Factors Influencing Scientific Data Sharing Intention: An Empirical and Simulation Study

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Abstract

Purpose/Significance: This study aims to identify the influencing factors, mechanisms, and dynamic evolution patterns of scientific data sharing intention, in order to provide references for subsequent research and practice. Methods/Process: Based on Stimulus-Organism-Response (S-O-R) theory, a theoretical model of scientific data sharing intention was constructed. Using 435 valid samples from a questionnaire survey, structural equation modeling was employed for empirical testing to determine path coefficients among variables. On this basis, a system dynamics model was constructed to simulate the dynamic evolution patterns of relationships among variables. Results/Conclusions: The "trust → sharing attitude → sharing intention" path constitutes the fundamental logic driving scientific data sharing. Reciprocity, social interaction, and data quality have significant positive effects on trust, with the effect ranking of "reciprocity > data quality > social interaction". Meanwhile, perceived behavioral control has a significant positive effect on sharing intention, while subjective norms have no significant effect on sharing intention. Trust rate, initial perceived behavioral control, and initial sharing intention under different contexts all influence scientific data sharing intention. Finally, recommendations for promoting scientific data sharing are proposed based on the main research conclusions.

Full Text

Empirical and Simulation Study on Influencing Factors of Scientific Data Sharing Willingness

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Abstract

[**Purpose/Significance**] This study aims to identify the influencing factors, mechanisms, and dynamic evolution patterns of scientific data sharing willingness, providing a reference for subsequent research and practice. [**Method/Process**] Based on Stimulus-Organism-Response (SOR) theory, a theoretical model of scientific data sharing willingness was constructed. Using 435 valid questionnaire samples, structural equation modeling was employed for empirical testing to determine path coefficients among variables. On this basis, a system dynamics model was built to simulate the dynamic evolution of relationships among variables. [**Result/Conclusion**] The path of "trust → sharing attitude → sharing willingness" constitutes the fundamental logic driving scientific data sharing. Reciprocity, social interaction, and data quality exert significant positive effects on trust, with effect sizes ranked as "reciprocity > data quality > social interaction." Meanwhile, perceived behavioral control significantly positively influences sharing willingness, whereas subjective norms show no significant effect. Under different scenarios, trust rates, initial perceived behavioral control, and initial sharing willingness all impact scientific data sharing willingness. Finally, recommendations for promoting scientific data sharing are proposed based on the main findings.

Keywords: scientific data sharing; sharing willingness; Stimulus-Organism-Response theory; influencing factors; simulation
Classification Number: G350

With the deepening development of scientific research, vast amounts of scientific data are continuously generated. Researchers possess rich data resources, which serve as both the cornerstone for conducting scientific research and important products demonstrating their research value. Scientific data sharing represents a crucial means of transforming scientific data from private property to public scientific wealth [1] and has become an essential guarantee for driving research under the data-intensive paradigm. In December 2020, the China Science and Technology Information Institute hosted the "FAIR Principles and Scientific Data Management and Application Services" seminar, which put forward clear requirements for scientific data storage, management, and sharing. In June 2021, Science Europe released the *Practical Guide to Sustainable Research Data*, stating that sharing reusable scientific data to support scientific progress is increasingly becoming the norm, with more and more organizations expecting and encouraging open sharing of scientific data [2]. Scientific data sharing enables researchers to propose new perspectives and questions using existing research data, maximizes research transparency, helps reduce research costs, makes publicly funded research results accessible to the public, and facilitates cross-domain data utilization to enhance research and innovation levels. Scientific data providers (hereinafter referred to as "providers") constitute the foundational condition for scientific data sharing [3]. As the primary producers and providers of scientific data, researchers' sharing willingness directly affects the occurrence of sharing behaviors and the realization of data value. Research

indicates that while many researchers are willing to use shared data, fewer are willing to provide scientific data [4]. Therefore, it is necessary to further focus on individual researchers' data sharing activities and understand their data sharing decisions in scientific research. Scientific data exhibits significant variations in form, collection purpose, and research context across different fields. Some researchers worry that shared data may be misinterpreted, while others concern themselves with potential data quality issues. Consequently, scientific data has not yet achieved large-scale sharing across all fields. Although some influencing factors of researchers' data sharing willingness have been identified, several questions warrant deeper exploration: Can new theoretical perspectives explain the influencing factors of data sharing willingness? What trends characterize the interactions among these factors? How can sharing willingness be further promoted? To address these questions, this study adopts the provider perspective, constructs a theoretical model of influencing factors for scientific data sharing willingness based on SOR theory, and conducts empirical and simulation analyses to reveal the influencing factors and their dynamic change patterns, thereby discussing strategies for scientific data sharing and providing theoretical references and empirical support for future research.

