

Article

Research on Incentive Mechanisms in the Data Market Based on a Multitask Principal–Agent Model

Nan Jiang and Yiwen Ma * 

Shanghai International College of Intellectual Property, Tongji University, Shanghai 200092, China;
jiangnan@tongji.edu.cn

* Correspondence: 2010975@tongji.edu.cn; Tel.: +86-021-65983113

Abstract: In the Web 2.0 era, data have emerged as a pivotal element in driving the sustainable development of the digital economy. Data markets play a crucial role in enhancing the circulation and allocation of data as a production factor, thereby supporting sustainable development goals. Through a comparative analysis of China's data market dynamics and global trends, we identify systemic challenges in reconciling data security and market circulation. This study introduces a multitask principal–agent model grounded in mechanism design theory, examining the relationship between the data market regulator (principal) and the data exchange platform (agent) to develop a comprehensive incentive mechanism that optimizes both data circulation and security. The study finds that factors such as the marginal cost of public resources, data security uncertainty, the absolute risk aversion of the data exchange platform, and the marginal social benefit of data security significantly influence the effectiveness of these incentive mechanisms. These insights provide actionable guidance for subsequent policymaking.

Keywords: big data; data market; data exchange; digital economy; Web 2.0



Academic Editor: Yi Su

Received: 23 December 2024

Revised: 9 February 2025

Accepted: 13 February 2025

Published: 15 February 2025

Citation: Jiang, N.; Ma, Y. Research on Incentive Mechanisms in the Data Market Based on a Multitask Principal–Agent Model. *Sustainability* **2025**, *17*, 1623. <https://doi.org/10.3390/su17041623>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The Web 2.0 era signifies the emergence of a new industrial epoch characterized by advancements in data, computing, and product development, underscoring the escalating significance of the value of data [1]. With the rapid innovation of digital technologies such as big data, blockchain, and artificial intelligence, data are becoming an important force and key factor in promoting the digital economy and sustainable social development, influencing economic structures, and changing the international competitive landscape. The Web 2.0 era has given rise to a significant proliferation of platform-centric business models, in which organizations strategically utilize user data and exploit network effects to foster innovation and augment revenue generation [2]. This underscores the critical importance of leveraging data and advanced digital technologies in facilitating the digital transformation of the economy and promoting the sustainable development of the digital economy. The Shanghai Data Exchange (SDE) and other institutions jointly predicted that the compound annual growth rate of the exchange scale of China's data market will reach 34.9% between 2021 and 2025, which is far above the rates in Asia and globally. By 2030, the overall exchange scale of China's data market will reach CNY 515.59 billion [3]. As a reflection of the strategic intent behind the sustainable development of the digital economy, data circulation, data exchanges' actual application, and governance are receiving increasing attention. To further leverage the driving role of data in sustainable economic development, in March 2022, the State Council of the People's Republic of China (PRC)

proposed promoting unimpeded flows in the economy, stepping up efforts to develop data markets, and striving to accelerate the development of a unified domestic market. In July 2024, the Third Plenary Session of the 20th Communist Party of China (CPC) Central Committee proposed promoting the aggregation of advanced production factors, such as data, toward new quality productive forces with an overall concept and systematic thinking to nurture a nationwide integrated data market.

The construction of an integrated data market is not just a “China issue” but a hot topic that has attracted widespread attention from all over the world. From a global perspective, institutions, departments, and new business models related to data exchange in countries and regions such as the US, the EU, the United Kingdom (UK), France, and Japan have sprung up like mushrooms after rain. Some examples include the UK’s active promotion of the National Data Strategy (NDS) to build a trusted data ecosystem for individuals, businesses, and organizations. Japan actively leverages its industrial advantages, with chain owners such as Nippon Telegraph and Telephone Corporation (NTT), Fujitsu, and the Japan Data Exchange (JDEX) constructing comprehensive data exchange markets such as the “Data Plaza”, creating the innovative “Personal Data Store” (PDS) and “Data Bank”, and exploring personal data revenue sharing systems. A large number of data exchange platforms and the data markets that they cover have emerged, including Datatrade, the world’s largest external data marketplace, Systemanalyse Programmentwicklung (SAP) Data Marketplace, which can effectively reduce the data integration workload and costs of data providers and data consumers, and data exchange platforms such as International Business Machines Corporation (IBM), Amazon Web Services (AWS) Data Exchange, and Databricks Marketplace. Developed economies around the world have incorporated data market construction into their sustainable development planning blueprints. The “European Green Deal” and “Sustainable Europe Investment Plan” emphasize the important roles of data support, digital technology applications, and related policy transparency in the sustainable development and environmental protection actions of European Union (EU) member states. The EU is actively building a data ecosystem and a digital single market, advocating international standardization to ensure trusted data exchange.

An integrated data market, as an important policy measure for promoting the sharing, optimization, and integration of various data resources, furnishes research conditions conducive to studying the data flow and sustainable development of the digital economy. However, the construction of an integrated data market also faces many challenges. Ensuring data security and privacy, promoting data circulation and sharing, etc., are issues that we need to think about and solve together. Particularly in the Web 2.0 environment, where internet users frequently engage in communication, dialog, and data-driven content generation, constructing a secure and efficient nationwide integrated data market, along with the analysis of its incentive mechanisms, is of urgent practical significance. As data can achieve high-intensity penetration into various fields, the issue of data market incentives also falls within the interdisciplinary domain of information technology, computational law, and economic management. This study summarizes the opportunities and challenges faced by constructing an integrated data market based on the development status of China’s data market and the mainstream development trend of the international data market. Based on mechanism design theory and principal–agent theory, a multitask principal–agent model was applied to introduce multiple task analysis frameworks such as data circulation and data security in a data exchange. The aim was, through reasonable incentive mechanisms, to promote the efficient, long-term, and secure circulation of data and ultimately drive the sustainable development of the digital economy.

2. Theoretical Background and Methodology

2.1. Data Market and Digital Economy Sustainability

The application of data in real life is extensive, including applications in resource and energy management, ecosystem and environmental management, education, agriculture, transportation and urban planning, the Internet of Things, policymaking, health, business, social networks, etc. [4–7]. Data help to form an open, shared, and sustainable new economic ecology and new business models by improving resource and energy utilization and economic operation efficiency, promoting integrated innovation, and significantly reducing resource transmission costs [8]. A sustainable digital economy relies on abundant data resources and efficient data exchange mechanisms, which require the collection, analysis, and utilization of large amounts of data, inevitably requiring data flow. The data market, as an online transactional location where data can be purchased, sold, or shared, can support the development of a data-driven digital economy by providing many heterogeneous data sources, data exchange and sharing mechanisms, management services such as data security and privacy protection, and data analysis tools and services [9]. Therefore, to maximize the overall social benefits and promote the sustainable development of the digital economy, the efficient circulation of data markets should be promoted.

