Postprint: Motivation Analysis of Different Stakeholders in Scientific Data Open Sharing Activities

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Abstract

[Purpose/Significance] This study investigates the motivations for scientific data open sharing to provide theoretical guidance for the practice of scientific data open sharing in China. [Method/Process] Employing stakeholder theory and normative analysis, it analyzes the motivations of different stakeholders participating in scientific data open sharing. [Results/Conclusion] Stakeholder theory can be applied to guide the practice of scientific data open sharing. Stakeholders in scientific data open sharing primarily include government, research institutions, research funding agencies, library and information institutions, data centers, industry associations, publishers, researchers, other enterprises, users, etc. These stakeholders can all benefit from scientific data open sharing and possess different interests and motivations.

Full Text

Preamble

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An Analysis of Different Stakeholders' Motivations in Open Sharing of Scientific Data

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Abstract

[**Purpose/Significance**] This study examines the motivations behind open sharing of scientific data to provide theoretical guidance for China's scientific data open sharing practices. [**Method/Process**] Using stakeholder theory and normative analysis, the paper analyzes the motivations of different stakeholders participating in scientific data open sharing. [**Result/Conclusion**] Stakeholder theory can guide scientific data open sharing practice. The stakeholders in scientific data open sharing mainly include governments, research institutions, research funding agencies, library and information institutions, data centers, professional associations, publishers, researchers, other enterprises, users, and society. All these stakeholders can benefit from open sharing of scientific data and possess different interests and motivations.

Keywords: scientific data, open sharing, stakeholder, motivation
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The term "stakeholder" first appeared in a 1963 internal memorandum of the Stanford Research Institute, initially defined as "groups essential to the survival of an organization, primarily including shareholders, employees, customers, suppliers, lenders, and society" [1]. In 1965, American scholar H.I. Ansoff first used the term "stakeholder theory" [2]. Subsequently, through the joint efforts of scholars such as R.E. Freeman, J.D. Blair, T. Donaldson, R.K. Mitchell, M.B. Clarkson, T.J. Rowley, and J. Fruoman, the theory developed rapidly in the 1990s and exerted significant influence on corporate governance and strategic management worldwide [3]. Stakeholder theory has permeated numerous fields and is closely related to strategic management, marketing, production, financial management, human resource management, research and development, organizational ethics, corporate governance, corporate performance, healthcare management, and information technology system management, providing guidance for practice in these areas [4]. Open sharing of scientific data (OSSD) involves numerous stakeholders. Although current research both domestically and internationally has extensively explored policies, platforms and projects, benefits and barriers, mechanisms and models, stakeholder roles and responsibilities, applications and surveys, and countermeasures and suggestions regarding scientific data open sharing, few studies have deeply analyzed the motivations of different stakeholders in participating in scientific data open sharing. To promote the development of China's scientific data open sharing practice, this paper provides a comprehensive and in-depth analysis of this issue.

1. Stakeholder Theory and Its Applicability in Scientific Data Open Sharing Activities

1.1 Main Ideas of Stakeholder Theory

Stakeholder theory draws on sociology, economics, political science, and ethics, particularly literature on corporate planning, systems theory, corporate social responsibility, and organizational research, with a focus on management decisions [5]. Its main ideas include: (1) A corporation is essentially composed of stakeholders who have signed explicit or implicit contracts with the enterprise, forming an interconnected network of stakeholder interests [6]. Stakeholders are groups or individuals who benefit from or are harmed by corporate actions and whose rights are respected or violated [7]. They are also individuals or organizations that have contractual relationships with the enterprise, receive returns from business operations, and bear certain business risks, typically including shareholders, creditors, corporate managers, employees, consumers, suppliers, government, community, and environment [8]. (2) Stakeholders have three attributes: legitimacy, power, and urgency, with their magnitude dynamically changing [9-10]. Different corporate stakeholders have varying degrees of multiple interest demands (i.e., value dynamics) [11]. Maximizing the interests of all stakeholders (rather than just shareholder interests) is the goal of modern enterprises [12]. Enterprises must understand and balance the various interests of different stakeholders [13], equally recognize and protect stakeholder property rights, to obtain long-term stable returns and development [14]. (3) The resources indispensable for corporate survival and development are invested by various stakeholders, not solely dependent on equity capital invested by shareholders. Corporate operation and development require the joint participation and support of stakeholders [15]. Only by collaborating with stakeholders can enterprises discover new value creation opportunities [11]. (4) Stakeholder relationships are the unit of analysis in stakeholder theory. These relationships have demographic characteristics (such as interests, social identity, size, legitimacy, urgency) and structural characteristics (such as power, proximity, network density, centrality of local organization, resource dependency, relationship strength) [16].