1.1 Research on Influencing Factors of Scientific Data Sharing Willingness

Willingness represents a psychological tendency before engaging in an activity and can predict behavior. Scientific data sharing willingness refers to the intensity of researchers' subjective willingness to share scientific data [5]. Sharing attitude indirectly affects sharing behavior through sharing willingness [4]; thus, sharing willingness plays a crucial role in the scientific data sharing process, prompting numerous scholars to investigate its influencing factors from multiple dimensions.

At the individual dimension, Wang Dandan et al. [6] found that age, gender, and disciplinary background influence scientific data sharing willingness, with females showing stronger willingness than males, and fields such as climate, ecology, and biology demonstrating stronger willingness than social sciences and medicine. Based on mental accounting theory, Shen Tingting [7] discovered differences in scientific data sharing willingness between acquaintances and strangers. W. Z. Mltgen [8] found that attitude and sharing experience affect data sharing willingness among authors in sociology and political science. Other scholars have considered additional dimensions. Zhang Jinchao [9] investigated from individual and institutional dimensions, finding that subjective norms and beliefs positively influence scientific data sharing willingness, while perceived behavioral control shows no significant effect. From the resource dimension, data source credibility positively affects scientific data sharing willingness through perceived usefulness and perceived ease of use [4]. Liu Yan [10] examined university researchers' sharing willingness from personal, policy, environmental, and resource dimensions, identifying influencing factors including

self-value realization, trust, subjective norms, institutional policies, disciplinary requirements, platform system security, and ease of operation. Research combining personal, institutional, and cost dimensions found that benefit returns, data literacy, group atmosphere, journal publication pressure, and funding agency pressure can promote researchers' data sharing [11-12].

1.2 Application Research on Stimulus-Organism-Response Theory

Stimulus-Organism-Response (SOR) theory, proposed by environmental psychologist A. Mehrabian, is a widely applied theoretical model for behavior prediction [13]. The model explains how external environmental stimuli affect organism cognition and psychology, and further predicts behavioral intentions and actual behaviors.

In recent years, SOR theory has been applied to information behavior research, particularly in information sharing and knowledge sharing, providing robust explanations for individual behaviors. For instance, Zhang Hai [14] drew on SOR theory to construct a theoretical model of scientific data openness willingness from system and environmental stimuli. Peng Lihui [15] treated motivation, opportunity, and ability as stimulus factors and knowledge innovation behavior as response factors to study knowledge innovation behavior in virtual communities. As an important output of scientific research, scientific data is similarly influenced by external stimuli during the sharing process, and providers undergo changes in cognitive and emotional states before making corresponding responses. Therefore, SOR theory provides a solid theoretical foundation for studying scientific data sharing willingness.

Literature review reveals that existing research primarily constructs theoretical models of scientific data sharing willingness and behavior based on planned behavior theory, technology acceptance theory, and dual-path theory. Although these theoretical models continue to evolve, the theoretical perspectives remain relatively singular. Most scholars build relatively static models based on planned behavior theory to explore influencing factors of scientific data sharing willingness and behavior [16-17]. While these studies fully consider researchers' individual factors and deeply examine how psychological states under different identity characteristics affect sharing willingness and behavior, the influencing factors are relatively subjective, and different individuals may overestimate or underestimate their own situations, overlooking emotional factors such as trust and dependence generated during the behavior process. SOR theory can demonstrate how external stimuli affect organism cognition and psychology, better explaining the dynamic process where individuals' emotional changes induced by external factors influence their behaviors. Moreover, system dynamics simulation helps analyze the dynamic evolution patterns among influencing factors and has been applied to predict scientific data sharing security systems. Given the complexity and continuity of scientific data sharing, it is necessary to explore the dynamic evolution patterns of scientific data sharing willingness from a system dynamics perspective. However, relying solely on system dynamics simulation

makes it difficult to ensure the scientific validity of stock-flow diagrams and simulation data. Therefore, this study combines structural equation modeling with system dynamics simulation based on SOR theory to construct a system dynamics model of scientific data sharing willingness, revealing relationships among influencing factors and their effects on the evolution of sharing willingness. This approach is expected to enrich existing research findings, improve domestic research theories and methods, and provide references for promoting scientific data sharing.