Data-driven sustainable development relies not only on fundamental data resources but also on the application support of related technologies such as big data, artificial intelligence (AI), blockchain, cloud computing, machine learning, and the Internet of Things (IoT). The digital economy supports the practices of the circular economy through the utilization of data and technology while the circular economy provides a sustainable direction and objectives for the digital economy. In addition to the application of data resources and digital technology, establishing a data market to facilitate the sustainable development of the digital economy also requires the popularization of physical infrastructure, such as data centers, servers, and network equipment, and information infrastructure, such as the Internet, communication networks, data markets, and data exchange platforms, as well as the necessary support provided by law, regulations, and supervision related to data security and privacy protection, policies and incentives to encourage data sharing, financial support and investment mechanisms, and digital skills among the public. The above-mentioned interrelated structures collectively constitute an effective data ecosystem, supporting the operation and development of the data market and providing the necessary support for a sustainable digital economy. Figure 1 illustrates the sustainable development of the digital economy driven by data.

2.2. Foundations for Sustainable Data Market Development

In addition to propelling the sustainable digital economy, the sustainable development of the data market also signifies its capacity to function effectively and sustainably over the long term. This sustainability is contingent upon the support of a comprehensive array of infrastructures, policies, technologies, and legal frameworks. This section characterizes and summarizes the current development status of the foundation required for building a sustainable data market in China.

2.2.1. Sustainable Data Supply

There has been a launch of a series of strategic action plans, overall layout plans, projects such as the building of computing infrastructure, national data center clusters, and a national computing power network, the “east data, west computing” project, and the integrated application of computing power, data, and algorithms. China’s total data volume and data exchange scale have grown rapidly. According to survey results from the National Data Administration of China, as at the end of March 2024, the total computing

power of China's national data center clusters exceeded 1.46 million standard racks and the overall availability rate was 62.72%. As shown in Figure 2, the demand for data center racks in China was 5.2 million in 2021 and is expected to reach 14 million by 2025. In addition, China is building a sustainable low-carbon to zero-carbon data supply industry chain that will optimize power usage effectiveness (PUE) and replace renewable energy sources.

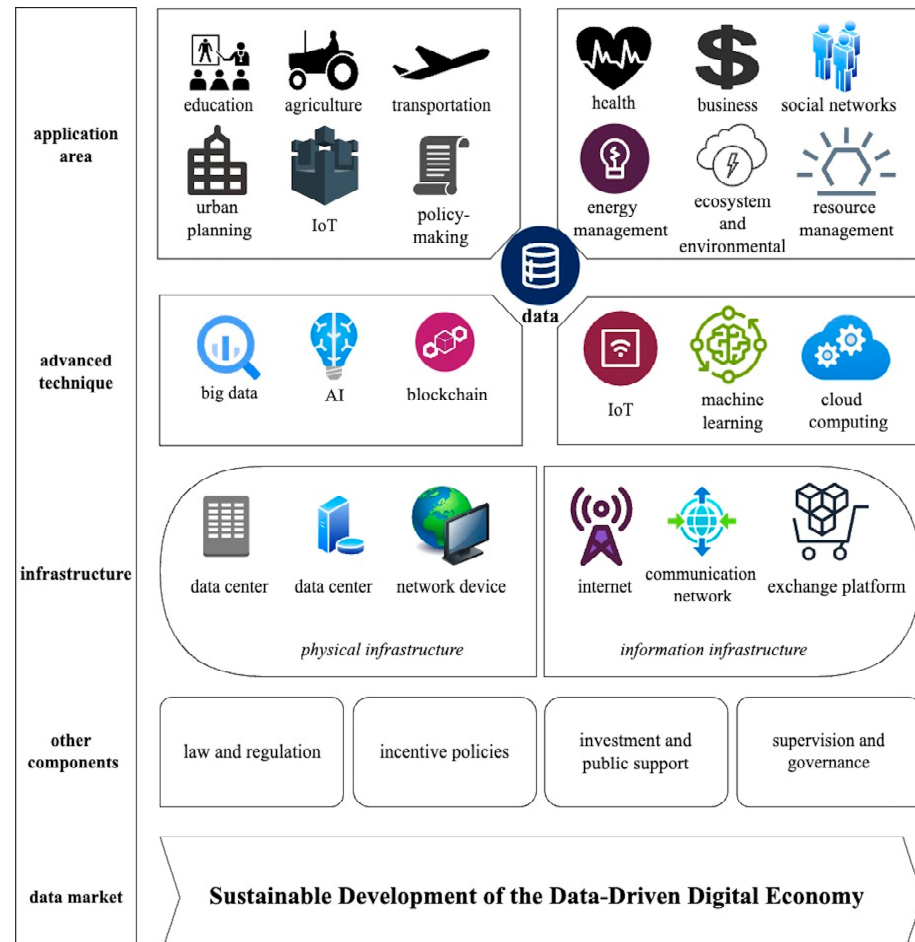


Figure 1. Sustainable development of the digital economy driven by data.

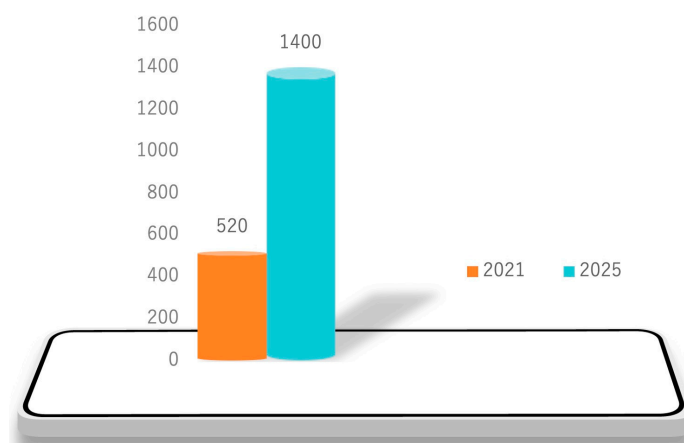


Figure 2. Forecast of national data center rack demand in China (tens of thousands). Data source: China Communications Digital Infrastructure Industry Research Institute.

