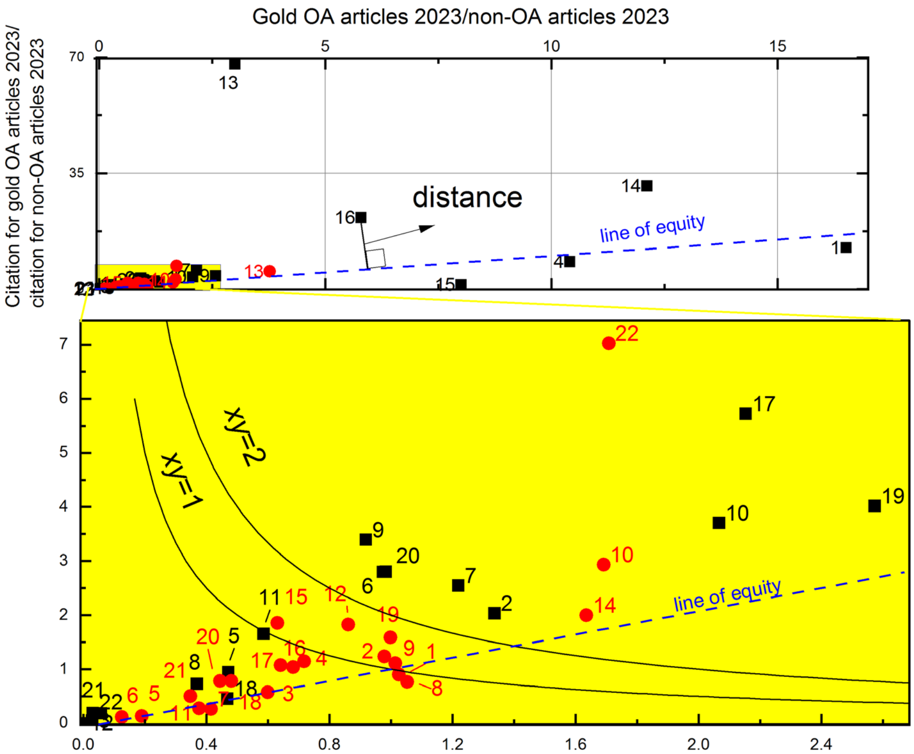

FIGURE 6 Two-dimensional evaluation of the citation ratios (*y*) and the article ratios (*x*) for gold OA versus non-OA articles in 2023 with respect to the Chinese mainland and the rest of the world. The black squares and red dots refer to different research fields in the Chinese mainland and the rest of the world, respectively. The hyperbolas $xy = 1$ and $xy = 2$ represent points where the products of the citation ratio (*y*) and the article ratio (*x*) equal 1 and 2, respectively.

Therefore, by dividing the sum of all JNCIs for gold OA articles by the sum of all JNCIs for non-OA articles within a specific field, we obtained a ratio that highlights the distinct citation effects between gold OA and non-OA models across different fields.

Second, it is crucial to recognize that within a specific field, citation counts can vary based on the quality of the published content. Specifically, articles originating from higher-quality journals tend to yield more pronounced citation counts compared with their counterparts from journals of lower quality tiers. As an illustration, articles from journals classified in Q1 of the Journal Citation Reports (JCR) are supposed to receive larger citation counts than articles in Q4. These diverse citation effects within a field can be characterized by the CNCI.

As such, to capture these nuanced variations in citations and further explore the underlying mechanism of the indicator "distance," the metrics of JNCI and CNCI on the InCites platform were employed to depict citation effects across and within fields, respectively. The two-dimensional evaluation displayed in Fig. 7 shows four quadrants (ABCD) based on the equivalence lines of gold OA CNCI/non-OA $\text{CNCI} = 1$ and gold OA JNCI/non-OA $\text{JNCI} = 1$. By comparing the bubble areas, it is evident that the prevalence of gold OA publishing is generally more pronounced in the Chinese mainland compared to the rest of the world. Many ESI fields in the Chinese mainland exhibit significantly higher gold OA publishing volumes compared with non-OA, such as 1 (Agricultural Sciences), 4 (Clinical Medicine), 14 (Molecular Biology & Genetics), 15 (Multidisciplinary) and 16 (Neuroscience & Behaviour); however, among these fields, 1 (Agricultural Sciences), 4 (Clinical Medicine) are within quadrant C, and 15 (Multidisciplinary) is within quadrant D.