2.1 Stimulus and Organism

Reciprocity, as a fundamental driving force for creating and regenerating social capital [18], refers to the expectation of corresponding returns after making contributions. The reciprocity rule involves mutual benefits, which in scientific data sharing primarily manifests as providers receiving returns that match the value of their contributions when sharing their scientific data. Numerous studies have confirmed the positive effect of trust on reciprocity. For example, Li Jing et al. [19] found from a social network perspective that interpersonal trust affects young and middle-aged people's mental health through the mediating role of reciprocity. As independent individuals, researchers are also members of social relationship networks. In the process from external stimulus to organism response, reciprocity as an external stimulus factor can not only cultivate trust relationships among researchers but also enhance providers' trust in data sharing platforms and tools. Therefore, the following hypothesis is proposed:

H1: Reciprocity significantly positively affects provider trust.

Social interaction is a channel for information exchange and dissemination among people. Providers establish trust within their professional fields through frequent interactions with users, managers, and others. Individuals' cognition and judgment of an activity depend on the stimuli they receive, which can be regarded as external stimuli such as social interaction. According to social capital theory, social interaction influences human behavior, and in scientific data sharing, the closeness of social interaction significantly impacts data sharing. As researchers' needs for collaborative research increase [20], data sharing emphasizes behavioral interaction among researchers [21] to reduce research costs and accelerate scientific output. Therefore, the following hypothesis is proposed:

H2: Social interaction significantly positively affects provider trust.

Data quality refers to the degree to which data characteristics meet explicit and implicit requirements when using data under specific conditions. The quality of scientific data is a focus of researchers' attention in data sharing [22], with various attributes including authenticity, completeness, authority, availability, and effectiveness. Liu Guifeng et al. [23] found that data quality is the most important and fundamental influencing factor. When data quality is high, it may enhance providers' trust in the reliability of shared data; conversely, it may

reduce trust in data sharing. Therefore, the following hypothesis is proposed:

H3: Data quality significantly positively affects provider trust.

2.2 Stimulus and Response

Subjective norms refer to the social pressure researchers perceive when deciding whether to engage in scientific data sharing activities, reflecting the influence of experts, colleagues, or collaborators on sharing decisions. Planned behavior theory posits that subjective norms are one of the direct influencing factors of behavioral intention. Some scholars have found that subjective norms also positively influence Chinese researchers' data sharing willingness [5,24]. When researchers are influenced by the behaviors or suggestions of experts, peers, or collaborators, they develop compliance motivation and are more likely to engage in scientific data sharing. Therefore, the following hypothesis is proposed:

H4: Subjective norms significantly positively affect provider sharing willingness.

Perceived behavioral control refers to researchers' perception of the difficulty level of scientific data sharing activities, reflecting whether researchers possess the necessary resources for scientific data sharing and can grasp sharing opportunities [25]. According to planned behavior theory, perceived behavioral control is the most direct factor influencing behavioral intention. When researchers have received education or training in scientific data sharing, mastered relevant skills, and possess knowledge and experience in data sharing, they are more likely to engage in data sharing. Conversely, if researchers lack the basic conditions for data sharing and perceive it as difficult, their likelihood of participating in data sharing decreases. Therefore, the following hypothesis is proposed:

H5: Perceived behavioral control significantly positively affects provider sharing willingness.

2.3 Organism and Response

In social exchange theory, trust is a fundamental condition for people to engage in social exchange, affecting their willingness and behavior to participate in an activity. In research on knowledge acquisition and sharing, K. Andrews found that trust is more important than the methods and procedures of knowledge acquisition and sharing. If participants have low trust in an activity, knowledge sharing behavior will not occur [26]. Based on investigating service industry employees' knowledge sharing attitudes and willingness, Zheng Wansong et al. found that trust significantly positively affects knowledge sharing attitude [27]. Scientific data sharing is a social exchange behavior. When providers develop trust in users and sharing platforms, their attitude toward data sharing becomes more positive. Therefore, the following hypothesis is proposed:

H6: Trust significantly positively affects provider sharing attitude.