Data exchange platforms, as important business tools that can provide a unified means of data exchange, can provide services such as exchange matching and security for data

flows [10]. In recent years, China has also actively introduced a series of institutions and related promotion policies to provide supply-side support for the data market. According to China's Securities Daily, there were more than 50 data exchange platforms in China as of July 2024. From the perspective of geographical distribution, the distribution of China's data exchange platforms has gradually spread from the southern region to the northern region in the early stage, and a layout structure radiating across the country has been formed.

2.2.2. Sustainable Tripartite Innovation

The sustainable circulation of the data market is inseparable from the dual drive of innovation and competition. A healthy relationship between innovation and competition can further stimulate the innovation cycle in the integrated data market and form a sustainable data industry chain, data market environment, and data ecosystem. As shown in Figure 3, China's data market's tripartite innovation includes technological innovation, data exchange model innovation, and innovation in data market entities; the three are complementary and mutually influential.

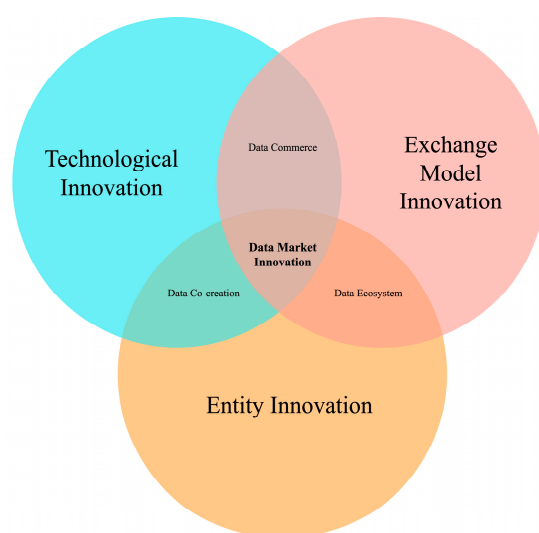


Figure 3. Tripartite innovations in China's data market.

From the perspective of specific regions, relatively developed regions, including Beijing, Shanghai, Shenzhen, and Guangdong, have become the pioneers in the construction of China's data market due to their advantages in funds, talents, and technology regarding the digital economy, and they have achieved some success. New data exchange platforms such as the Beijing International Data Exchange (with the IDeX system) focus on leading the innovation of digital exchange contracts and data asset certificates. The Shanghai Data Exchange advocates the concept of the "data ecosystem" (an economic entity that uses data as the primary object of business activities or the main raw material for production) and focuses on cultivating new data exchange entities, standardizing new data exchange formats, creating a data exchange supporting an ecological chain with the attributes of quasipublic service institutions, strengthening the construction of the International Data Port in the Lingang New Area (a special area in the Shanghai Pilot Free Trade Zone that is building integrated industry clusters and display exchanges), and forming a "three platforms in one chain" entity that connects the data exchange chain with the data registration, exchange, and settlement platform. Guangdong, as a major province of China's digital economy, has pioneered innovations in the service management system of data brokers and chief data officers (CDOs) in China. Other regions in China have also explored digital technologies,

data exchange service models, data market governance, and system mechanisms. The representative innovative measures in the process of building China’s data market are shown in Table 1.

Table 1. Representative innovations in China’s data market.

Region	Representative Innovations
Beijing	Digital exchange contracts; data asset certificates; IDeX system
Shanghai	Data ecosystem; “three platforms in one chain”; international data port
Guangdong	Data brokers; CDO; secondary data market
Guizhou	China’s first big data exchange and the rule system
Zhejiang	Privacy computing technology; “data high-speed rail”; multilevel data warehouse
Jiangsu	Big Data Association promotes standardization; pilot projects for data application in key industries
Shenzhen	China’s first uncollateralized data asset credit enhancement loan; trusted data space technology; dynamic compliance system

2.2.3. Evolving Legal Framework

A relevant legal framework can significantly protect the rights and interests of data market entities and reduce data exchange risks. China is gradually paying attention to the legislative protection of data rights and the construction of a data security governance rule system to reduce data market risks. The “three pillars” of the Data Security Law of the People’s Republic (DSL), the Personal Information Protection Law of the People’s Republic of China (PIPL), and the Cybersecurity Law (CL) of the People’s Republic of China further provide a preliminary protection framework for preventing data market risks. The DSL mandates the security of national, organizational, and personal data during the process of data development and processing. The PIPL stipulates the obligations that information processors should bear when collecting and processing personal data that have not been anonymized as well as the rights of data producers. The obligations of personal data-processing platforms, as proposed in Article 58, are also known as the Chinese version of the “gatekeeper” clause. The CL proposes corresponding data protection rules for various aspects such as network construction, network operation, network infrastructure, and network services. The “Measures for Cybersecurity Review (2021)”, the “Measures for the Security Assessment of Outbound Data Transfer”, and other departmental rules further provide legal guidance and norms for data market entities. Local governments are also actively exploring local regulations and institutional rules related to data protection. The above institutional system can, to a certain extent, strengthen the legitimacy and security of data market activities and reduce the risks of integrated data markets.

2.3. Research Design

Going a step further, similar to the data market mentioned earlier, there is another, narrower concept: the “data marketplace”. According to Sakr [11], a data marketplace is a platform where organizations and individuals can buy and sell data and it can be operated by government agencies, companies, or third-party providers. The data types involved include datasets, data streams, and data services and data providers can even monetize their data. In addition to the difference in the extension width of the concept of the “market” for data buying and selling, most of China’s data trading institutions, such as the Shanghai Data Exchange, are quasipublic service institutions established under the

guidance of local People's Governments. This means that most of China's data exchange institutions are state controlled. Institutions such as the Shanghai Data Exchange could not only provide the corresponding platform services as an exchange institution but could also be regarded as a complete data exchange platform. However, the internationally renowned "data marketplaces" are more commercial and market competitive and they are essentially platforms that support the buying and selling of data. Therefore, the alleged "data market" studied here refers to the broader market exchange category rather than the narrower concept of the data market. In China or other countries, irrespective of whether a platform or institution for data "transactions" is named a "data exchange", a "data marketplace", or something else, it may essentially involve the exchange of monetary value for data and there may also be relevant contracts or agreements. To understand the research presented in this study, it is important not to confuse the concept of "exchange" as the entity of the integrated data market with the concept of "exchange" as the commercial behavior in the data market and to avoid confusing "data marketplaces", which have a narrower concept extension, with the "data market", which has a broader concept extension. As mentioned above, this article uniformly refers to the buying and selling behaviors in the data market as "data exchange"; a platform for buying and selling data or an institution with the same function is referred to as a "data exchange platform"; the main research object of this study, the market of data exchange under the extension of the broad concept, is called the "data market".

