



Exploring institutional change in a knowledge commons: a longitudinal institutional analysis of journal policies

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Abstract

Introduction. Studies on shared information and its governance, known as knowledge commons, are closely related to open access (OA) initiatives. Understanding institutional changes is critical for knowledge commons, and systematic methods for such analyses are in demand. This study applies such a method to PLOS ONE, a typical OA mega journal, to explore the characteristics of the institutional change of the journal.

Method. This study introduces a research approach of combining content analysis based on Institutional Grammar, a tool for examining the syntactic structure of institutions, with data collection through the Internet Archive's Wayback Machine, focusing on policies and guidelines of PLOS ONE.

Analysis. Institutional changes of PLOS ONE were analysed by comparing institutional complexity and stringency at two time points.

Results. The analysis revealed that the institutions run by PLOS ONE have evolved toward greater complexity and stringency. This change explains an adaptation to environmental changes in scholarly-communication ecosystems over the past few decades. However, this may also impose additional burdens, especially those on PLOS ONE authors.

Conclusion. The findings support the existing hypothesis on the institutional change in knowledge commons and offer new hypothetical insights into its impact on actors.

Introduction

Studies on shared information and its governance have gained prominence since the 1990s in the field of information science (Uba & Sanfilippo, 2025). These studies, commonly known as knowledge commons, are closely linked to scholarly communication, particularly open access (OA) and open science movements (Hess, 2008). Early research on knowledge commons have already identified OA journals and repositories as the examples of such commons (Hess & Ostrom, 2003), and recent publications also have focused on sharing scholarly information (e.g., de Rosnay, 2021; Frischmann et al., 2017). Additionally, both researchers and practitioners in the field of scholarly communication sometimes use knowledge commons as a framework for reflecting on and advocating for OA (e.g., Ballantyne, 2022; Suber, 2007).

Studies on knowledge commons should address several key questions: How do knowledge commons function? When are they preferred? Under what conditions can they be sustainable (Madison et al., 2016; Ostrom & Hess, 2007)? Answering these questions will enhance our understanding of information and data governance and support the design of more effective governance institutions. However, advances in knowledge commons studies have presented several challenges, such as the identification of the nature of changes or the gradual evolution of knowledge commons governance (i.e., institutional change) and developing systematic and longitudinal research methods to analyse these changes (Frischmann et al., 2014a; Schweik, 2014).

This study considers PLOS ONE as a case of a knowledge commons and longitudinally analyses the characteristics of its institutional changes. PLOS ONE is a multidisciplinary, full-OA journal launched in 2006 that is recognised for its distinctive business model and high publication volume. It has adopted a unique peer review policy of prioritising methodological rigor in submitted manuscripts, enabling the rapid publication of diverse scientific contributions. Instead of evaluating the importance of a study, this evaluation is left to researchers as readers, who can comment on each article after its publication. Therefore, PLOS ONE has published significantly more OA articles than traditional journals. This business model, known as the OA megajournal, has greatly influenced subsequent journals, such as Scientific Reports. Furthermore, PLOS, the publisher of PLOS ONE, has played a pivotal role in the history of the OA movement. Therefore, studying PLOS ONE contributes to the knowledge commons studies and offers valuable insights into the governance of scholarly communication or OA.

This study aimed to obtain insights into institutional changes in knowledge commons by exploring such changes in PLOS ONE. To this end, it introduces the research approach of combining content analysis based on Institutional Grammar (IG)—a tool for examining the syntactic structure of institutions—with data collection through the Internet Archive’s Wayback Machine, focusing on the formal rules of PLOS ONE, such as its policies and guidelines. Although institutional changes can be analysed from multiple perspectives, the analysis of this study is based on the specific research questions outlined below.

- RQ 1. How has the institutional complexity of PLOS ONE changed?
- RQ 2. How has the institutional stringency of PLOS ONE changed?

Theoretical background

Knowledge commons and the Governing Knowledge Commons (GKC) framework
Frischmann et al. (2014b, pp.2-3) defined knowledge commons as ‘*the institutionalised community governance of the sharing and, in some cases, creation of information, science, knowledge, data, and other types of intellectual and cultural resources.*’ As governance is understood through its expression in institutions (Madison, 2020), knowledge commons research has focused on institutions.

Recent knowledge commons research has been built on the Institutional Analysis and Development (IAD) framework (cf. Ostrom & Hess, 2007), originally developed for studying commons in natural resource settings, or the Governing Knowledge Commons (GKC) framework, which adapts the IAD framework specifically to knowledge commons (cf. Frischmann et al., 2014b). The GKC framework illustrated in Figure 1 outlines key variables and their relationships in the analysis of knowledge commons. Within these frameworks, institutions are defined as ‘*formal and informal rules that are understood and used by a community*’ (Ostrom & Hess, 2007, p.42). In this context, formal rules refer to written rules, such as laws, policies, and terms of use, whereas informal rules encompass unwritten rules, including social norms, culture, and conventions.