2.4 Sharing Attitude and Sharing Willingness

Sharing attitude refers to the positive or negative psychological tendency that researchers hold toward scientific data sharing behavior. Sharing willingness is the degree to which providers are willing to share data. In the traditional technology acceptance model, sharing attitude positively affects sharing willingness [28]. This conclusion has also been confirmed in subsequent studies. For example, He Lin et al. [5] found that researchers' scientific data sharing attitude significantly positively affects sharing willingness. When researchers hold a positive attitude toward scientific data sharing, they are theoretically more likely to participate in it; conversely, the likelihood of sharing data decreases. Therefore, the following hypothesis is proposed:

H7: Sharing attitude significantly positively affects provider sharing willingness.

SOR theory can reflect the changes in individual cognition and psychological states when researchers face external stimuli. Based on SOR theory and the aforementioned hypotheses, this study constructs a theoretical model as shown in Figure 1 [Figure 1: see original paper].

3.1 Data Collection

This study primarily employed a questionnaire survey to obtain sample data. The first part of the questionnaire collected basic information about respondents, while the second part consisted of measurement scales using a 5-point Likert scale, comprising 8 latent variables and 33 items. Referencing C. M. Chiu [29], the reciprocity variable includes 4 items: research efficiency (RE1), academic influence (RE2), economic benefits (RE3), and long-term cooperative relationships (RE4). The social interaction variable includes 3 items: time spent on communication (SI1), establishing close connections (SI2), and proactive interaction (SI3). Referencing B. H. Wixom [30] and V. (DQ2), the data quality variable includes 5 items: authenticity (DQ1), completeness (DQ2), authority (DQ3), availability (DQ4), and effectiveness (DQ5). Referencing Yu Ling [32], the subjective norms variable includes 4 items: expert behavior or suggestions (SN1), colleague behavior or suggestions (SN2), collaborator behavior or suggestions (SN3), and academic promotion and advocacy (SN4). Referencing He Lin [5], the perceived behavioral control variable includes 4 items: education or training (PBC1), knowledge of data sharing (PBC2), experience in data sharing (PBC3), and relevant skills for data sharing (PBC4). Referencing H. H. Chang [33] and Zhang Yaming [34], the trust variable includes 5 items: data value (TR1), reliability of sharing channels or platforms (TR2), tool security (TR3), effectiveness of institutional guarantees (TR4), and rational data use (TR5). Referencing Wang Chunxiao [35], the sharing attitude variable includes 4 items: necessity (SA1), wisdom (SA2), sense of achievement (SA3), and research confidence (SA4). Referencing Guo Yu [36], the sharing willingness variable includes 4 items: sharing methods (SW1), voluntary data sharing (SW2), data reuse (SW3), and promoting the value of data sharing (SW4).

After pilot testing and multiple rounds of discussion, the final questionnaire was formed. Researchers from universities and research institutes were selected as survey respondents, and data were collected through various methods. The questionnaire collection period was January 2022. A total of 532 questionnaires were recovered. After screening out incomplete questionnaires, those with excessively high item repetition rates, short completion times, and respondents with low understanding of scientific data, 435 valid questionnaires were obtained, yielding an effective response rate of 81.8%.

3.2 Descriptive Statistical Analysis

Among the 435 researchers surveyed, females accounted for 59.9% of the sample, and ages were concentrated below 40 years old. Education levels were basically undergraduate and above, with most having research experience. Forty-three percent of researchers held professional titles, and 73.1% had less than 5 years of research experience, possibly because some researchers had relatively short research careers and had not yet obtained professional titles. In terms of workplace types, 77.7% of researchers worked in universities or research institutes, with fewer in enterprises, government departments, or other types of organizations, indicating that universities and research institutes are the preferred workplaces for most research personnel, which basically aligns with reality. Regarding disciplinary background, management accounted for 63.9%, engineering 18.6%, science 7.4%, economics 3.0%, and others 7.1%. In terms of understanding of scientific data sharing, all respondents had some understanding, though the degree varied.