1.2 Applicability Analysis of Stakeholder Theory in Scientific Data Open Sharing

Stakeholder theory is a theory about how different stakeholders interact to jointly create and exchange value [17]. It can be used to describe and explain specific corporate functions, characteristics, behaviors, and determine the ethical or philosophical guidelines for corporate management [18], as well as to handle relationships between enterprises and stakeholders and their impact on corporate goals [19], providing people with a framework to analyze complex interest relationships within modern enterprises [3]. Since publicly funded scientific data open sharing involves numerous stakeholders, stakeholder theory can also be used to guide scientific data open sharing practice for the follow-

ing reasons: (1) Stakeholder theory emphasizes that maximizing stakeholder interests is the fundamental purpose of enterprises, which has extremely important guiding significance for formulating scientific data open sharing plans and action programs. In today's open science environment, many international organizations and foreign institutions have formulated scientific data open sharing plans, with the main goal of promoting open research and open innovation for all humanity through comprehensive open sharing of scientific data, enhancing organizational and individual knowledge management and innovation capabilities, and achieving coordinated development of society, organizations, and individuals. This concept essentially coincides with "maximizing stakeholder interests." Applying the idea of "maximizing stakeholder interests" can help different organizations formulate reasonable scientific data open sharing plans and action programs, breaking the barriers that previously limited scientific data sharing to research groups, departments, units, or regions, and forming a pattern of open sharing oriented toward society, so that scientific data generated by publicly funded, especially national science and technology programs, can be effectively managed and widely applied, benefiting as many stakeholders as possible and thereby maximizing the benefits of scientific data open sharing. (2) Stakeholder theory emphasizes that enterprises need the joint participation of stakeholders and must cooperate with them to create value and maximize stakeholder interests. This has guiding significance for understanding why scientific data should be open and shared. Publicly funded scientific data is a public good because it meets the two main criteria for judging public goods—non-rivalry in consumption and non-excludability in benefits [20]. As a public good, scientific data has an inherent sharing demand and can be used or reused by numerous stakeholders. Although scientific data open sharing does not directly create value, it plays a key bridging role in the scientific data value chain, connecting scientific data stakeholders, spawning more and more scientific data value chain activities, thereby enabling the sharing and amplification of scientific data value, and achieving knowledge creation spirals and maximization of stakeholder interests. (3) Stakeholder theory emphasizes that stakeholder relationships are its unit of analysis, which is instructive for understanding scientific data open sharing behavior. Open scientific data, stakeholders, and stakeholder relationships constitute the scientific data open sharing network. In this network, there are various stakeholder relationships, such as funding relationships, cooperative relationships, colleague relationships, citation relationships, linking relationships, exchange relationships, and user relationships. Using these relationships and their characteristic indicators, such as social identity, power, size, centrality, network density, and relationship strength, we can deeply analyze the structure of the scientific data open sharing network and scientific data open sharing behavior, providing references for improving the efficiency and effectiveness of scientific data open sharing. (4) Stakeholder theory emphasizes that different stakeholders have multiple interest demands, which is instructive for analyzing the motivations of scientific data open sharing. Similar to how corporate stakeholders have multiple different interest demands, stakeholders in scientific data open sharing, such as researchers, research institutions, library and information

institutions, publishers, and governments, also have their own interest demands. By analyzing these different interest demands, we can gain insight into the motivations of different stakeholders to participate in scientific data open sharing and formulate corresponding countermeasures for different stakeholders.

2. Different Stakeholders in Scientific Data Open Sharing Activities

Scientific data open sharing is not an isolated activity but a value creation activity directly related to scientific data production, organization, publication (or publishing), dissemination, and utilization, involving producers, funders, organizers, publishers, disseminators, managers, and users of scientific data. The stakeholders in scientific data open sharing activities mainly include governments, research institutions, research funding agencies, library and information institutions, data centers, professional associations, publishers, researchers, other enterprises, users, and society (see Figure 1 [Figure 1: see original paper]). Here, "users" refer to actors who only use scientific data without producing or providing it. As a whole, society necessarily benefits from scientific data open sharing activities and is therefore also a stakeholder. Regardless of which stakeholder, all are in an open science environment, which creates conditions for scientific data open sharing.

Based on the different roles of stakeholders in the scientific data open sharing value chain, they can be classified (see Table 1).

Table 1. Classification of Stakeholders Based on Roles in Scientific Data Open Sharing

Role in OSSD	Stakeholders
Producers of scientific data	Researchers, research institutions, library and information institutions, data centers, publishers
Funders of scientific data	Research institutions, library and information institutions, research funding agencies, professional associations, other enterprises, governments, society
Organizers of scientific data	Library and information institutions, data centers, governments
Publishers of scientific data	Researchers, research institutions, library and information institutions, professional associations, publishers
Disseminators of scientific data	Library and information institutions, data centers, professional associations, publishers, governments

Role in OSSD	Stakeholders
Managers of scientific data	Library and information institutions, data centers, governments
Users of scientific data	Researchers, research institutions, library and information institutions, data centers, professional associations, publishers, governments, society

3. Analysis of Motivations for Different Stakeholders to Participate in Scientific Data Open Sharing

Scientific data sharing is hailed as the lifeblood of scientific research, and conducting scientific research exchange and cooperation through completely open scientific data has become a consensus in the scientific community [21]. Especially in the era of big data, scientific and technological innovation increasingly relies on comprehensive analysis of scientific data, particularly large-scale scientific projects that depend on large amounts of credible basic scientific data. Conversely, failure to open scientific data would at least lead to: (1) other scientists being unable to share relevant data, which is not conducive to increasing overall scientific research output; (2) inability to verify research conclusions based on scientific data, leading not only to erroneous or fabricated scientific conclusions but also reducing the credibility of the scientific community; (3) scientific research being seen as self-entertainment of scientists hidden in laboratories, unable to establish close connections with the public, leading to public skepticism about the value of scientific research [22]. The positive benefits of scientific data open sharing provide inexhaustible motivation for stakeholders. Although scientific data open sharing can bring enormous benefits to society, since society is not a single actor, its motivations are not examined here. This section mainly analyzes the motivations of ten other types of stakeholders to participate in scientific data open sharing.