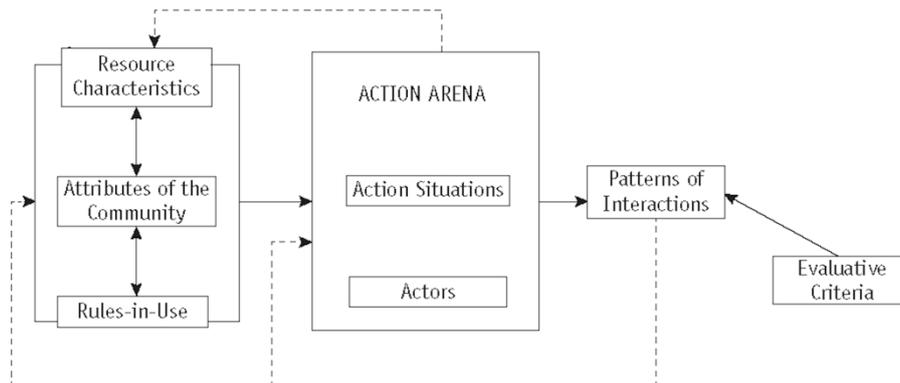


Figure 1. The GKC framework (the Knowledge Commons framework) (adapted from Frischmann et al. (2014b), p. 19, Figure 1.2)

In general, a key criterion for distinguishing the knowledge commons from non-commons is the institutionalised sharing of resources among the members of a community (Madison et al., 2010). For example, PLOS ONE publishes articles as OA and has established and continuously updated various institutions to promote manuscript submission while maintaining quality. Therefore, it is reasonable to consider PLOS ONE as a knowledge commons. In fact, some previous studies have positioned PLOS ONE or its publisher, PLOS, as knowledge commons, although they have not empirically analysed its institutional changes (Fuster Morell, 2010; Hess & Ostrom, 2003; Suber, 2007).

A basic approach to knowledge commons research using the GKC framework involves qualitative case studies grounded in the framework (cf. Frischmann et al., 2014b). For such case studies, detailed descriptions of each element of the framework are usually provided. However, because this study adopted a quantitative-research design using IG, as will be described later, and because of space limitations, detailed descriptions were not provided. Instead, an overview of PLOS ONE as a knowledge commons using subparts of the framework and related concepts is offered below.

The assumption in the IAD/GKC framework is that knowledge commons typically face collective action problems or social dilemmas that require an institutional response. For PLOS ONE, the primary issue is that of coordination—specifically, sustaining the ongoing participation of multiple contributors and users in the provision, management, and use of resources. This stems from PLOS ONE’s goals and objectives. Since its founding as a publisher, PLOS has aimed to publish scientific knowledge as OA. Under this mission, PLOS ONE seeks to make all ethically and methodologically rigorous research openly accessible to everyone (Chenette, 2021), and encourages open post-publication discussions by allowing users to comment on published articles (Patterson, 2010). Achieving these goals depends on the continued engagement of those who submit, read, comment on, or review articles. Therefore, coordination can be considered the most significant problem confronting PLOS ONE.

In line with these goals, the key resources of PLOS ONE can be understood as the articles it publishes and users' associated comments. Additionally, in a knowledge commons, the governance of resource sharing and creation is undertaken by a community whose members typically include resource providers, users, and managers (Ostrom & Hess, 2007). In the case of PLOS ONE, providers include authors who submit papers and readers who post comments; users are those who read the papers and comments; managers consist of reviewers, editorial members, and the internal staff of PLOS and PLOS ONE.

The preceding discussion on resources and communities corresponds to the *Resource Characteristics* and *Attributes of the Community* components shown in Figure 1. The final element on the left side of the framework is *Rules-in-Use*, which refers to rules that are recognised and enforced, in contrast to rules-in-form, which are written but not enforced. As described in detail in the methods section, this study focused on formal rules, specifically various guidelines, and policies. As many of these are assumed to be followed to a certain extent in practice, they can be considered rules-in-use.

These three elements influence institutional change as exogenous variables. Institutional change is brought about at the centre of the framework as *Action Arena*, which consists of *Actors*—members of the community involved in decision-making—and *Action Situations*—specific situations in which these actors operate. Action arenas can emerge in various situations and levels. This study focused on the following specific situations related to the aforementioned key resources of PLOS ONE: the submission of articles, management of published articles, peer review of submitted manuscripts, and posting comments. This study considers institutional change as an outcome of interactions among actors operating under these institutions or rules in use, whereby institutions are revised or updated over time.