Additionally, the minimum value of all scale items was 1, the maximum value was 5, sample means ranged between 3.25-4.2, and standard deviations ranged between 0.627-1.038, indicating that respondents exhibited subjective differences during questionnaire completion, which aligns with reality. Statistical results show that the sample has good dispersion and meets research requirements.

3.3 Reliability and Validity Tests

Reliability refers to the stability, consistency, and dependability of results when measuring the same object using the same method, i.e., whether the measurement tool can stably measure the intended construct or variable. Scholars commonly use Cronbach's α to test scale reliability, with α coefficients ranging from 0 to 1. Generally, when $0.7 \leq \alpha < 0.8$, scale reliability is high; when $0.8 \leq \alpha < 0.9$, reliability is very high; and when $\alpha \geq 0.9$, reliability is extremely high. SPSS analysis results are shown in Table 1 . Cronbach's α for all 8 latent variables exceeds 0.8, indicating high stability, consistency, and reliability within each scale dimension.

Validity comprises content validity and construct validity. This study adopted mature scales from domestic and international research and conducted multiple rounds of expert consultation to ensure content validity. Construct validity

refers to the degree of consistency between measurement items and the theoretical concepts under investigation, typically divided into convergent validity and discriminant validity, usually tested using factor analysis methods. In exploratory factor analysis, the principal component method was used to extract common factor variance, extracting 8 factors, and the factor component matrix was rotated using the maximum variance method. Results showed that all common factor variance extraction values exceeded 0.5, indicating that the extracted common factors had good representativeness and explanatory power for latent variables. Based on this analysis, the rotated factor component matrix was examined. According to factor clustering and measurement item content, three items (RE1, TR1, SW1) were eliminated, and the clustering relationships of the remaining factors were basically clear.

Confirmatory factor analysis was conducted on the scale using AMOS, with results shown in Table 1. Convergent validity assesses whether multiple observed indicators under a latent variable can represent that variable's characteristics. Standardized factor loadings, average variance extracted (AVE), and composite reliability (CR) are basic indicators for measuring convergent validity, where standardized factor loadings and AVE should exceed 0.5, and CR should be above 0.7. Table 1 shows that all 25 indicators meet these criteria, indicating good convergent validity.

Discriminant validity verifies whether significant differences exist in correlations between different latent variables, generally judged by comparing the arithmetic square root of AVE with inter-variable correlation coefficients. Comparison results show that the arithmetic square roots of AVE all exceed inter-variable correlation coefficients, indicating good discriminant validity.

Table 1 Reliability and Validity Test Results

3.4 Structural Equation Model Testing

Model fit is typically tested using indicators such as ^{2}/df, GFI, AGFI, NFI, IFI, CFI, and RMSEA, with fit parameters shown in Table 2 . Comparing observed values with standard values indicates that the theoretical model is acceptable.

Table 2 Model Fit Parameters

Seven hypotheses were tested and verified. Based on P-values, the correlation degree of hypothesized paths was determined. As shown in Table 3 , * indicates $P < 0.05$ (significant correlation), ** indicates $P < 0.01$ (relatively significant correlation), and *** indicates $P < 0.001$ (highly significant correlation). Standardized path coefficients (β) indicate whether the hypothesis represents positive or negative influence, with larger values indicating more significant influence. Results show that all hypotheses except H4 ($P = 0.712 > 0.05$) are supported, and all represent significant positive influences.

Table 3 Hypothesis Test Results

4.1 Stock-Flow Diagram Construction

System dynamics emphasizes studying the internal logical relationships among system components from a holistic and dynamic development perspective, and discovering impacts generated by interactions among internal system elements based on causal relationship feedback information. For example, Ruan Bingying [37] used system dynamics models to explore dynamic patterns among different factors in scientific data sharing security systems. This study initially identified 8 influencing factors of scientific data sharing willingness. However, empirical results showed that subjective norms had no significant effect on sharing willingness, so the final model included 7 influencing factors (excluding subjective norms). Referencing measurement variables from the structural equation model, the system dynamics model was determined to include 7 state variables, 7 rate variables, and 26 constants. Based on the theoretical model and empirical results constructed above, a stock-flow diagram was built to establish the foundation for relational equations among elements, as shown in Figure 2 [Figure 2: see original paper].