3.1 Motivations for Government Participation in Scientific Data Open Sharing

In scientific data open sharing activities, governments can play multiple roles (see Table 1) and have extremely important functions. If other scientific data open sharing stakeholders influence scientific data open sharing activities at the data object level, then governments play a role at the national political, democratic, economic, and social levels. Their motivations mainly include:

3.1.1 Enhancing the Overall Level of National Scientific Data Open Sharing and Maximizing the Utilization of Scientific Data Value. On the one hand, governments provide macro guidance for domestic scientific data open sharing activities by formulating scientific data open sharing policies, en-

suring that scientific data open sharing practice can receive policy support for personnel, finance, and materials, thereby enhancing the overall national level of scientific data open sharing. On the other hand, by opening and sharing their scientific data, government departments can enable scientific data generated by public funding to be more widely applied, maximizing the utilization of scientific data value. In August 2015, the State Council promulgated the "Outline for Promoting Big Data Development," explicitly requiring the establishment of a unified national government data open platform by the end of 2018, and taking the lead in achieving reasonable and moderate opening of public data resources to society in important fields such as credit, transportation, medical care, health, employment, social security, geography, culture, education, science and technology, resources, agriculture, environment, safety supervision, finance, quality, statistics, meteorology, oceans, and enterprise registration and supervision, to fully release data dividends and stimulate mass entrepreneurship and innovation vitality [23]. After NASA's Landsat satellite images of the Earth's surface environment were made freely available via the Internet, they created an annual environmental management industry value of $935 million, with the United States gaining over $100 million in economic benefits annually and promoting application development by other companies [24]. The EU's open data strategy can generate €70-140 billion in economic value annually within the EU [25].

3.1.2 Enhancing Transparency of Government Policies and Fairness in Scientific Data Utilization. Opening scientific data open sharing policies can enhance the transparency of various policies and provide other stakeholders with fair opportunities to utilize scientific data, solving the problem of uneven utilization of scientific data and making open scientific data a tool for implementing transparent government. NASA's "Data & Information Policy" requires full open sharing of all data and implementation of non-discriminatory data access principles [26]. Currently, the China Meteorological Administration provides open sharing of 5 categories and 17 types of basic meteorological data and products through the China Meteorological Data Network, providing an equal platform for using meteorological data for research and educational institutions and meteorological information service enterprises [27].

3.1.3 Promoting Economic Growth. Governments can achieve the goal of promoting economic growth through open sharing of scientific data. After the U.S. government implemented the "complete, open, and free" data sharing policy in 1990, the average annual growth rate in the latter five years (1991-1999) was 1.1 percentage points higher than in the first five years, of which 0.5 percentage points were generated from the transmission and application of data and information [28].

3.1.4 Realizing the Social Value of Government Scientific Data and Improving Its Social Benefits. Open government data contains many extremely valuable scientific data. After these government scientific data are opened to the public, they can trigger chain chemical reactions and generate

enormous social benefits. For example, after the U.S. Environmental Protection Agency opened and shared environmental data collected at an annual cost of nearly $400 million (including information on drinking water, atmosphere, waste, and toxic substances across the country), it significantly enhanced citizens' environmental protection awareness, increased public supervision of polluting enterprises, and maintained high support rates for government environmental protection decisions and specific policies, strongly supporting environmental protection in the United States [28]. In addition, government scientific data open sharing can break information barriers between government departments and industries, achieving collaborative governance of scientific data management between government and enterprises and other social organizations in fields such as public transportation and urban development, public health and food safety, pollution control and environmental protection, and public safety and emergency management, further enhancing enterprise and national scientific and technological innovation capabilities [29].

3.1.5 Building Citizen Trust in Government and Improving Democratic Participation. Government scientific data open sharing is also conducive to building citizen trust in government [30], promoting citizen participation, obtaining citizen authorization, improving democratic participation [31], and accepting citizen supervision of public investment in scientific data, thereby creating a more democratic social atmosphere and promoting harmonious social development.

3.2 Motivations for Researchers and Research Institutions to Participate in Scientific Data Open Sharing

For a long time, researchers and research institutions have been the main advocates and practitioners of the Open Access (OA) movement and the open science movement. Scientific data open sharing is of great significance to them, and they have the following motivations:

3.2.1 Shortening the Scientific Data Publication Cycle and Improving the Timeliness of Scientific Data Release. In various scientific research activities or work practices, if researchers can open and share relevant scientific data immediately after obtaining them, even if final research results (such as research reports or papers, books, etc.) have not yet been formed, it will greatly shorten scientific data publication delays, accelerate scientific data exchange speed, improve the timeliness and practicality of scientific data, promote external researchers' access to data [30], and accelerate innovation speed. The League of European Research Universities requires in its "Statement on Open Research Data" that research data should be timely and freely publicly available as a public good [32].