Institutional grammar

IG is a tool embedded within the IAD/GKC framework for parsing and analysing the content of individual institutions based on generalisable features. Originally introduced by Crawford and Ostrom (1995) as *A Grammar of Institutions*, IG has undergone multiple updates (Basurto et al. 2010; Frantz et al., 2013; 2015; Siddiki et al., 2011; Weible & Carter, 2015). Institutional Grammar 2.0, an amended version of the IG in which updates are systematically integrated, is currently being proposed and adopted in various studies (cf. Frantz & Siddiki, 2022). Another promising option is a new framework and research approach for analysing privacy governance in knowledge commons by integrating the GKC framework and original IG with Nissenbaum (2009)'s Contextual Integrity framework (Sanfilippo & Frischmann, 2018; Sanfilippo et al., 2021; Shvartzshnaider et al., 2022). However, this study adopted IG 2.0 because it did not focus on privacy governance, and several tools that support its application were provided.

The IG can be described as a content-analysis coding scheme specifically designed for institutional analysis. Its focal unit is *Institutional Statements* (ISs), originally defined as 'a shared linguistic constraint or opportunity that prescribes, permits, or advises actions or outcomes for actors (both individual and corporate)' (Crawford & Ostrom, 1995, p.583). In the analysis of formal rules, each IS typically corresponds to an individual rule statement of guidelines or policies in practice. In IG 2.0, ISs are categorised into two types by their function: regulative statements, which specify actions expected of actors and constitutive statements, which parameterise institutional settings. An example of a regulative statement is as follows: *Authors must submit text files in Word format*. This example shows the expected action of the actor—in this case, *authors*. An example of a constitutive statement is as follows. *Authors retain the right to submit their manuscripts elsewhere after publication*. This does not indicate a specific expected action; instead, it parameterizes settings by defining rights possessed by authors.

The assumption in IG 2.0 is that both regulative and constitutive statements consist of specific, generalisable syntactic components (see Table 1). When the coding institutions used IG 2.0, the components within each institution were parsed, thus converting the ISs into categorical data for systematic analysis. *Attributes*, *Aim*, and *Context* are the necessary components of regulative statements whereas the *Constitutive Entity*, *Constitutive Function*, and *Context* are necessary components of constitutive statements. A statement that lacks these necessary components does not qualify as an institution.

Regulative statements		Constitutive statements	
Component	Description	Component	Description
Attributes (A)	Actor whose behaviour is regulated as part of the institutional statement	Constituted Entity (E)	Entity that is constituted in the statement
Deontic (D)	Describes whether the statement action is compelled, restrained, or discretionary	Modal (M)	Operator signalling necessity or (im-)possibility of the constitution specified in the Constitutive Function
Aim (I)	Activity, goal, or outcome is regulated in statement	Constitutive Function (F)	Expression that functionally links the Constituted Entity to the institutional setting
Direct/Indirect Object (Bdir/Bind)	The receiver of the action. A direct object is an object targeted by the action (Bdir), and an indirect object is an object affected by this application (Bind).	Constituting Properties (P)	Properties linked to Constituted Entity as mediated by the Constitutive Function
Common			
Component	Description		
Context	A statement clause captures conditions for instantiating a statement or qualifying an action or constitutive function		
Or else	The consequence of violating a statement		

Table 1. IG 2.0 Syntactic components (created by the author based on Frantz et al. (2022)). The components categorized under *Common* can be observed in both regulative and constitutive statements.

ISs may be nested. An individual IS that only contains one of each necessary and optional components and cannot be further decomposed is called an *Atomic Institutional Statement* (hereafter, atomic IS), while an IS composed of multiple atomic ISs is referred to as a *Composite Institutional Statement* (hereafter, composite IS) (Frantz & Siddiki, 2022). Figure 2 illustrates examples of both composite and atomic ISs.

A composite IS:

Authors must write the title and abstract as concisely as possible.

Its nested atomic ISs:

1. Authors must write the title as concisely as possible.
2. Authors must write the abstract as concisely as possible.

Figure 2. Examples of composite and atomic ISs

Institutional complexity and stringency

Institutional complexity and stringency are not concepts specific to the IAD/GKC framework but are widely used in institutional research. Institutional complexity literally refers to the complexity of institutions, whereas institutional stringency denotes the degree of intensity with which actors are required or prohibited from acting in a certain way, primarily in the context of regulative statements (Frantz & Siddiki, 2022). According to Frey and Sumner (2019), increasing institutional complexity is a response to environmental changes, particularly as the environment becomes increasingly complex. The environment in which PLOS ONE operates—the scholarly communication ecosystem—has undergone a significant transformation for decades. Numerous scholarly standards and best practices have emerged in the context of open science and research integrity. Additionally, the growth trajectory of the journal has shifted with the emergence of other mega-journals, such as Scientific Reports, which adopt similar business models (e.g., Petrou, 2020). PLOS ONE seems to have adapted to this change by updating existing institutions and introducing new ones. Examining how the complexity and stringency of PLOS ONE institutions have changed provides insight into how knowledge commons have adapted over time in the context of scholarly communication.