In light of the existing literature, early studies, such as that of Zeng and Wang [12], adopted qualitative approaches to outline foundational incentive structures, emphasizing infrastructure development (e.g., telecom networks) and fiscal tools for value redistribution. This laid the groundwork for subsequent quantitative explorations. Zhang et al. [13] advanced the field through evolutionary game theory, demonstrating how tailored incentives mitigate privacy–security trade-offs between data providers and users. Concurrently, Liu and Han [14] systematically classified incentive models, underscoring the necessity of hybrid mechanisms that balance economic rewards with privacy safeguards—a perspective echoed by Biswas [15], who proposed privacy-sensitive pricing models to align data providers' truthful reporting with market efficiency. Liu and Lin [16] introduced revenue-sharing protocols to foster cross-enterprise collaboration, thus promoting the overall improvement of the data value in the data market.

While these studies are substantial in content, there are still some areas that could be further explored. Most existing research focuses on the responsibilities and tasks of data providers and users, such as data enterprises or users, in the sustainable development of the data market while neglecting the important role of the data exchange platform as a vital component. Moreover, in-depth systematic analysis is still needed to balance different incentive objectives, such as how to balance data security and data circulation incentives. Our study utilized a mixed-method approach, which integrates theoretical and applied research. This systematic and structured mixed-method research ensures a comprehensive understanding of data exchange and the integrated data market, providing a foundation for achieving the sustainable development of the digital economy. In the descriptive analysis section, the focus is on two descriptive analysis perspectives: development status and current challenges. This section investigates the collection and analysis of materials related to data markets and data exchange in China and other countries. In the applied research phase, the mechanism design theory and the principal–agent theory are combined in the context of information asymmetry. Our research aims to bridge these gaps by constructing a comprehensive incentive mechanism based on a multitask principal–agent model, considering both data circulation and security, and providing actionable guidance for formulating incentive policies to promote the sustainable development of the data market.

2.4. Inadequacies in China's Data Market

Taubman [17] asserted that any new stage of economic development will inevitably face new opportunities and challenges. As an emerging phenomenon, the data market inevitably has many areas that need to be improved.

2.4.1. Circulation Constraints of the Market

The development obstacles faced by the nationwide integrated data market also include insufficient market-oriented allocation and a lack of market participation and vitality. At present, although the number of data exchange platforms and the size of data markets in various regions have significantly increased year by year, the overall data market in China has not yet reached the ideal operating state and it is far from achieving the expected value positioning and benefits. According to Peng's [18] statistics, in recent years, the annual growth rate of China's social data volume has been about 40% but the growth rate of the truly utilized data volume is only 5.4%. The overall data market is facing challenges such as an insufficient supply of computing power with advanced layouts and a lack of diversified data circulation modes. Moreover, data circulation is mainly based on the signing of service contracts, with characteristics such as small-scale "peer-to-peer exchanges" (P2P) and low amounts. Some data exchange platforms still have poor performance and insufficient value-added services in actual operation. There are few advantageous exchange platforms in the data market and the market entities are relatively loose. There are also problems with the small quantity and scale and lack of cooperation among data exchange intermediary service agents and dealmaking institutions. Furthermore, although some Chinese companies have established commercial data exchange platforms, the platforms with enterprise backgrounds are relatively inadequate regarding data interface quality and data product listing scale and they are even difficult to sustain in the long term. Poor data quality and significant differences in data formats will substantially affect the development of the circular economy.

2.4.2. Security Risks of the Market

The secure operation of an integrated data market is a complex issue involving multiple fields such as privacy, technology, and law. From the perspective of exchange security, there are widespread security risks in the data market, such as the possession or distribution of illegal data, data breaches or data leaks [19], data misuse, and data theft, which have become new targets of illegal behavior and crime in the black and gray market networks. There are also many "OTC" (where direct data exchange is similar to "over-the-counter" exchange) data exchanges in reality. This informal data market often operates outside the data market governance system and has legal protection gaps. Kong et al. [20] also suggest that the illegal collection, exchange, and use of personal information, as well as data breaches and data misuse, pose data security risks to personal privacy, corporate trade secrets, and national data sovereignty. That is to say, the scope of data security is relatively broad, referring to the technical and institutional safeguards implemented to prevent unauthorized access, leakage, theft, or malicious exploitation of data throughout their lifecycle, addressing risks posed by illegal possession, informal transactions (e.g., OTC markets), and systemic governance gaps. It encompasses protection mechanisms against breaches, misuse, and noncompliant data practices that threaten individual privacy, corporate intellectual property, and national sovereignty.

Furthermore, the current data market security standards mainly focus on security technology, management, and evaluation and there are still deficiencies in the provision of technologies for behavior prevention and control and data monitoring, recovery, and deletion. The overall strength of the incomplete data market security guarantee system and

related upstream and downstream industries, such as data and network security, needs to be improved.

2.4.3. Information Asymmetry

The data market, due to its mixed public goods attributes, is also not a completely sufficient environment for private goods exchange and it faces problems such as low information efficiency and insufficient incentives. Sellers are concerned about the loss of value caused by disclosing data information, while buyers enter the market cautiously, resulting in a “double trust dilemma” in the data market [21]. Furthermore, the intangibility and complexity of data themselves make their degree of incomplete information more significant than that of other production factors [22].