Figure 2 Stock-Flow Diagram of Scientific Data Sharing Willingness

In the system dynamics model of scientific data sharing willingness, correlation coefficients and weight coefficients for all variables reference factor loadings and path coefficients from the structural equation model empirical process. Constants take values as the mean of each questionnaire item, state variables calculate weights based on standardized factor loadings, and initial values of state variables are calculated through weights and constant values, as specifically shown in Table 4 .

Table 4 Initial Parameter Values for System Dynamics Model

Scholars typically introduce logistic models during system dynamics model simulation [38]. Through debugging the system dynamics model, simulation results can be more intuitively displayed. Accordingly, this study sets 10 as the standard for scientific data sharing realization, 52 weeks as the simulation duration, and 0.5 as the simulation step size.

4.2 Simulation of Scientific Data Sharing Willingness Under Natural Conditions

Before conducting simulation experiments, the model's logical consistency and system stability must be tested to ensure reliability and stability. After the model passed verification, Vensim was used to calculate mathematical equations and output simulation results. Within the simulation period, scientific data sharing willingness shows a continuously rising trend over time, as shown in Figure 3 [Figure 3: see original paper]. The growth trend is relatively fast before week 30 and gradually slows down thereafter. In the early stage of sharing, increases in reciprocity, social interaction, and trust have a relatively large impact on providers' sharing willingness, resulting in a rapid upward trend. After

30 weeks of accumulation, providers have mastered rich data sharing knowledge, reached peak trust in scientific data users, sharing platforms, and related institutions, and gained sufficient understanding and recognition of the economic benefits and influence obtained from data sharing. At this point, providers have developed relatively mature data sharing capabilities, and the increasing trend in later-stage data sharing willingness also slows down.

Figure 3 Trends of Scientific Data Sharing Willingness and Influencing Factors

As shown in Figure 3, both trust and sharing attitude exhibit trends of rapid early growth followed by slower later growth. Since trust's rate of change is comprehensively influenced by reciprocity, social interaction, and data quality, trust's growth trend cannot form a stable linear relationship. As time increases and influencing factors on trust reach their peaks, the later growth trend correspondingly slows down. Similarly, sharing attitude's rate of change is directly influenced by trust, with reciprocity, social interaction, and data quality also indirectly affecting sharing attitude through trust. Its growth trend is almost linear and relatively stable in the short term.

4.3 Simulation of Scientific Data Sharing Willingness Under Different Scenarios

Sensitivity analysis adjusts initial values and variable rates to analyze dynamic change trends of scientific data sharing willingness under different scenarios.

(1) Changing Trust Rate

According to SOR theory, the organism changes when receiving external stimuli. Provider trust is influenced by reciprocity, social interaction, and data quality, while different providers exhibit varying abilities to respond to external stimuli and generate different changes. Scenario 1 increases trust's influence from reciprocity, social interaction, and data quality by 50% and decreases its initial value by 30%; Scenario 2 decreases trust's influence from these factors by 50% and increases its initial value by 30%. These scenarios observe change trends in trust, sharing attitude, and sharing willingness, testing providers who are sensitive to external influences but have low initial trust versus those who are insensitive to external influences but have high initial trust. The comparison reveals differences in responding to external stimuli and time trends of trust, further analyzing differences in sharing attitude and sharing willingness.

Figure 4 Comparison of Different Trust Rates

As shown in Figure 4, in Scenario 1, providers with strong ability to respond to external stimuli show very rapid trust growth in the first 13 weeks, with speed gradually slowing down later, and remain higher than providers with weak response ability until week 35. In Scenario 2, although the initial trust value is set high, due to weak ability to respond to external stimuli and smaller influence from reciprocity, social interaction, and data quality, trust remains continuously lower than that of providers with strong response ability after

week 25. Providers with higher trust in data sharing platforms, channels, and tools consistently show higher sharing attitude and sharing willingness over time than those with lower trust. Sharing attitude and sharing willingness are influenced not only by reciprocity, social interaction, and data quality but also by trust and perceived behavioral control, ultimately presenting trends somewhat inconsistent with trust.