Methods

Data collection and coding process

Data were collected for this study through content analysis using IG 2.0 as a coding schema. The coding targeted PLOS ONE institutions at two time points: 2007 and 2025. As discussed in the theoretical background section, the two key resources in PLOS ONE, articles and comments, are associated with four key actions: submission of articles, management of published articles, peer review of submitted manuscripts, and posting comments. Table 2 presents major institutions corresponding to each action. Although additional institutions may be relevant to some of these actions, the institutions listed here have existed continuously as single entities since 2007, despite undergoing name changes. Accordingly, this study focuses on these rules.

2007		2025	
Institutions	Date	Institutions	Date
PLoS ONE Guidelines for Authors	04/05/2007	PLOS ONE Submission Guidelines	17/02/2025
PLoS ONE License	05/07/2007	Licenses and Copyright	17/02/2025
PLoS ONE Guidelines for Commenting	23/05/2007	Comments	17/02/2025
PLoS ONE Guidelines for Reviewers	16/05/2007	Guidelines for Reviewers	17/02/2025

Table 2. The target institutions. The ‘Date’ in 2007 corresponds to the date recorded in the Wayback Machine, while the ‘Date’ in 2025 refers to the date when the author collected data of institutions from the PLOS ONE website.

PLOS ONE *Submission Guidelines* (titled *PLoS ONE Guidelines for Authors* in 2007) govern the submission of manuscripts, with the main actors being the authors as providers. *Licenses and Copyright* (formerly *PLoS ONE License*) govern the management of published articles, specifically the handling of rights, and primarily involve authors. *Comments* (formerly *PLoS ONE Guidelines for Commenting*) are related to commenting and mainly involve readers as contributors. Finally, *Guidelines for Reviewers* (titled *PLoS ONE Guidelines for Reviewers* in 2007) govern the peer review of submitted manuscripts and primarily involve reviewers as managers. This study analysed how these institutions have changed since 2007.

Institutional data from 2007 were retrieved using the Internet Archive’s Wayback Machine and data from 2025 were collected directly from the PLOS ONE website. Although PLOS ONE was launched in 2006, data of the institutions listed in Table 2 could be collected only in 2007.

Therefore, the data collection spanned from 2007, the earliest available year, to 2025, the most recent year at the time of collection.

The author decomposed the above institutions into individual ISs, performed preprocessing, and coded them as a single coder. Preprocessing involves two primary tasks. First, sentences that did not qualify as institutions (i.e., those lacking the necessary components discussed in the subsection on IG) were excluded from the collected data. Second, for ISs written in passive form, the implied subject was added, and the statement was rewritten in active form, but only when the implicit subject was clear and minimal rewriting was required beyond adding the subject, as proposed by Frantz and Siddiki (2024). The IG Parser, a web application designed for IG 2.0 based coding, was used (Frantz, n.d.). The coding procedures and criteria were based primarily on Frantz and Siddiki (2022, 2024), the latter of which is a codebook for the practical implementation of IG 2.0. After completing the coding process, minor variations within the same component type, such as singular and plural forms, were consolidated before analysis.

Coding reliability assessment

According to Krippendorff (2004), coding reliability comprises three dimensions: stability, reproducibility, and accuracy. In most content analyses, reliability is assessed based on either stability or reproducibility (Riffe et al., 2023). Stability refers to intra-coder reliability, which is evaluated by measuring the consistency of a single coder through the application of the same coding scheme to the same dataset at two different time points. Reproducibility refers to intercoder reliability. Although reproducibility is more commonly used in reliability testing, this study adopted a stability-based approach, because coding was conducted by a single coder, and assessing intra-coder reliability, as with inter-coder reliability, can reinforce the argument for data validity when a project involves coding over a certain period (Riffe et al., 2023).

To test intra-coder reliability, the author re-coded a subset of the dataset three months after the initial coding in March 2025. Table 3 presents the results which were evaluated using three metrics: simple percentage agreement, Cohen's kappa coefficient, and Gwet's AC₁. All coding components, except *Indirect Object*, showed high levels of reliability across all metrics. Although *Indirect Object* yields a high percentage of agreement, its kappa value is relatively low. This discrepancy can be attributed to a known limitation of Cohen's kappa, which tends to underestimate reliability when coding categories contain infrequent values (Gwet, 2008). In contrast, Gwet's AC₁, designed to address this issue, also indicates high reliability for *Indirect Object*. Accordingly, the coding results of this study can be considered sufficiently reliable.