3. Model Formulation and Optimization

3.1. Theoretical Framework

3.1.1. Mechanism Design

Mechanism design is an important economic research tool for ensuring that the distribution of data rights approaches social optimality [23]. The so-called mechanism design refers to the theory of designing corresponding mechanisms to achieve established goals under decision-making conditions such as incomplete and asymmetric information in decentralized exchange with the participation constraints of free choice and voluntary exchange [24,25]. This theory originates from the exploration of the issues of information transmission, communication, and information cost [26]. Information and incentives constitute the two core key issues in the design and operation of market mechanisms [27]. As Hurwicz [28] stated, from the perspective of information, economic mechanisms are considered a form of information exchange. Without information transmission, it is difficult for the information receiver to make corresponding decisions, which means that the information sender should credibly reveal some information to the receiver [29]. The lack of incentive mechanisms for various entities in the data market has suppressed their enthusiasm for information communication. Scholars represented by Hurwicz further proposed the viewpoint of information transmission and incentive compatibility, believing that mechanism design and operation should minimize the dimension of information space involved to reduce information cost waste, incentivize participants to share information, emphasize the functions of the mechanism of transmission of information and coordinated action, and establish incentive schemes to enable each participant to achieve overall goals while maximizing their benefits [30]. The theoretical framework based on mechanism design clarifies the importance of building a market mechanism for information integration and incentive compatibility [31]. It can be observed that the prerequisite for applying mechanism design theory is in line with the current development status of the data market and mechanism design theory provides tools for data market construction, governance, and policymaking. Because of this, based on the theory of mechanism design, this study comprehensively applied the ideas of mechanism design theory and incentive mechanisms, combined with the rules of the market-oriented economy and the actual situation of China's national conditions, and it attempted to construct a nationwide integrated data market mechanism and corresponding regulatory system that are incentive compatible, sustainable, and scientifically feasible. The core consideration in the construction of an integrated data market is that of designing data market incentive mechanisms to ensure that the self-interested behavior of market entities is consistent with the optimal goals of overall social benefits in the context of information asymmetry and individual rationality [32].

3.1.2. Multitask Principal–Agent Model

To some extent, especially in situations where information is incomplete, the principal–agent relationship can be seen as a specific application scenario for mechanism design [33]. The principal–agent theory refers to the theory of designing incentive mechanisms to enable agents to represent the principal’s interests as evenly as possible. When the agent maximizes their utility, the principal’s expected utility is also maximized and problems such as information asymmetry, moral hazard, and adverse selection are solved [34]. The specific implementation process for consistency goals includes using tools such as reverse reasoning (designing incentive structures based on the expected results) and constraint optimization (such as individual rationality constraints and incentive compatibility constraints) to maximize incentive compatibility [35]. It can be observed that the cross-application of the principal–agent theory and mechanism design provides powerful tools for understanding and solving many real-world economic problems. Then, Holmstrom and Milgrom [36] further extended the principal–agent model to a multitask principal–agent model.

Through the descriptive analysis presented in the previous section, we found that the integrated data market involves multiple tasks such as data security protection and efficient data circulation. The data market faces complex incentive challenges brought by multiple tasks [37]. For example, enhancing data privacy protection may reduce data accessibility and affect overall data flow efficiency. There may be trade-offs and conflicts between the different target tasks mentioned above. A multitask principal–agent model combined with mechanism design theory can more comprehensively reflect the reality of the data market.

3.1.3. Principal–Agent Setup

By summarizing the development and existing challenges of the data market both domestically and internationally, we have identified that various issues—such as data security risks, legislative protection gaps, data leaks, and theft—are fundamentally security concerns within the data market. On the other hand, technical barriers to data standardization and interoperability, fragmentation of the market, and information asymmetry among exchange platforms are detrimental to long-term sustainable data circulation.

This means that the multitask scenario involved in the data market can be significantly summarized into two core tasks and objectives: Task 1: efficient data circulation; Task 2: data security. These two tasks exhibit a clear trade-off and are central to the functioning of an integrated data market and each task has a corresponding level of effort for a data exchange platform.

Research on incentives for individuals and businesses in the data market has been widely discussed by existing research institutions and the purpose of this study is to provide a fast and practical framework for data market incentive policy recommendations, which means that the government level is already the main object of this research. Data exchange platforms are crucial in connecting the supply and demand sides, promoting data circulation, providing data products, services, exchange venues, and security management, formulating platform standards, supervising compliance within the platform scope, and facilitating industry cooperation in the nationwide integrated data market. If the normal supervision mechanism is not utilized during the implementation process, there is a high probability of obstruction. The regulator of the data market, such as a country or governmental agency, which is responsible for formulating policies, regulations, and monitoring the operation of the integrated data market, can promote the compliant flow and exchange of data by entrusting the data exchange platform, ensuring the security and privacy protection of data, and forming a typical agency relationship between regulation and market operation. Additionally, research resources on the emerging data market are limited. The analysis with the selection of these two objects provides a more concise

perspective and this helps to quickly identify and resolve key issues and contradictions in the data market.

Therefore, this research is conducted with the regulator as the principal and the data exchange platform acting as the agent, further exploring how to motivate the platform to address practical challenges in multiple aspects such as data security and data circulation. The principal–agent setup used in this study is depicted in Table 2.

Table 2. Principal–agent setup.

Assumed Identity	Description
Principal (P): The country or governmental agency as the regulator of the data market	Aiming to maximize social welfare by ensuring data security and privacy while promoting efficient data circulation and market vitality
Agent (A): The data exchange platform	Responsible for managing data exchange in the platform to align with the principal’s objectives

3.2. Model Construction

3.2.1. Basic Assumptions

This research builds upon the findings of Li and Jiang [38] on China’s institutional incentive mechanism using a multitask principal–agent model. A multitask principal–agent model was applied to introduce the two core tasks in the nationwide integrated data market. The principal aims to maximize social welfare by ensuring data security and privacy while promoting efficient data circulation and market vitality within the data market. Reasonable incentive mechanisms enable the agent to simultaneously address these two tasks, balancing the benefits of data circulation and data security. The agent manages data exchange within the platform, ensuring alignment with the principal’s objectives. To make the parameter settings in the model clearer, as shown in Tables 3 and 4, we explain and demonstrate the key parameters and core concepts in the model construction process.

Table 3. Model parameters and definitions.

Parameter	Definition
$1 + \lambda/\lambda$	Marginal cost of public resources
σ_2^2	Uncertainty associated with data security
σ_1^2	Uncertainty associated with data circulation
ρ	Absolute risk aversion coefficient of the data exchange platform
w'_{x_2}/v	Marginal social benefit of data security
x_1	Effort exerted on data circulation
x_2	Effort exerted on data security
π_1	Output related to data circulation
π_2	Output related to data security
α	Fixed income component of the data exchange platform
k_1	Incentive parameter for data circulation
k_2	Incentive parameter for data security

The following basic assumptions are proposed.