(2) Changing Initial Perceived Behavioral Control Value

Perceived behavioral control's impact on scientific data sharing has not formed a unified view [24,39], but this study found it has a significant positive effect on sharing willingness. Considering gaps in providers' education, knowledge, and relevant skills, as well as differences in scientific data sharing experience, two comparison scenarios were designed. Scenario 1 sets the initial value of perceived behavioral control at 5, while Scenario 2 sets it at 1, to respectively test providers with relatively more versus less education or training, knowledge, experience, and skills in scientific data sharing.

Figure 5 Comparison of Different Perceived Behavioral Control Levels

As shown in Figure 5, providers in Scenario 1 and Scenario 2 differ only in their initial perceived behavioral control values, with Scenario 1 having higher initial values. Simulation comparison results show that Scenario 1 reaches its peak growth rate in week 13, while Scenario 2 reaches the same peak in week 23. This indicates that providers who have received more data sharing education or training early on and possess rich knowledge and experience can adapt to data sharing activities faster and demonstrate higher sharing willingness. From the trend of sharing willingness change, before week 19, the increase in sharing willingness in Scenario 1 consistently exceeds that in Scenario 2, while after week 19, the opposite trend emerges. This suggests that by week 19 of the simulation period, providers have accumulated rich knowledge and experience in scientific data sharing education or training, and their sharing willingness has developed to a relatively mature stage. Conversely, their data sharing willingness still has considerable room for improvement. Therefore, after week 19, the change in sharing willingness in Scenario 2 consistently exceeds that in Scenario 1.

(3) Changing Initial Sharing Willingness Value

The questionnaire item "Under certain conditions, are you willing to provide your scientific data to others?" offers five options ranging from strong to weak willingness. To clearly present the time trend of sharing willingness under the influence of influencing factors, three scenarios were established. Scenario 1 sets the initial sharing willingness value at 1 to test providers with weak sharing willingness; Scenario 2 sets it at 3 to test providers with moderate sharing willingness; and Scenario 3 sets it at 5 to test providers with strong sharing willingness.

Figure 6 Trends of Sharing Willingness Under Different Initial Conditions

As shown in Figure 6, the changes in sharing willingness in Scenarios 1, 2, and 3

decrease sequentially, reaching peaks in weeks 22, 15, and 10, respectively. Simulation comparison results show that in the first 6 weeks, Scenario 3's change in sharing willingness and sharing willingness are both higher than Scenarios 1 and 2; between weeks 6 and 16, Scenario 2's change in sharing willingness exceeds Scenarios 1 and 3; and after week 16, Scenario 1's change in sharing willingness exceeds Scenarios 2 and 3. Scenario 3's sharing willingness remains consistently higher than Scenarios 1 and 2. Providers in Scenario 1, influenced by trust and perceived behavioral control, show relatively large changes in sharing willingness in later stages, indicating considerable potential for data sharing.

5 Results Analysis and Discussion

The following discusses the empirical and simulation results and proposes targeted recommendations.

(1) The "trust → sharing attitude → sharing willingness" path is the fundamental logic driving scientific data sharing. Reciprocity, social interaction, and data quality have significant positive effects on trust, with the effect ranked as "reciprocity > data quality > social interaction."

Previous knowledge sharing research found that perceived reward mechanisms positively affect trust [40]. Such rewards include economic benefits, research influence, and data publication opportunities. Scientific data sharing shares many similarities with knowledge sharing. This study found that reciprocity has a stronger effect on trust than data quality and social interaction. Reciprocity constitutes the basic condition for researchers' scientific data sharing, while trust is the driving force that further enhances sharing enthusiasm based on reciprocity. Y. Kim [40] confirmed through open-ended questions that researchers choose credible colleagues and collaborators to share their data. Relevant stakeholders should emphasize the positive roles of reciprocity, social interaction, and data quality in building trust. Studies have also verified the influence path from sharing attitude to sharing willingness [24]. If researchers consider data sharing valuable and hold positive attitudes toward it, they are more willing to share their data. Therefore, relevant institutions and departments should actively promote the importance of data sharing to weaken researchers' negative evaluations of data sharing and improve their participation. They should also clarify responsibilities at each stage, establish unified data standards, ensure data availability and usability, and provide material or honorary rewards to researchers who share high-quality scientific data with good reputations, while imposing appropriate penalties for non-compliance [41].

(2) Subjective norms have no significant effect on provider sharing willingness.