Component	Simple percentage agreement		Cohen's Kappa		Gwet's AC ₁	
	2007	2025	2007	2025	2007	2025
Attributes	93.13	95.39	0.88	0.94	0.93	0.95
Deontic	95.00	96.05	0.91	0.95	0.95	0.96
Aim	93.75	94.08	0.89	0.93	0.94	0.94
Direct Object	94.38	92.11	0.89	0.91	0.94	0.92
Indirect Object	95.63	94.74	0.21	0.32	0.96	0.95
Constituted Entity	94.38	95.39	0.94	0.92	0.94	0.95
Modal	95.00	96.05	0.87	0.89	0.95	0.96
Constitutive Function	87.50	95.39	0.86	0.92	0.87	0.95
Constituting Properties	90.63	93.42	0.87	0.87	0.91	0.93

Table 3. The intra-coder reliability of coding

Metrics for institutional complexity and stringency

Previous studies have proposed various metrics of institutional complexity. This study used metrics drawn from these studies to assess institutional complexity. The selected metrics included

the size of institutions (measured as the number of ISs and atomic ISs), the number of atomic ISs per ISs, and the number of unique values of each syntactic component (Frantz & Siddiki, 2022; Frey & Sumner, 2019). Further, the number of external links included within each IS, when present, was used as a metric. The targets of the links included other ISs within the same institution, different PLOS ONE institutions, and institutions or documents from organisations outside PLOS ONE.

Institutional stringency can be measured using the *Deontic* shown in Table 1. In IG2.0, *Deontics* are understood to exhibit varying degrees of *Deontic strength*—defined as ‘the extent to which a Deontic is discretionary or normative’ (Frantz & Siddiki, 2022, p.84)—depending on their assigned values. As shown in Figure 3, *Deontic strength* is expressed on a continuum. At its strongest, a *Deontic* is normative, obligating (Obligation) or prohibiting (Prohibition) an actor’s action. Operators such as ‘must’, ‘must not’, and words of similar meaning typically fall into these categories. At the centre of the continuum lies an Optional domain, where the decision of whether to act rests with the actors. When expressed through operators such as ‘should/should not’ or ‘may/may not,’ a *Deontic* is regarded as Optional, that is, discretionary. In this study, the metric of institutional stringency was the proportion of normative or discretionary *Deontics* among all atomic ISs.

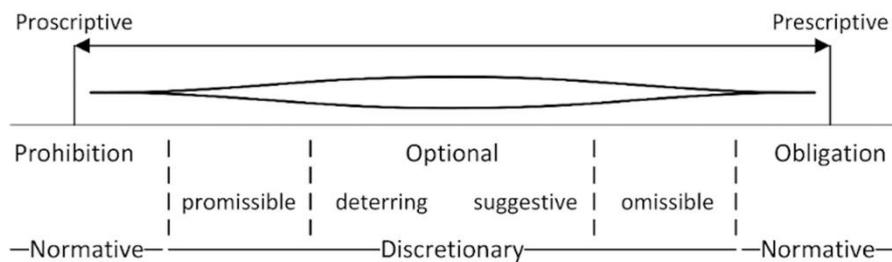


Figure 3. Continuous deontic conception (adopted from Frantz & Siddiki (2022, p. 84, Figure 4.3))

Results

Overview of PLOS ONE institutions

Figure 4 aggregates the number of ISs at the atomic IS level by type in 2007 and 2025. The total number of institutions increased over time, and while constitutive statements accounted for a larger proportion of all atomic ISs in 2007, regulative statements surpassed them in 2025. Tables 4 and 5 present the most frequent component value. The most frequent *Attributes* and *Constitutive Entity* remained unchanged across both time points, with *author* and *PLOS ONE* being the most common, respectively. However, other components exhibited changes over time. Notably, the most frequent *Deontic* in 2025 [imperative], indicates that the corresponding atomic ISs were written as imperative sentences. Further details are discussed in the subsection on institutional stringency.