3.2.2 Overcoming Scientific Data Dissemination Barriers and Broadening the Scope of Scientific Data Dissemination. Since public Internet allows any user to freely download, copy, analyze, reprocess open scientific data,

and transmit scientific data to other users without financial, legal, or technical barriers, scientific data open sharing can break the monopoly position of publishers in traditional academic exchange systems, break information barriers between departments and industries [29], prevent data resource monopolies [33], enable publicly funded research results to be used by the public [34], and significantly expand the coverage of scientific data users.

3.2.3 Enhancing the Visibility of Scientific Data and Promoting Open Scientific Research. Scientific data open sharing can help researchers display recently obtained scientific data and their management processes in real time through the public Internet, allowing the display of links to data files, interoperability of different datasets, and new insights obtained through data mining and analysis [31]. This facilitates research reproducibility [34], supports online application of automated knowledge discovery tools [35], facilitates public participation in data review [30], reduces the incidence of forged and inaccurate data [36], and further promotes open scientific research [37].

3.2.4 Improving the Efficiency of Scientific Data Use and Maximizing Scientific Data Value. Scientific data open sharing not only helps researchers more easily access, discover, and reuse data, reduces research costs [38], verifies the authenticity of data or research results, avoids data errors, duplicate research, and inefficient research, but also helps researchers synthesize existing data from experts and non-experts to form new viewpoints, create new datasets through data combination, make scientific research face decision-making directly, exert the economic benefits of scientific data [39], and maximize scientific data value. In fact, the open sharing of Global Earth Observation System of Systems (GEOSS) data has generated various values such as economic, social, research and innovation, education, and effective governance [40].

3.2.5 Obtaining Scientific Data (or Results) Publication Funding. Some domestic and foreign organizations or institutions have formulated scientific data open sharing policies, with a key provision being the provision of financial support for scientific data open sharing. In surveys of UK Economic and Social Research Council grant recipients and Wellcome Trust grant recipients on motivations for sharing data, "obtaining additional funds to pay for fees" accounted for as high as 74% and 63% respectively [41], indicating that obtaining scientific data publication funding is one of the motivations for researchers.

3.2.6 Enhancing the Academic Influence, Reputation, and Prestige of Researchers and Research Institutions. Research has confirmed that sharing research data can increase the citation rate of scientific papers by 69% [42]; the citation advantage of OA journal papers is universally present and very significant [43]. In addition, scientific data open sharing can promote the production of high-level research results [44] and enhance research and innovation levels, further improving the academic reputation and influence of researchers and research institutions. Surveys have found that "data sharing can improve academic reputation" is a motivation for data sharing recognized by 56% of

Wellcome Trust grant recipients [41].

3.3 Motivations for Research Funding Agencies to Participate in Scientific Data Open Sharing

As a relatively special type of stakeholder, research funding agencies (also called funding agencies or research funding bodies) are responsible for formulating research funding policies and allocating funding to support various scientific research and research infrastructure construction. Research funding agencies have important influence in scientific data open sharing [45], and their driving forces mainly include:

3.3.1 Formulating Scientific Data Open Sharing Policies in Industry or Discipline Fields and Providing Financial Support for Scientific Data Open Sharing. Research funding agencies often promote the implementation of scientific data open sharing by formulating open data policies (or research data management policies, OA policies, etc.) in industry or discipline fields and ensuring that scientific data open sharing can obtain sufficient financial support. For example, the UK Medical Research Council (MRC) not only funds various clinical trials and other medical research but also includes clinical trial and clinical intervention research data, public health intervention research data, and observational research data generated from its research funding in the open sharing scope, requiring researchers to follow the guidelines of "Good Practice Principles for Sharing Individual Participant Data from Publicly Funded Clinical Trials" to ensure that research protocols, analysis plans, and all relevant statistical analyses and research data are open for sharing and utilization [46].

3.3.2 Stimulating More Citizen Participation in Scientific Research and Spawning Innovative Research and Applications. By funding scientific data open sharing, research funding agencies can further stimulate more citizen participation in scientific research [47], explore topics unforeseen by researchers, promote interdisciplinary, cross-sectoral, cross-institutional, and international research [35], and stimulate downstream applications and commercial innovation of research results [39].

3.3.3 Supporting Scientific Data Creation and Providing a Continuous Source of Data for Scientific Data Open Sharing. One of the prerequisites for scientific data open sharing is the existence of valuable scientific data to share, but scientific data production is not easy, requiring both high-quality researchers and financial support. At this point, research funding agencies have great advantages and can mobilize researchers' enthusiasm by establishing scientific research funding, enable researchers to create valuable scientific data through various research activities, and provide a continuous source of data for scientific data open sharing.