DISCUSSION

Strategizing gold OA dynamics in the Chinese mainland: Addressing international dominance and field-specific disparities

The momentum of gold OA scientific output by Chinese authors is now largely driven by international publishers, which highlights the need to enhance the independence of the gold OA publishing industry in the Chinese mainland. This independence can yield multiple benefits by fostering the development of OA publishing and evaluation systems in the Chinese mainland, reducing current APC expenditures through domestic cluster-based publishing, and, at the very least, alleviating uncertainties in cost-effectiveness to facilitate the economic management of the journal publishing industry. Therefore, this study proposes several strategies to address the shortcomings in the gold OA publishing landscape of the Chinese mainland.

1. The mismatch between gold OA publishing volumes in the Chinese mainland and the gold OA scientific output by Chinese researchers with respect to 22 ESI fields are put forward in section 3.2 Field-specific gold OA uptake and publishing volume, accentuating those fields (3, Chemistry; 4, Clinical Medicine; 7, Engineering; etc.) with the statistically most pronounced disparities. Thus, it is pivotal to optimize gold OA adoption of these fields in the journal publishing of the Chinese mainland.
2. The field-specific impacts of gold OA compared with non-OA articles need to be considered in understanding gold OA

TABLE 5 Distances are present with respect to the line of equity in the perpendicular direction, for various disciplines of the Chinese mainland and the rest of the world in 2023.

	Chinese mainland		World	
	Distance	Quadrant		Quadrant
1. Agricultural Sciences	−2.783	C	−0.087	C
2. Biology & Biochemistry	0.493	A	0.182	A
3. Chemistry	0.017	A	−0.019	C
4. Clinical Medicine	−1.479	C	0.303	A
5. Computer Science	0.336	A	−0.038	C
6. Economics & Business	1.288	B	−0.006	C
7. Engineering	0.940	A	−0.105	C
8. Environment/Ecology	0.257	A	−0.203	C
9. Geosciences	1.753	A	0.066	A
10. Immunology	1.159	A	0.879	A
11. Materials Science	0.755	A	−0.072	C
12. Mathematics	0.000	n/a	0.680	A
13. Microbiology	45.962	A	1.133	A
14. Molecular Biology & Genetics	13.496	A	0.258	A
15. Multidisciplinary	−4.691	D	0.864	A
16. Neuroscience & Behaviour	11.212	A	0.251	A
17. Pharmacology & Toxicology	2.525	B	0.308	A
18. Physics	−0.008	A	0.211	A
19. Plant & Animal Science	1.024	A	0.416	A
20. Psychiatry/Psychology	1.291	B	0.238	A
21. Social Sciences, general	0.092	B	0.112	A
22. Space Science	0.114	A	3.762	A
Average	3.352	-	0.415	-

Note: In this table, quadrants for these disciplines as shown in Fig. 7, are also highlighted with different background colours: red for A, yellow for B, green for C, and no background for D and n/a. Fields where the Chinese mainland exhibits relatively greater distance values than the rest of the world are highlighted in bold with a cyan background.

dynamics. The disciplines in the Chinese mainland that exhibit greater "distance" values compared with the rest of the world, as indicated in bold and a cyan background in Table 5, such as 13 (Microbiology), 14 (Molecular Biology & Genetics) and 16 (Neuroscience & Behaviour), demonstrate a comparatively superior academic impact of the gold OA model in the Chinese mainland compared with the rest of the world. It is implied that in these fields, the relatively favourable academic influence of gold OA could be leveraged to enhance the expansion of gold OA publishing volume in the Chinese mainland.

3. It is equally important to focus on the disciplines where the gold OA model currently exhibits a less favourable citation effect in the Chinese mainland compared with the rest of the world, such as 1 (Agricultural Sciences), 15 (Multidisciplinary) and 21 (Social Sciences, general). Understanding the underlying mechanisms of these less desirable OA citation effects is crucial for optimizing academic influence of gold OA across all fields.