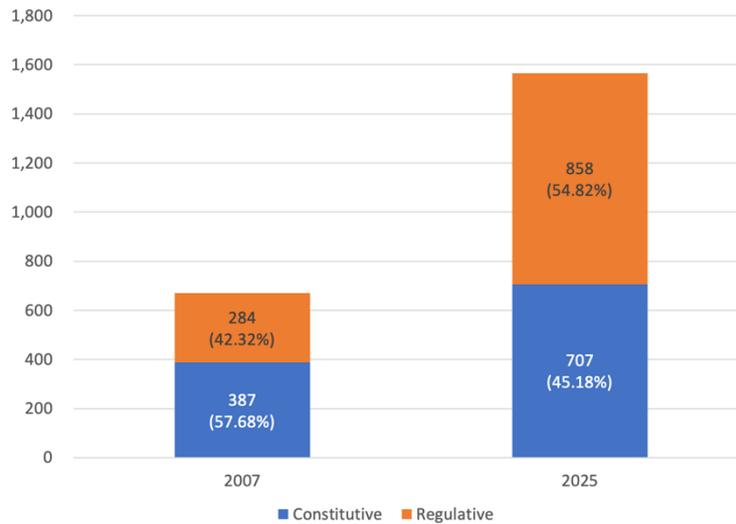


Figure 4. Number of atomic ISs by type

	Attributes		Deontic		Direct Object		Indirect Object	
	2007	2025	2007	2025	2007	2025	2007	2025
Value	Author	Author	Should	[imperative]	Link	Information	Journal; reviewer	Content
%	58.8	72.7	34.0	36.1	6.8	2.5	25.0	14.8
n	167	624	89	286	17	19	2	4

Table 4. Most frequently occurring component value in regulative statements

	Constitutive Entity		Modal		Constitutive Properties	
	2007	2025	2007	2025	2007	2025
Value	PLOS ONE	PLOS ONE	Will	Should	Minor revisions; PLOS Terms of Use	Detail
%	13.7	9.1	29.9	31.2	3.1	2.3
n	53	64	40	100	8	11

Table 5. Most frequently occurring component value in constitutive statements

Institutional complexity

Table 6 summarises the institutional complexity metrics discussed in the methods section, including the number of ISs and atomic ISs, the number of atomic ISs per IS, and the proportion of links among each institution's atomic statements. Here, the number of ISs refers to the count obtained without decomposing composite ISs into atomic ISs. The names of each institution were standardised to their 2025 versions. The number of ISs and atomic ISs increased for all institutions, except *Comments*, with the most notable increase observed in *PLOS ONE Submission Guidelines*, where the authors are the primary actors. In contrast, the number of atomic ISs per IS slightly decreased in all institutions, except in *Guidelines for Reviewers*. Overall, the proportion of atomic ISs containing links has increased. By institution, this increase was particularly notable in *Guidelines for Reviewers*, whereas *Licenses and Copyright* and *Comments* showed a decline.

Institutions	2007				2025			
	IS	Atomic	Atomic per IS	Link (%)	IS	Atomic	Atomic per IS	Link (%)
PLOS ONE Submission Guidelines	183	383	2.09	38 (9.9)	572	1,145	2.00	118 (10.3)
Licenses and Copyright	9	28	3.11	3 (10.7)	41	88	2.15	7 (8.0)
Comments	63	125	1.98	8 (6.4)	52	95	1.83	2 (2.1)
Guidelines for Reviewers	61	135	2.25	4 (3.0)	99	237	2.39	32 (13.5)
Total	316	671	2.12	53 (7.9)	764	1,565	2.05	159 (10.2)

Table 6. The counts of ISs and links

Tables 7 and 8 present the number of unique values of each component at the level of atomic ISs at the two time points. The row of *All institutions* in the two tables represent the number of unique values for each component across all institutions. Overall, the number of unique values increased for all component types. By institution, the number of unique values for each component increased notably in the *PLOS ONE Submission Guidelines*. The *top new value* columns basically indicate the most frequent newly introduced value in 2025; however, when the number of unique values is greater in 2007, they instead indicate the most frequent value observed only in 2007.

Institutions	Attributes			Direct Object			Indirect Object		
	2007	2025	Top new value	2007	2025	Top new value	2007	2025	Top new value
PLOS ONE Submission Guidelines	7	28	ethics committee	95	272	research	2	8	DOI; PLOS journals
Licenses and Copyright	2	4	author	4	20	content	1	2	content
Comments	1	3	reader	21	28	tab	0	2	content; staff
Guidelines for Reviewers	8	6	PLOS ONE	16	72	name	3	7	author; research
All institutions	14	35	reader	125	357	content	6	18	content

Table 7. The count of unique values of each component in regulative ISs

Institutions	Constitutive Entity			Constitutive Properties		
	2007	2025	Top new value	2007	2025	Top new value
PLOS ONE Submission Guidelines	77	154	name	78	198	work
Licenses and Copyright	7	17	PLOS ONE	7	23	license; shapefile
Comments	20	21	responses	18	12	annotation; rating
Guidelines for Reviewers	43	46	Study Protocol	48	43	minor revisions
All institutions	112	209	name	124	251	protocol