3.3.4 Standardizing Scientific Data Open Sharing Behavior and Enabling More Efficient Utilization of Scientific Data. While providing research funding to researchers, research funding agencies can further standard-

ize scientific data open sharing behavior and improve scientific data utilization efficiency through their open data policies. For example, the UK Met Office's "Open Data Policy" establishes eight standards for data openness [48]: (1) Data formed by public meteorological service funding, belonging to agreed public meteorological service products, must be open for sharing; (2) Data must follow agreed formats and do not require specialized tools or knowledge to interpret these data; (3) Data volume is reasonable and can be effectively disseminated within minutes to three hours; (4) The benefits of open data resources are realized by ensuring the maximum number of users can benefit from data release; (5) Data should be actionable, documented and described using appropriate metadata and service management; (6) The UK Met Office owns the intellectual property rights of the data or is authorized to provide these data under the Open Government License; (7) Data should be consistent with other open data from the UK Met Office to minimize the risk of inconsistent or conflicting forecast information; (8) Various data will be evaluated for long-term economic sustainability before data release. These standards lay the foundation for the UK Met Office's scientific data open sharing.

3.3.5 Promoting Cooperation Among Scientific Data Stakeholders to Better Achieve Scientific Data Open Sharing. Research funding agencies can negotiate with scientific data stakeholders to formulate scientific data open sharing policies, accurately define the responsibilities and roles of each stakeholder in scientific data open sharing, and promote international and domestic cooperation among researchers, research institutions, data managers, and publishers to better implement scientific data open sharing activities. As early as 2012, the Royal Society proposed that different stakeholders should strengthen cooperation to promote scientific data open sharing and open science development. For example, governments should formulate open scientific data policies; scientists should allow free, OA exchange of data they collect and models they create; universities and research institutions should play important roles in supporting an open data culture; academic societies, academic institutions, and professional bodies should provide continuous financial support for OA journal papers; research councils and charities should provide data and metadata management costs and cooperate with others to improve research data exchange; industry sectors and relevant regulatory departments should cooperate to determine methods for sharing data, information, and knowledge [24]. Thanks to strong cooperation among stakeholders, the European Commission-funded OpenAIRE project has achieved open sharing of 11,465 repositories and OA journals, 688,870 datasets, and 24,085,848 publications, as well as cross-linking between publications and data [49].

3.4 Motivations for Library and Information Institutions to Participate in Scientific Data Open Sharing

The inherent social attributes (such as academic and service nature) and social functions (such as transmitting scientific intelligence or applicable information,

developing intellectual resources) of library and information institutions endow them, like researchers and research institutions, with the same four scientific data open sharing motivations: shortening the scientific data publication cycle and improving timeliness; overcoming scientific data dissemination barriers and broadening dissemination scope; enhancing scientific data visibility and promoting open scientific research; and improving scientific data use efficiency to maximize scientific data value. In addition, library and information institutions have five other motivations for open sharing of scientific data:

3.4.1 Overcoming the Scientific Data Access Crisis. Due to the extremely high political, economic, cultural, and scientific research value of scientific data, they are often locked in "black boxes" for fear that their value will be known and used by outsiders. Even when sharing exists, it is limited to research group members, departments, or units, preventing large amounts of scientific data from being effectively utilized. However, we have now entered the era of open science, and library and information institutions are major participants in implementing open science work, with inherent requirements and unique advantages for open sharing of scientific data, and can play a key role in overcoming the scientific data access crisis.

3.4.2 Enriching Information Sharing Resources and Improving Data Sharing Efficiency. For a long time, the information sharing resources of library and information institutions have mainly been books, newspapers, journals, dissertations, conference papers, research reports, microfilms, music tapes, patents, audio-visual materials, library catalogs, academic journal databases, e-book databases, ancient books databases, reference book databases, online teaching courses, and multimedia databases, without paying attention to data. Today, scientific data is becoming a new form and source of information sharing resources for library and information institutions. Open sharing of scientific data can make information sharing objects more concrete, transforming from traditional entire documents, reports, or works to specific scientific data. This helps library and information institutions more accurately and efficiently find and share relevant scientific data according to users' data needs, reduces scientific data acquisition costs, and improves data sharing efficiency.

3.4.3 Achieving Semantic Interconnection of Open Scientific Data and Enhancing the Relevance and Use Value of Scientific Data. In an open science environment, library and information institutions can use linked open data to achieve semantic interconnection of scientific data and obtain multiple benefits from linked open data applications, such as publishing scientific data in universal formats (such as RDF) so that these data can be easily aggregated and utilized by other systems, thereby linking scientific data across different industries, fields, and information systems and improving their relevance; facilitating library and information institutions to implement intelligent federated retrieval and semantic-based search; enabling library and information institutions to effectively support "evidence-based decision-making"; and making library and information institutions a linking hub connecting scientific data stakeholders

[50]. All these will significantly enhance the relevance and use value of open scientific data.