The underlying mechanisms driving the growth of gold OA publishing volume due to field-specific academic influence are better understood by examining Fig. 7; when x-axis values exceed the dashed line $y = 1$, it indicates an improvement in the content quality of gold OA articles relative to non-OA articles within the ESI field. Likewise, when y-axis values exceed the dashed line $x = 1$, it suggests an enhancement in the quality of gold OA journals compared to non-OA ones within the field. By decomposing the citation impact of gold OA using CNCI and JNCI indicators from the InCites database, we can further categorize the positive citation effects of gold OA journals into two

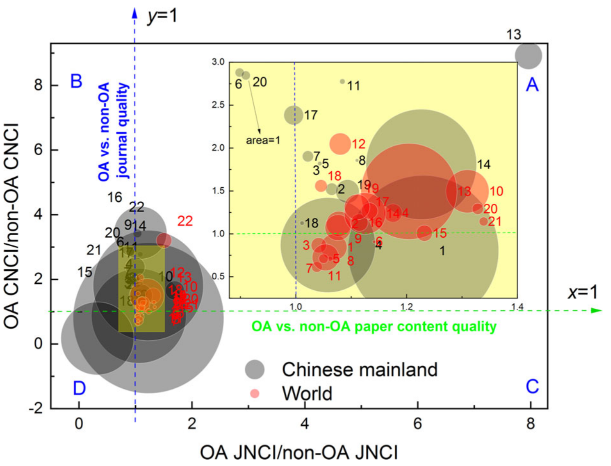

FIGURE 7 The two-dimensional evaluation compares the ratios of category normalized citation impact (CNCI) and journal normalized citation impact (JNCI) for gold OA versus non-OA articles in 2023, focusing on the Chinese mainland and the rest of the world. The areas of the bubbles represent the ratios of publishing volumes, with bubbles 6 and 20 from the Chinese mainland serving as a reference with an area of 1. The inset shows an enlargement of the yellow area from the main body. The dashed lines at $x = 1$ and $y = 1$ represent the equivalence lines between gold OA and non-OA models.

quadrants (A and B) and the negative citation effects of gold OA journals into two quadrants (C and D).

In summary, there is a need globally to establish high-quality gold OA journals, as evidenced by the presence of seven data points in quadrant C, with others in quadrant A. Additionally, for the Chinese mainland, a tailored strategy is required to address specific challenges, as data points are distributed across all four quadrants (ABCD). Nonetheless, efforts towards more robust OA dynamics in the Chinese mainland rely on inputs from all walks of life, especially those inactive fields for gold OA such as Mathematics (12) and Multidisciplinary (15), as shown in Table 5. These insights provide a foundation for evidence-based strategies aimed at enhancing research impact and scholarly communication both in China and globally.

Significance and originality of the current study

Highlighting journal-level academic influence of gold OA on disciplines

Previous studies on OACA, such as those by Basson et al. (2021), Langham-Putrow et al. (2021), Piwowar et al. (2018), and Tennant et al. (2016), have primarily focused on citation counts or journal impact factors (JIFs). For example, Tennant et al. (2016) reported an OACA increase of +600% for Agricultural Sciences, suggesting gold OA has a higher academic impact than green OA. Similarly, Harnad et al. (2008) quantified the OACA in Physics as +250% to +580%. However, these studies may not fully capture the changes brought about by the OA era.

The field-specific academic influence of gold OA articles evaluated here is relatively robust, as it takes into account both the publishing volume of gold OA articles and their field-normalized citation impact, represented by the "distance" metric within a two-dimensional diagram. This approach is crucial because gold OA operates on an author-pays model, making it similar to a commodity; thus, the volume of gold OA articles in an ESI field reflects authors' willingness to pay. While JIFs may indicate journal reputation for traditional journals, the academic influence of a gold OA journal should be assessed by combining field-normalized citation counts and the annual article volume of that journal. Accordingly, to evaluate the academic influence of all gold OA journals within a specific ESI field, it is essential to integrate field-normalized citation counts with the annual publishing volume of gold OA articles in that field, ideally using a two-dimensional approach.

Therefore, Fig. 7 suggests that enhancing the relative content quality of gold OA articles compared to non-OA articles within an ESI field—that is, moving from quadrants B and D to A and C—improves OACA. Moreover, according to the "distance" metrics, the potential for OACA would be even greater if the gold OA market momentum were driven by higher journal-level academic influence, resulting from the publication of high-quality gold OA journals. In other words, prioritizing quadrants A and B over C and D, in relation to the positive sign of the "distance" metrics for various ESI fields, proves to be more advantageous. This approach is preferable to relying heavily on the APC-funded business model.

New perspective on evaluating academic performance

The methodological advancements in this study should be highlighted, especially its integrated analysis of gold OA publishing volume and citation impact within a two-dimensional framework to evaluate field-specific academic influence of gold OA articles. These advancements not only refine the measurement of academic impact but also align seamlessly with the proposed initiative to leverage the journal-level academic influence of the gold OA model.