Table 8. The count of unique values of each component in constitutive ISs

Institutional stringency

Table 9 lists the counts of atomic ISs containing *Deontic* components at the two time points, based on their *Deontic strength*. As noted in Table 4, the most frequent value of *Deontic* components include [*imperative*], which indicates that the corresponding atomic ISs were written as imperative sentences. However, the extent to which imperative sentences possess *Deontic strength* remains debatable, and whether they can be directly mapped to specific deontic operators is unclear. According to Han (1999), while some imperative sentences may correspond to operators, such as ‘*must/must not*’ or ‘*should/should not*’, their exact deontic classification remains generally unspecified. Therefore, this study measures institutional stringency under three different assumptions: (1) imperative sentences (i.e. [*imperative*]) are considered not to have a *Deontic* component (excluding [*imperative*] in Table 9); (2) they correspond to operators, ‘*should/should not*’, aligning with the *discretionary* ([*imperative*] as *discretionary*); and (3) they correspond to operators ‘*must/must not*’, aligning with the *Normative* in Figure 3 ([*imperative*] as *Normative*).

As shown in Table 9, assuming that imperative sentences correspond to some form of the *Deontic* component, the proportion of atomic ISs containing a *Deontic* component relative to all atomic ISs increased from 39.0% in 2007 to 50.6% in 2025 (see *Total* part). Notably, regardless of the applied assumptions, the proportion of atomic ISs containing a *Deontic* component classified as *Normative* has substantially increased.

	2007			2025		
	Excluding [<i>imperative</i>]	[<i>Imperative</i>] as discretionary	[<i>Imperative</i>] as normative	Excluding [<i>imperative</i>]	[<i>Imperative</i>] as discretionary	[<i>Imperative</i>] as normative
Normative						
n	32	32	85	134	134	450
%	4.8	4.8	12.7	8.6	8.6	28.8
Discretionary						
n	177	230	177	342	658	342
%	26.4	34.3	26.4	21.9	42.0	21.9
Total						
n	209	262	262	476	792	792
%	31.1	39.0	39.0	30.4	50.6	50.6

Table 9. The counts of atomic ISs containing Deontic components by deontic strength

Discussion

What institutional changes have occurred in PLOS ONE?

This study explored the institutional changes in PLOS ONE from the perspectives of institutional complexity (RQ1) and stringency (RQ2). Regarding RQ1, as shown in Table 6, the overall size of ISs has increased, and particularly high growth rates were observed in the *Submission Guidelines* and *License and Copyright*, both of which primarily involve authors as key actors. Additionally, the proportion of atomic ISs that contain links to entities other than the IS itself has increased. However, as indicated in Table 6, the number of atomic ISs per IS slightly decreased. Because the inclusion of multiple atomic ISs within a single IS suggests a nested and complex structure, these results indicate that relatively simple ISs have increased over time.

However, as Tables 7 and 8 demonstrate, the number of unique values of each component generally increased across the board. Because *Attributes* represent the actors of an IS, an increase in the number of distinct *Attributes* suggests the diversification of the main actors of these institutions. Similarly, because *Constitutive Entities* represent the subjects of constitutive ISs, their increasing diversity indicates that the scope of the parameterisation of institutional settings has broadened. Additionally, as *Direct/Indirect Objects* refer to receivers of actors' actions, their increasing diversity suggests the expansion of the range of entities influenced by ISs. The increase in the number of distinct *Constitutive Properties* indicates the diversification of how institutional parameterisation influences *Constitutive Entities*. As Table 4 shows, the most frequent *Attributes* at both time points remained *author*, and the proportion of total atomic ISs increased. This suggests that authors continue to be the primary actors in *Submission Guidelines* and *Licenses and Copyright* at both time points. However, the diversification of the values of each component, as described above, can be interpreted as a sign that the content of these institutions has become more complex. The findings lead to the conclusion that from 2007 to 2025, PLOS ONE institutions have generally become more complex, particularly in terms of size and content diversification.

For RQ2, as Table 9 shows, the proportion of stronger *Deontic* components (i.e., those corresponding to normative components) among all atomic ISs clearly increased. Additionally, the proportion of statements containing *Deontic* components, regardless of whether they were normative or discretionary, increased among all atomic ISs. This suggests that PLOS ONE has undergone institutional changes from 2007 to 2025, particularly by increasing the number of institutions that obligate or prohibit specific actions by actors, thereby enhancing institutional stringency.