3.4.4 Innovating Library and Information Institution Service Methods. Scientific data open sharing, as a new resource sharing model, provides opportunities for service innovation. Many university libraries in the Triangle Research Libraries Network have carried out scientific data management services for faculty, alliance users, and researchers, such as providing research datasets and their classification, organization, and one-stop access; providing data management consultation and guidance services; providing long-term preservation services for research data; providing various data processing, visualization tools, and analysis services; providing data cleaning services; providing data use training; and providing customized teaching [51]. By carrying out scientific data open sharing services, library and information institutions can further expand service methods and content, including providing automatic question answering for linked data [52]; using Drupal to publish linked data [53]; building institutional repositories for linked data [54]; achieving digital resource aggregation based on linked data, developing knowledge discovery and knowledge services based on linked data, and digital virtual reference consultation [55]. Currently, Peking University's Open Research Data Platform can provide users with open scientific data management, publication, browsing, retrieval, download, storage, and usage tracking services, encouraging researchers to open and share data, promoting the dissemination, reuse, and standardized citation of scientific data [56], thereby innovating original service methods.

3.4.5 Enhancing the Social Status and Role of Library and Information Institutions in the Open Science System. The four basic goals of open science are: achieving transparency of experimental methods, observations, and data collection; achieving public use and reuse of scientific data; achieving public participation and transparency in scientific communication; and using network tools to promote scientific cooperation [57]. Library and information institutions are core elements in the open science system, being both producers, funders, and users of open scientific data, as well as organizers, publishers, and disseminators of open scientific data, and can fully support the realization of open science goals. In particular, library and information institutions have long formed core capabilities in data, information, and knowledge organization and sharing, and have strong competitive advantages in data, information, and knowledge organization and sharing compared with other institutions. Library and information institutions can become chief planners of scientific data open sharing, chief managers and key developers of open scientific data infrastructure, and leaders of the open science movement, thereby fully playing their backbone role and demonstrating their core status in the open science system.

3.5 Motivations for Data Centers to Participate in Scientific Data Open Sharing

Scientific data open sharing cannot be separated from the strong support of data centers (sometimes called data sharing centers or data sharing platforms). Data centers mainly perform the functions of collecting, storing, and sharing data in relevant fields or topics, and can provide users with data acquisition, data storage space, and training and consultation services around data creation, preservation, and use. Data centers can significantly enhance data value through quality control procedures, ensuring appropriate metadata, pooling data from different sources, and providing online tools for searching, visualizing, and downloading data in appropriate formats for further research [58]. China has built six major scientific data sharing centers (platforms): the Forestry Science Data Platform, the Earth System Science Data Sharing Platform, the Population and Health Science Data Sharing Platform, the Agricultural Science Data Sharing Center, the Earthquake Science Data Sharing Center, and the Meteorological Science Data Sharing Center, forming a scientific data open sharing system. According to the global scientific database registration system re3data.org, it has collected more than 2,000 disciplinary databases, of which about 85% have achieved data open sharing [59]. Fudan University's Social Science Data Platform has accumulated a large amount of open data, enabling researchers to conveniently store, publish, exchange, share, and conduct online analysis of scientific data on the platform [60]. Thus, data centers have become key nodes in the scientific data open sharing system, with main driving forces being: (1) widely collecting scientific data from different disciplines or topics to better pool professional field knowledge; (2) classifying, processing, organizing, and mining collected scientific data to facilitate others' use of these data; (3) centrally storing collected scientific data in a trusted environment to ensure data quality and security and that relevant infrastructure can support scientific data use; (4) enabling permanent access and open sharing of scientific data to significantly improve the efficiency and effectiveness of scientific data utilization; (5) strengthening domestic and international exchange and cooperation in scientific data open sharing to enhance the level of open science.

3.6 Motivations for Publishers to Participate in Scientific Data Open Sharing

Publishers are another important stakeholder in scientific data open sharing. Since the rise of the OA movement, publishers have actively adjusted their pricing and publishing strategies, including adopting delayed OA publishing, hybrid OA publishing, complete OA publishing, and other methods, injecting new impetus into traditional publishers in the OA environment. This includes shortening the scientific data publication cycle, improving the timeliness of scientific data release; overcoming scientific data dissemination barriers and broadening the scope of scientific data dissemination; enhancing the visibility and use efficiency of scientific data, and promoting open scientific research and maximization of

scientific data value utilization. In addition, there are two other motivations:

3.6.1 Changing Traditional Scientific Data Exchange Models and Achieving Innovation in Scientific Data Publishing Methods. Publishers adopting OA publishing models will completely change traditional paper-based scientific data exchange models, simplify scientific data publishing processes, shorten scientific data publication cycles, and achieve innovation in scientific data publishing methods. The Public Library of Science (PLOS) in the United States requires that all data and related metadata related to designated PLOS journal papers be stored in appropriate public repositories to ensure that data and materials underlying any papers published in PLOS journals are openly available, making PLOS a leader in open sharing of scientific data in the U.S. publishing industry. Springer Nature has established a successful model for research data open sharing in the UK publishing industry by clarifying different requirements and practices for implementing open sharing of four types of research data for journals under its group [61].

3.6.2 Forming New Profit Growth Points for Publishers. High-value scientific data brings new opportunities for publishers to increase profits [62]. According to the "Big Data Industry Development Plan (2016-2020)," China's big data-related products and service business revenue will exceed 1 trillion yuan by 2020 [63]. This provides publishers with opportunities to create greater profits from data publishing, including adopting the OA publishing model of "author pays, reader free" or other fixed fee models to obtain more profits from scientific data publishing.