Moreover, the two-dimensional evaluations offer additional insights through visual representation. As illustrated in Fig. 6, the hyperbolas represent points where the product of the citation count ratio (y) and article count ratio (x) is constant. These points demonstrate scenarios where higher OA publishing output with lower citation counts cannot be differentiated from lower output with higher citation counts by using size-dependent indicators (e.g., total citations of all OA articles within a specific field), as long as the product of x and y remains constant. Whereas in this two-dimensional framework, data points along the hyperbolas are spread out with varying "distance" values. This dispersion allows for a more nuanced differentiation of citation behaviours compared with size-dependent indicators, while still accounting for the size effect, thus also making it superior to size-independent indicators (e.g., the JIF). This differentiation, based on the indicator's "distance" mechanism, helps to distinguish between volume-driven and citation-driven journal development dynamics.

LIMITATIONS AND PERSPECTIVES

1. The field-specific distribution of gold OA uptake, citations, and related metrics discussed in this study serves more as a profile of the WoS database than as an accurate reflection of disciplinary practices (Basson et al., 2022).
2. The susceptibility of the CNCI and JNCI ratios in Fig. 7 to significant influence from just a few highly cited papers becomes particularly pronounced when the gold OA publishing volume in ESI research fields is small. For example, in the field of Physics within the Chinese mainland, the placement in quadrant A with a slightly negative distance value, as shown in Table 5, illustrates this effect. This highlights the importance of increasing the volume of gold OA publishing in many disciplines (e.g., Chemistry, Engineering and Physics in the Chinese mainland) to leverage its relatively positive academic influence compared with traditional publishing.
3. In the present study, we did not distinguish the diamond OA model from among the gold OA journals, as the InCites database does not list the diamond OA model separately from gold OA models. Moreover, determining whether journals qualify as diamond OA presents challenges, as the exact figures related to APC expenses and revenues remain with the authors (or the paying institutions) and the invoicing publishers. According to Open Access Publishing in China (2022) (CAST & STM, 2022), as of 17 May 2022, diamond OA journals constituted only 0.46% of the total Chinese STM journals. Nevertheless, diamond OA is a promising OA business mode and may be the ultimate solution, although necessitating more inclusive, participatory, and delicate design of the OA framework at all levels (Ancion et al., 2022; Ross-Hellauer et al., 2022). Thus, future studies should comprehensively examine the complex implications of diamond OA.

CONCLUSION

This study comprehensively evaluated the dynamics of gold OA articles concerning 22 ESI research fields for both the Chinese mainland and the rest of the world. Initially, we identified a significant gap between scientific output by authors from the Chinese mainland and the gold OA publishing volume in the Chinese mainland, with Chemistry, Clinical Medicine, and Engineering requiring urgent attention due to the statistically significant mismatch. Next, using the Wilcoxon signed-rank test and a two-dimensional evaluative framework encompassing article and citation counts of both gold OA and non-OA, our analysis revealed an upward trend in gold OA publishing and citation practices in the Chinese mainland that is more pronounced than the rest of the world. Furthermore, by analysing the field-normalized indicators, CNCI and JNCI within this two-dimensional framework, we conducted a quantitative assessment of gold OA's academic influence both across and within research fields.

The two-dimensional analysis reveals certain ESI fields, for example, Microbiology, Molecular Biology & Genetics, and Neuroscience & Behaviour, that demonstrate a relatively higher academic influence of the gold OA model in the Chinese mainland compared with the rest of the world, which can be leveraged to further support domestic OA publishing in the Chinese mainland. However, it is equally important to address disciplines with unfavourable academic influence of gold OA, such as Agricultural Sciences, Multidisciplinary, and Social Sciences for the Chinese mainland.

The methodological advancements in this study for evaluating academic influence are demonstrated through the "distance" metric. These advancements provide a more nuanced understanding of gold OA adoption in the journal publishing industry concerning various ESI disciplines by integrating the analysis of gold OA publishing volume and citation impact within a two-dimensional framework. Prioritizing high-quality gold OA journals over those driven primarily by APC-funded business models is recommended to drive gold OA dynamics.

AUTHOR CONTRIBUTIONS

Conceptualization: XC; Data curation: XC; Formal Analysis: XC; Investigation: XC, ZL; Methodology: XC, ZL; Visualization: XC; Writing – original draft: XC; Writing – review & editing: XC, ZL.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The original data that support the findings of this study are available from Clarivate Analytics. Restrictions apply to the availability of these data, which were used under licence for this study. The original data are available from the authors with the permission of Clarivate Analytics. All other data that support the findings of this study are available from the corresponding author upon reasonable request.

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