Although this conclusion deviates from planned behavior theory, it supports Y. Kim's [42] research findings on social scientists' data sharing behaviors. This study found during investigation that while most providers were willing to share

their scientific data, relatively few actually participated in sharing. This may be because experts, colleagues, and collaborators around providers lack scientific data sharing experience, and their behaviors or suggestions have minimal influence on providers, resulting in low explanatory power of subjective norms on sharing willingness that does not reach significance.

(3) The stronger the provider's ability to respond to external stimuli, the higher their trust level in data sharing channels, platforms, tools, related institutional guarantees, and users, and consequently, the stronger their scientific data sharing willingness.

The questionnaire survey shows that researchers' trust in the reliability of scientific data sharing channels or platforms has the highest mean value, while trust in users' rational use of shared data has a relatively lower mean value. Compared with other hardware facilities and institutional guarantees, researchers are more concerned about users' inability to rationally utilize their shared data. In various fields, there exist opportunistic, dishonest, and selfish members, while the research field requires a practical and realistic academic atmosphere. Therefore, trust's effect on sharing attitude ($\beta = 1.031$) is stronger than other paths. Additionally, testing providers who are sensitive to external influences but have low initial trust versus those who are insensitive but have high initial trust reveals that initial trust level has minimal impact on final sharing willingness, while maintaining high sensitivity to factors such as reciprocity, social interaction, and data quality helps improve data sharing willingness.

(4) Perceived behavioral control significantly positively affects provider sharing willingness, and providers who have received more data sharing education or training early on and possess rich knowledge and experience consistently show higher sharing willingness than those without such education or training.

Perceived behavioral control's effect on willingness varies according to specific research environments [43]. If researchers have received education or training in data sharing and possess knowledge, experience, or relevant skills, they are more willing to share their data with others. Researchers can actively participate in relevant training and lectures, engage in data sharing practices, identify their weak links in data sharing, and improve their data sharing capabilities. Relevant institutions and departments should strengthen the cultivation of scientific data talents and integrate these talents into all stages of scientific dataset generation, sharing, and reuse to accelerate knowledge diffusion and meet the rapidly developing needs of scientific data management and services [44].

(5) Providers with weak initial sharing willingness show significant improvement in sharing willingness over time under the influence of stimulus and organism factors, demonstrating considerable data sharing potential. Providers with strong initial sharing willingness show large changes in early sharing willingness and maintain strong sharing willingness throughout.

The time trends of willingness changes among providers with different willingness levels under the influence of influencing factors conform to objective laws of development. Providers with weak initial sharing willingness show approximately normal distribution in willingness changes over time, with sharing willingness following a growth curve and demonstrating considerable data sharing potential. According to the "trust → sharing attitude → sharing willingness" influence path, the key to improving sharing willingness is enhancing trust in scientific data sharing. For providers with weak sharing willingness, their initial trust is relatively low. Reciprocity's influence on trust ($\beta = 0.435$) indicates that reciprocity is a more critical influencing factor of trust. Therefore, sharing willingness can be indirectly improved through reciprocity. Additionally, research funding agencies and scientific journals can establish corresponding incentive mechanisms, clarify providers' contributions, and provide rewards in terms of economic benefits and academic reputation, enabling researchers to benefit from shared data and thereby creating a favorable data sharing atmosphere.

This study constructs a theoretical model of scientific data sharing willingness based on SOR theory, empirically tests influencing factors of researchers' sharing willingness from the provider perspective, and introduces a system dynamics model to design three test scenarios under different situations for simulation, exploring dynamic evolution patterns of scientific data sharing willingness. This approach is expected to provide theoretical references and empirical support for future research. This study has several limitations that warrant continued attention and improvement. First, sample data were collected only through questionnaires. Future research could collect data through multiple approaches and consider integrating multiple methods to explore new influencing factors. Second, due to limited survey scope, management discipline samples predominate. Whether research conclusions apply to other disciplinary fields requires further verification. Third, sharing willingness does not directly translate into sharing behavior. Future research could examine the reciprocal cycle among data sharing willingness, actual behavior, and predicted results, and deeply explore strategies for promoting data sharing behavior.

Author Contributions: Zhi Fengwen: Proposed research topic and ideas, revised and approved the manuscript.
Zhang Meng: Designed research framework, collected and processed data, wrote and revised the manuscript.

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