3.7 Motivations for Professional Associations to Participate in Scientific Data Open Sharing

Professional associations or societies are also important participants in scientific data open sharing activities. Generally, professional associations have basic functions such as industry service, industry self-discipline, industry representation, and industry coordination, as well as multiple specific functions such as industry planning and statistics, formulating industry quality or service standards, and conducting domestic and international economic and technical exchanges and cooperation. Many professional associations also have research and education functions, communication and service functions, standardization and coordination functions, and incentive and demonstration functions [64]. In scientific data open sharing activities, professional associations can play multiple roles (see Table 1), with motivations mainly being:

3.7.1 Providing Policy Guidance for Scientific Data Open Sharing and Enhancing the Level of Scientific Data Open Sharing in the Industry. On the one hand, professional associations can provide consulting services for relevant institutions in formulating scientific data open sharing policies. For example, the American Psychological Association requires that when government agencies, research institutions, academic institutions, publishers, scientific soci-

eties, and other entities formulate data sharing policies, they need to carefully balance the rights, responsibilities, interests, and burdens among stakeholders, and should define specific levels and permissions from completely open access to restricted access, and clarify time requirements for data sharing and applicable regulations and prior agreements [65]. On the other hand, professional associations can collaborate with relevant institutions or experts to formulate industry scientific data open sharing policies, providing guidance for member institutions and individuals to carry out scientific data open sharing activities. For example, the American Heart Association (AHA) issued the "Open Science Policy Statement for AHA-Funded Research" on January 1, 2015 [66], requiring not only that journal papers funded by AHA be open shared through the Public Medical Center within 12 months of publication, but also that factual data supporting journal research conclusions be open shared within 12 months after funding ends, unless these data involve personal privacy, legal restrictions, intellectual property rights, or cause excessive financial burden. These principles have effectively promoted scientific data open sharing among AHA members.

3.7.2 Securing Funding to Support Scientific Research and Open Sharing Practices in the Industry. Professional associations can raise scientific research funds from government departments, foundations, charitable organizations, and relevant enterprises, or through crowdfunding or fundraising, to provide financial support for scientific research and data open sharing for member institutions and individuals. As the world's most influential non-profit organization on Alzheimer's disease research, the Alzheimer's Association has obtained substantial funding since 2011, including an additional $414 million grant from the U.S. National Institutes of Health in 2018 and $109 million in research funds provided by American philanthropists, to fund Alzheimer's disease research and scientific investigation [67].

3.7.3 Promoting Trust Relationships Among Stakeholders to Drive Implementation of Scientific Data Open Sharing. First, professional associations can use the association platform to connect members, conduct mutual exchanges, establish mutual trust relationships, and lay the foundation for cooperation and sharing. Second, professional associations can establish industry norms and standards to strengthen trust and cooperative relationships among members, especially when professional associations formulate scientific data open sharing policies or norms, these policies or norms can become guides for members to implement scientific data open sharing practice. Third, membership and reward-punishment mechanisms of professional associations help consolidate and develop trust and cooperative relationships among members, further promoting the implementation of member scientific data open sharing.

3.7.4 Publicizing, Promoting, Coordinating, and Communicating Scientific Data Open Sharing Activities to Maximize the Utilization of Open Scientific Data. Professional associations can organize industry training, technical consultation, information exchange, exhibitions, and product promotion activities on data science and open sharing, publicize and promote the

value, significance, and successful experiences of scientific data open sharing, strive to improve members' data literacy, and make scientific data open sharing a part of members' daily work. At the same time, professional associations can coordinate the allocation of funding for scientific data open sharing among member institutions, and conduct full communication and collaboration on various problems encountered in the practice of scientific data open sharing by member institutions and individuals, such as intellectual property protection, sharing agreements, and technical support, so that open scientific data can be open shared and efficiently utilized to the greatest extent possible.

3.8 Motivations for Other Enterprises to Participate in Scientific Data Open Sharing

Today, society has entered the era of open economy and sharing economy. In addition to research institutions, library and information institutions, data centers, publishers, and other entity institutions, other enterprises can also obtain numerous benefits from scientific data open sharing. The motivations for enterprise participation in open sharing behavior mainly include the following three aspects:

3.8.1 Innovating Products and Services and Improving Company Product Innovation Capability. Enterprises can track the sources of open scientific data and use these data to formulate corporate strategies, transform open data into products and services; companies can also use open data to improve processes, products, and services, develop more innovative or customized products and services, and improve company product innovation capability [30].

3.8.2 Promoting Enterprise Informatization and Digital Construction. Open data sharing can promote enterprise informatization and digital facility construction, create an open sharing corporate culture, help enterprises obtain maximum benefits from the sharing economy, greatly enhance enterprise informatization and digital construction levels, and help enterprises win long-term competitive advantages. As early as 2011, Jack Ma built Alibaba into a data sharing platform; Tencent already had a large number of partners accessing the Tencent open platform. Data open sharing has become a competitive strategy for Alibaba and Tencent to leverage their advantages as Internet enterprises and achieve sharing and win-win results.