Assumption 1: The two core task objectives are as follows: (i) data circulation (Task 1) and (ii) data security (Task 2). Let x_1 be the effort exerted by the agents on Task 1 ($x_1 > 0$) and let x_2 be the effort on Task 2 ($x_2 > 0$). It is difficult for the regulator (principal) to directly observe the real-time effort levels of the data exchange platform (agent) in the targets of the above tasks. Still, it can more conveniently observe the outputs and total revenues of various tasks determined by the agent’s effort levels. Referring to the research

of Pan et al. [39], linear output functions are employed, defined as $\pi_1 = x_1 + \varepsilon_1$ (where π_1 represents efficient data circulation) and $\pi_2 = x_2 + \varepsilon_2$ (where π_2 represents data security assurance). It should be noted that π_1 and π_2 correspond to the outcomes attained by the data exchange platform in the domains of data circulation and data security, respectively. The data circulation and data security in the market are influenced not only by efforts but also by random external environmental variables. Under normal conditions, the random variables ε_1 and ε_2 follow a probabilistic distribution and both have a mean of zero, with standard deviations denoted by σ_1 and σ_2 ; they have variances denoted as σ_1^2 and σ_2^2 , respectively. Additionally, there is a correlation between them, quantified by the covariance σ_{12} . However, especially when it comes to more complex social welfare functions, it is difficult to draw effective conclusions. As stated by Soliño [40], x_1 and x_2 , as purely instrumental variables, can have defined “units” and measurements. The difficulties in measuring and estimating data circulation (such as the volume and number of exchanges through data exchange) are limited and this estimation is lower than the accurate measurement of the appropriate level of data security used in incentive contracts. Therefore, the measurement and valuation errors regarding the level of data security efforts will be greater and receive more attention. That is to say, we can assume that $\sigma_1 = 0$ (to focus the analysis more directly and clearly on the estimation error of data security, $\sigma_1^2 = 0$). Aside from this special case, the study can also be extended to cases where the measurement error of data security is significantly greater than data circulation (i.e., $\sigma_2 > \sigma_1$).

Table 4. Definitions of core concepts.

Concept	Definition
Marginal cost of public resources	Opportunity cost per unit of governmental resources (e.g., subsidies) invested in market regulation
Uncertainty associated with data security	Variance metric quantifying deviations from expected security levels due to technical flaws, institutional gaps, or behavioral risks
Absolute risk aversion coefficient of the data exchange platform	Measure of the platform’s aversion to risk, reflecting the degree to which it avoids uncertain outcomes in decision-making
Marginal social benefit of data security	Incremental societal benefit derived from enhanced data security such as reduced breaches and increased trust

Assumption 2: In this approach, the remuneration of the data exchange platform (denoted as S) is incorporated into the model as a linear incentive system, considering the optimality of such systems [41]. Its linear form is $S(\pi_1, \pi_2) = \alpha + k_1\pi_1 + k_2\pi_2$, where $\alpha > 0$ is the transaction commission and other fixed income that the agent can earn; the fixed remuneration of the data exchange platform does not affect its effort levels and incentive intensity, which are determined by the amount of retained earnings based on individual rationality (IR). k_1 and k_2 ($0 < k_1, k_2 < 1$) are parameters that represent the incentives for data circulation and for data security, respectively. In the specific scenario outlined above, if π_1 is equivalent to x_1 , the following expression applies: $S(\pi_1, \pi_2) = \alpha + k_1x_1 + k_2\pi_2$ and the expected value of the agent’s remuneration can be restated as $E[S] = \alpha + k_1x_1 + k_2x_2$; its variance will be specified by $\text{Var}(S) = \sigma_2^2k_2^2$.

Assumption 3: $C(x_1, x_2)$ is the agent’s effort cost function, which is an increasing convex function with first-order continuous partial derivatives and second-order differentiability [42]. The cost function is set as follows: $C(x_1, x_2) = C_0 + x_1^2 + x_2^2 + rx_1x_2$. Here, C_0 denotes a fixed cost that is unaffected by the level of effort expended and the cost factor r indicates the degree of substitutability between different tasks. This cost function excludes the cost savings resulting from the agent’s activities, which will be incorporated

into the model as a benefit via the social welfare function. In the real world, data exchange platforms with varying business strategies or technical capabilities may exhibit different points of interaction between data circulation and data security. One case is that, in certain situations, enhancing data security measures (such as implementing stricter encryption technologies and authentication mechanisms) can indeed increase the operational costs of the platform. This may lead to higher data circulation costs as the platform must allocate more resources to maintain these security measures. In other words, strengthening data security restrictions may increase the circulation costs of data, thereby exacerbating the resistance and difficulty of data sharing and circulation. For data exchange platforms, this is reflected in the fact that the marginal effort cost of data circulation increases with the intensity of data security restrictions. Another case is that certain platforms (such as AWS) offer more advanced data security features (such as automated exchange or compliance checks). These security measures may, in fact, lower the average data circulation costs by enhancing user trust, improving the efficiency of data transactions, and increasing the overall transaction volume. The model assumes that the agent's efforts, x_1 and x_2 , exhibit interdependencies in their marginal costs. The first-order partial derivatives with respect to x_1 and x_2 are derived as $\frac{\partial C}{\partial x_1} = 2x_1 + rx_2$, $\frac{\partial C}{\partial x_2} = 2x_2 + rx_1$. In the scenario where the value of r is negative, increasing the effort allocated to one task will lead to a decrease in the marginal cost of effort for each task. Conversely, when r is positive, the marginal cost of effort for each task increases with the level of effort in the other task. In this study, the value of r ranges from 0 to 2, with $r = 0$ indicating that the effort tasks are independent of each other and $r = 2$ suggesting complete substitutability.

Assumption 4: Generally speaking, the regulator is risk neutral. While the data exchange platform may be risk averse, its utility function has a constant absolute risk aversion characteristic, represented as $u = -e^{-\rho S}$. Here, ρ is the absolute risk aversion degree of the data exchange platform, $\rho > 0$; a larger value of ρ indicates that the data exchange platform is more risk averse.