These findings prove that PLOS ONE has undergone institutional changes characterised by increased institutional complexity and stringency. Generally, institutional changes occur in response to environmental changes (Zhong et al., 2022). As discussed in the methods section, institutional complexity is a response to environmental complexity (Frey & Sumner, 2019). Between 2007, when PLOS ONE was in its beta stage, and 2025, the journal faced several environmental changes, including a dramatic increase in the number of published articles, followed by stagnation and decline amid the emergence of other mega journals (Petrou, 2020), the expansion of services for authors (Chenette, 2021), and the rise of academic standards, good practices, and scholarly infrastructure in line with the progress of initiatives related to open science and research integrity (e.g. the EQUATOR network's SAMPL guidelines, the CRediT taxonomy, preprint servers, LOCKSS, and so on). In response to these changes, PLOS ONE has adapted by increasing the complexity and *Deontic strength* of its institutions, particularly those directed at authors.

How do these institutional changes affect actors' behaviour? Although the context differs from that of scholarly communication, empirical studies of institutional change suggest that increasing institutional complexity can affect individuals' compliance with institutions. For example, Raaijmakers et al. (2015) report that actors addressing highly complex institutions tend to require

more time to comply. Similarly, Stafford (2006) found that complex institutions are more likely to lead to unintentional noncompliance. These findings suggest that, while the increased complexity of PLOS ONE's institutions may have been necessary to adapt to environmental changes, it may also have increased the time cost and risk of unintentional violations by actors, particularly the authors. Meanwhile, Kim and Stanton (2016) demonstrated that stronger regulative pressure in journal policies tends to promote data-sharing behaviour among researchers. Since the *Deontic strength* of regulative ISs can be a form of regulative pressure, increasing institutional stringency at PLOS ONE may help enforce the expected behaviours more effectively.

Contributions and limitations

The main contributions of this study are as follows. First, it provides new insights into institutional changes in knowledge commons. Previous studies have suggested that knowledge commons may evolve in response to changes in the environment or exogenous variables such as resource characteristics (Frischmann et al., 2014a; Schweik, 2014). This study supports this hypothesis using empirical evidence. Moreover, other knowledge commons with characteristics similar to those of PLOS ONE may experience institutional changes in the same direction, specifically increasing institutional complexity and stringency over time. As discussed in the theoretical background section, the key characteristics of PLOS ONE include facing a coordination problem and aiming to make resources widely accessible in the context of scholarly communication.

The second contribution of this study lies in proposing an approach for analysing institutional changes in knowledge commons. To empirically examine institutional change in PLOS ONE, this study combines content analysis based on IG 2.0, with data collection via the Wayback Machine. This approach was used in response to the need for longitudinal and systematic methods in knowledge commons research, as highlighted by Schweik (2014) and Frischmann et al. (2014a). Since the IG and IAD frameworks— the predecessors of the GKC framework—have been widely applied to institutional analysis beyond commons studies, this approach may also be widely applicable to various longitudinal analyses of institutions governing online information and data beyond knowledge commons research.

Third, the previous subsection discussed how institutional changes in PLOS ONE could impact its actors, particularly authors, both negatively and positively. These findings may be valuable for practitioners involved in institutional design in the context of scholarly communication.

Conversely, the main limitations of this study are as follows. First, the scope of the institutions analysed was limited. Specifically, institutions with editorial members, who are important managers in PLOS ONE as well as reviewers, were not included. In addition, data collection was limited to two time points: 2007 and 2025. These limitations were due to the focus on consistently comparable institutions and time constraints during coding. However, expanding the number of time points for data collection and including all institutions at each point while comparing the results with historical events in PLOS ONE and scholarly communication in a more granular manner may provide deeper insights into the mechanisms of institutional change.

Moreover, while the IAD/GKC framework is used to conceptualize institutional change as the outcome of interactions among actors, this study focuses solely on changes in institutions' syntactic characteristics. Thus, it does not clarify how interactions among actors have led to institutional changes. Relatedly, it does not describe specific action situations, such as incentives held by different actors, in detail. To address these limitations, combining a detailed qualitative case study grounded in the GKC framework with the quantitative approach employed in this study provides theoretical insights into the mechanisms of institutional change in knowledge commons.

Conclusion

This study explored institutional changes in PLOS ONE by combining Institutional Grammar 2.0, with data collection via a Wayback Machine. The analysis shows that, between 2007 and 2025, PLOS ONE institutions, particularly those concerning authors, changed in a way that increased their complexity and stringency. These changes appear to reflect adaptation to changes in the surrounding environment but may also impose additional burdens on the authors. This finding supports the existing hypothesis on institutional change in knowledge commons and offers new hypothetical insights into its impact on actors. The research approach proposed in this study can be applied more widely to the analysis of institutional changes of other platforms of knowledge commons and to the institutional analysis of online information and data in general. Future research that expands the scope of institutional data and combines the quantitative approach employed in this study with detailed qualitative case studies based on the GKC framework may lead to a deeper understanding of institutional change in PLOS ONE as a knowledge commons.

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