3.8.3 Achieving Collaborative Innovation and Development and Creating Greater Social Wealth. On the one hand, enterprises can improve productivity and create more profits by using (i.e., inputting) open data. On the other hand, they can also output (i.e., share) proprietary data to society, share best practices, promote the development of the open data industry, and create greater social wealth. In 2010, Intel helped create the "Open Data Center Alliance" jointly formed by more than 70 leading global enterprises to collaboratively develop open cloud computing and data center solutions. According to

survey data from the McKinsey Global Institute, open data can create $3.2-5.4 trillion in economic value annually in seven fields: education, transportation, consumer goods, electricity, oil and gas, healthcare, and consumer finance [68].

3.9 Motivations for Users to Participate in Scientific Data Open Sharing

In addition to the above nine types of stakeholders who are all users of scientific data (see Table 1), there are also some users who only use scientific data without producing or providing it. These users can also obtain multiple benefits from scientific data open sharing: (1) free access to scientific data, overcoming barriers to scientific data acquisition; (2) timely acquisition of scientific data, as scientific data open sharing can reduce scientific data publication delays and even be published at the moment of data generation; (3) understanding the usage of scientific data and promoting personal awareness of scientific data value, as scientific data open sharing can facilitate interested users to understand the latest scientific data and research in relevant fields; (4) communicating and interacting with scientific data producers, as users can use clues or links provided by open shared scientific data and scientific data open sharing platforms to actively contact scientific data producers or providers for consultation or exchange, improving personal ability to utilize scientific data; (5) improving user decision-making, as users can use open shared scientific data to help themselves make scientific decisions in daily work and life. For example, open data reflecting the competitiveness of universities and their disciplines can provide decision-making basis for users to choose a university for degree study or further education; real-time open shared road traffic information can provide references for users to choose travel routes. All these benefits are motivations for users to participate in scientific data open sharing.

In summary, different stakeholders can obtain different benefits and behavioral motivations from scientific data open sharing, and some benefits are common goals pursued by different stakeholders in scientific data open sharing activities. For example, certain social benefits generated by scientific data open sharing, such as promoting citizen participation, improving democratic participation, promoting national data management capacity building, equal data utilization, narrowing the information gap, promoting information fairness and freedom, improving and innovating citizen services, improving citizen satisfaction, utilizing crowd wisdom to promote social development, and improving the social benefits of public investment, are motivations for cooperation in scientific data open sharing among different stakeholders such as governments, research institutions, research funding agencies, library and information institutions, data centers, and professional associations. Similarly, certain research benefits generated by scientific data open sharing, such as breaking data resource monopolies, improving data resource utilization rates, reducing research costs and duplicate research, improving scientific research efficiency, maximizing the research value of scientific data, verifying original research results, reducing the incidence of forged

and inaccurate data, strengthening interdisciplinary and cross-institutional research, promoting open scientific research, and improving the citation frequency of scientific research results, are also motivations for cooperation in scientific data open sharing among different stakeholders such as research institutions, researchers, and research funding agencies.

However, currently, data openness from scientific projects supported by domestic public finance is still very limited. Scientific data remain distributed among research groups, scientists, and researchers, lacking exchange and communication of data between departments, industries, or units, let alone open sharing of scientific data with society [69]. Therefore, China must vigorously promote scientific data open sharing practice to implement the national strategy of "implementing the national big data strategy and promoting open sharing of data resources." To this end, effective incentive measures or countermeasures must be adopted to stimulate stakeholders' enthusiasm and motivation to participate in scientific data open sharing and transform these motivations into practical actions for scientific data open sharing. These countermeasures include: (1) establishing and improving scientific data open sharing management methods based on the "Management Measures for Scientific Data" recently promulgated by the State Council, and encouraging and promoting scientific data open sharing behavior; (2) providing long-term and sufficient financial support for scientific data open sharing to achieve sustainable development of scientific data open sharing; (3) establishing institutional scientific data open sharing incentive mechanisms to make scientific data open sharing one of the daily businesses of institutions; (4) establishing individual scientific data open sharing reward systems to make scientific data open sharing a conscious behavior of individuals; (5) breaking down data sharing barriers between departments and across institutions, cultivating new motivations for cross-departmental or cross-institutional scientific data open sharing, and establishing long-term mechanisms for cross-departmental or cross-institutional scientific data open sharing collaborative cooperation; (6) strengthening open sharing culture construction throughout society to create a favorable environment and atmosphere for scientific data open sharing.

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An Analysis of Different Stakeholders' Motivations in Open Sharing of Scientific Data

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Abstract: [Purpose/significance] This paper aims to provide theoretical guidance for the practice of open sharing of scientific data in China by clarifying

the motivations of open sharing of scientific data. [Method/process] The paper used stakeholder theory and normative analysis to analyze the motivations of different stakeholders to participate in the open sharing of scientific data. [Result/conclusion] Stakeholder theory can be used to guide the practice of open sharing of scientific data. The stakeholders of open sharing of scientific data include governments, research institutions, research funding agencies, library and information institutions, data centers, professional associations, publishing companies, researchers, other enterprises, users, and so on. These stakeholders all can benefit from the open sharing of scientific data, with different interests and motivations.

Keywords: scientific data; open sharing; stakeholder; motivation

Note: Figure translations are in progress. See original paper for figures.