3.2.2. Constraint Analysis

As Markowitz assumed, the data exchange platform also has “mean–variance”-type preferences [43]. The certainty equivalence (CE) of the data exchange platform is equal to the expected revenue of the data exchange platform minus the effort cost and risk cost, as shown in Equation (1).

$$CE = E[S] - C(x_1, x_2) - \rho \text{Var}(S) \quad (1)$$

Due to our aim of achieving the maximization of social welfare during the transition from the Web 2.0 epoch to the Web 3.0 epoch within the digital economy, we introduce an incentive mechanism designed to ensure the secure and efficient flow of data in the data market. Consequently, we propose the corresponding social welfare function. In the aforementioned equation, the social welfare function is derived by subtracting the social costs associated with providing the aforementioned services (including the risk aversion costs of the data exchange platform) from the social benefits $W(x_1, x_2)$. SW (social welfare) denotes the maximization of social welfare and we assume that $W(x_1, x_2)$ is an increasing concave function, represented by w'_i (the first derivative) > 0 and w''_{ii} (the second derivative) ≤ 0 [44,45]. $\lambda E[S]$ represents the additional cost of public resources, where $\lambda > 0$. In addition, $(1 + \lambda)$ denotes the marginal cost of public resources [46]. There is no fixed value for λ but, generally, λ increases with the total tax burden [47]. Building on the CE model equation established earlier, we obtain $SW = W(x_1, x_2) - (1 + \lambda)[C(x_1, x_2) + \rho \text{Var}(S)] - \lambda CE$. According to $C(x_1, x_2)$, and the risk cost of the data exchange platform is $\rho \text{Var}(S) = \rho \sigma_2^2 k_2^2$.

Ultimately, by replacing certain terms with their specific values, the preceding equation can be reformulated as follows:

$$SW = W(x_1, x_2) - (1 + \lambda)(C_0 + x_1^2 + x_2^2 + rx_1x_2 + \rho\sigma_2^2k_2^2) - \lambda CE \quad (2)$$

There is information asymmetry in the data market; after considering risks and expectations, the principal needs to achieve maximum social benefits through incentive mechanisms, while the agent is still willing to put in sufficient effort on various tasks. Therefore, constraints on IR and incentive compatibility (IC) should also be considered. By incorporating the IC constraint into the objective function of the data exchange platform, the agent is incentivized to optimize it. In other words, IC refers to the data exchange platform selecting the optimal effort levels x_1^* and x_2^* to maximize its CE . Therefore, the optimization design model for incentive contracts is as follows:

$$\text{s. t. (IC) } (x_1, x_2) \in \arg\max(E[S] - C(x_1, x_2) - \rho\text{Var}(S)) \quad (3)$$

According to the first-order conditions of the IC constraint, $\frac{\partial CE}{\partial x_1} = k_1 - 2x_1 - rx_2 = 0$ and $\frac{\partial CE}{\partial x_2} = k_2 - 2x_2 - rx_1 = 0$,

$$\text{Then, we obtain } \begin{cases} k_1 = 2x_1 + rx_2 \\ k_2 = 2x_2 + rx_1 \end{cases} \quad (4)$$

The IR constraint implies that the CE of the data exchange platform is not less than its amount of retained earnings, $CE \geq 0$; otherwise, the platform will not accept the contract. Based on the SW , the optimization issue is formulated as follows:

$$\text{s.t. (IR) } \text{Max}(CE, x_1, x_2, k_1, k_2)^{\{SW\}} \quad (5)$$

3.3. Model Optimization

According to Equation (2), since λ is positive, an increase in λCE implies that to maintain the agent's utility at a constant level, society must incur higher costs. In other words, an increase in CE leads to a decrease in SW , represented as $\frac{\partial SW}{\partial CE} < 0$. When $\lambda > 0$ and the agent is risk averse, CE signifies that the data exchange platform's expected utility has reached a certainty equivalent (the agent requires no additional compensation for the risks undertaken). If SW decreases monotonically with CE , then an increase in the agent's utility may imply that they demand higher remuneration, thereby increasing public costs and diminishing social welfare. Therefore, to maximize social welfare, CE can be set to $CE^* = 0$, where the agent does not demand additional risk compensation.

Consequently, the optimization issue can be simplified as follows:

$$\text{Max}(x_1, x_2, k_1, k_2)^{\{W(x_1, x_2) - (1 + \lambda)(C_0 + x_1^2 + x_2^2 + rx_1x_2 + \rho\sigma_2^2k_2^2)\}} \quad (6)$$

We bring this into Equation (4). These conditions reflect the balance between the incentives offered to the agent and the efforts that they exert on both tasks, taking into account the interdependence of the tasks as represented by the parameter r . This formulation encapsulates the goal of maximizing social welfare while accounting for the costs and risks associated with the efforts of the data exchange platform as well as the public resource costs represented by λ ; then, we have

$$\text{Max}(x_1, x_2)^{\{W(x_1, x_2) - (1 + \lambda)(C_0 + x_1^2 + x_2^2 + rx_1x_2 + 4\rho\sigma_2^2x_2^2 + 4\rho\sigma_2^2rx_1x_2 + \rho\sigma_2^2r^2x_1^2)\}} \quad (7)$$

In the context of optimal solutions, the marginal changes in the social welfare function W with respect to x_1 and x_2 are equated to the marginal changes in the agent's remuneration. To represent the sensitivity of social welfare to the agent's efforts on both tasks, the first-

order conditions provide the necessary relationships between the efforts and the incentives for the agent to act per the principal's objectives. Then, the first-order conditions are as follows:

$$\begin{cases} \frac{\partial W}{\partial x_1} - (1 + \lambda)(2x_1 + rx_2 + 4\rho\sigma_2^2rx_2 + 2\rho\sigma_2^2r^2x_1) = 0 \\ \frac{\partial W}{\partial x_2} - (1 + \lambda)(2x_2 + rx_1 + 8\rho\sigma_2^2x_2 + 4\rho\sigma_2^2rx_1) = 0 \end{cases} \quad (8)$$

Then, we use a gradient vector representation for conversion. The gradient vector ∇W for the function $W(x_1, x_2)$ can be represented as follows:

$$\nabla W = \begin{bmatrix} \frac{\partial W}{\partial x_1} \\ \frac{\partial W}{\partial x_2} \end{bmatrix}$$

Partial derivative with respect to x_1 (first component of the gradient vector):

$$\frac{\partial W}{\partial x_1} = (1 + \lambda)(2x_1 + rx_2 + 4\rho\sigma_2^2rx_2 + 2\rho\sigma_2^2r^2x_1)$$

Partial derivative with respect to x_2 (second component of the gradient vector):

$$\frac{\partial W}{\partial x_2} = (1 + \lambda)(2x_2 + rx_1 + 8\rho\sigma_2^2x_2 + 4\rho\sigma_2^2rx_1)$$

Gradient vector in matrix form:

$$\nabla W = \begin{bmatrix} \frac{\partial W}{\partial x_1} \\ \frac{\partial W}{\partial x_2} \end{bmatrix} = (1 + \lambda) \begin{bmatrix} 2x_1 + rx_2 + 4\rho\sigma_2^2rx_2 + 2\rho\sigma_2^2r^2x_1 \\ 2x_2 + rx_1 + 8\rho\sigma_2^2x_2 + 4\rho\sigma_2^2rx_1 \end{bmatrix}$$

This gradient vector represents the local rate of change of the function $W(x_1, x_2)$ at the point (x_1, x_2) , where each component corresponds to the partial derivative with respect to the respective variable. We solve the system of equations, where $1 + \lambda$ is treated as a nonzero constant, resulting in the following equations:

$$(1 + \lambda) \begin{bmatrix} \frac{\partial W}{\partial x_1} \\ \frac{\partial W}{\partial x_2} \end{bmatrix} = \begin{bmatrix} 2 + 2\rho\sigma_2^2r^2 & r + 4\rho\sigma_2^2r \\ r + 4\rho\sigma_2^2r & 2 + 8\rho\sigma_2^2 \end{bmatrix} \begin{bmatrix} x_1^* \\ x_2^* \end{bmatrix}$$

As mentioned earlier, $r \in (0, 2)$, $4 - r^2 \neq 0$, $r^2 \neq 4$; therefore,

$$x_1^* = \frac{1}{4 - r^2} \left(2 - \frac{rw'_{x_2}}{1 + \lambda} \right) \quad (9)$$

$$x_2^* = \frac{1}{4 - r^2} \left(\frac{(2 + 2r^2\rho\sigma_2^2)w'_{x_2}}{(1 + \lambda)(1 + 4\rho\sigma_2^2)} - r \right) \quad (10)$$

The above equations provide x_1^* and x_2^* and they are the functions of λ , r , ρ , w'_{x_2} , and w'_{x_1} .

3.4. Analysis of the Optimal Incentive Intensity

3.4.1. Analysis of the Optimal Data Circulation Incentive Intensity

As mentioned earlier, the participation constraints are $CE \geq 0$, $CE^* = 0$, and the IC conditions are as shown in Equation (4). Based on x_1^* and x_2^* , we obtained the corresponding optimal incentive value $k_1^* = \frac{1}{2(4 - r^2)} \left(4 - 2\frac{rw'_{x_2}}{1 + \lambda} + \frac{r(2 + 2r^2\rho\sigma_2^2)w'_{x_2}}{(1 + \lambda)(1 + 4\rho\sigma_2^2)} - 2r^2 \right)$. It can be equivalently converted into

$$k_1^* = 1 - \left(\frac{2\rho\sigma_2^2}{(1 + \lambda)(1 + 4\rho\sigma_2^2)} w'_{x_2} \right) \quad (11)$$

Under the initial assumptions regarding the social benefit function, the second-order conditions consistently yield a negative sign, indicating the presence of a maximum. We further clarify the incentive mechanism of the data market by analyzing the variations in the optimal incentives based on the equation for k_1^* about the relevant parameters. w is treated as an increasing concave function, $w'_{x_2} > 0$. In a general sense, we set the marginal social return of data security assurance, w'_{x_2} , to a constant value v . As mentioned earlier, $r > 0$, $\rho > 0$. Therefore, as the marginal cost of public resources $(1 + \lambda)$ increases, the optimal incentive for data circulation, denoted as k_1^* , also increases correspondingly. Subsequently, we applied the chain rule and the quotient rule of derivatives to calculate the partial derivative of k_1^* with respect to σ_2^2 , yielding the following result:

$$\frac{\partial k_1^*}{\partial \sigma_2^2} = -\frac{(1+\lambda)(1+4\rho\sigma_2^2)(2\rho rw'_{x_2}) - (2\rho r\sigma_2^2 w'_{x_2})(4\rho(1+\lambda))}{((1+\lambda)(1+4\rho\sigma_2^2))^2} = -\frac{2\rho r(1+\lambda)}{((1+\lambda)(1+4\rho\sigma_2^2))^2} w'_{x_2} \quad (12)$$

Since the denominator $(1 + \lambda)^2(1 + 4\rho\sigma_2^2)^2$ is always positive, based on the preceding assumptions, we find that the expression primarily influencing the sign of the partial derivative is actually $\text{sgn} \{-(1 + \lambda)[2\rho r(1 + 4\rho\sigma_2^2) - 4\rho(2\rho r\sigma_2^2)]\} = \text{sgn} \{-(1 + \lambda)[2\rho r(1 + 4\rho\sigma_2^2 - 4\rho\sigma_2^2)]\} = \text{sgn}[-(1 + \lambda)2\rho r]$. Because $1 + \lambda$ and $2\rho r$ are positive, $\text{sgn}[-(1 + \lambda)2\rho r] < 0$. It is evident that under the assumption of substitutive efforts, k_1^* is a decreasing function of the uncertainty of data security assurance, σ_2^2 . As σ_2^2 increases, k_1^* will gradually decrease.

Similarly, we calculated $\frac{\partial k_1^*}{\partial \rho}$ and obtained

$$\frac{\partial k_1^*}{\partial \rho} = -\frac{(1 + \lambda)(1 + 4\rho\sigma_2^2) \cdot 2r\sigma_2^2(1 + \lambda) - 8\rho r\sigma_2^4(1 + \lambda)}{((1 + \lambda)(1 + 4\rho\sigma_2^2))^2}, \text{sgn} [-(1 + \lambda)2r\sigma_2^2] < 0 \quad (13)$$

Based on the above equations, the optimal data circulation incentive intensity (k_1^*) is an increasing function of the absolute risk aversion of the data exchange platform. As ρ increases, k_1^* will gradually decrease.

We calculated $\frac{\partial k_1^*}{\partial w'_{x_2}}$ and obtained

$$\frac{\partial k_1^*}{\partial w'_{x_2}} = -\frac{2\rho r\sigma_2^2}{(1 + \lambda)(1 + 4\rho\sigma_2^2)} \quad (14)$$

Based on the previous series of conditions, we can conclude that $\frac{\partial k_1^*}{\partial w'_{x_2}} < 0$. In other words, as the marginal social return of data security assurance, $w'_{x_2}(v)$, increases, k_1^* actually decreases.

3.4.2. Analysis of the Optimal Data Security Incentive Intensity

Then, we optimize k_2^* , differentiate the social welfare function SW with respect to x_2 , and set the derivative equal to zero:

$$\frac{\partial SW}{\partial x_2} = \frac{\partial W}{\partial x_2} - (1 + \lambda) \left[\frac{\partial C}{\partial x_2} + 4\rho\sigma_2^2(2x_2 + rx_1) \right] = 0 \quad (15)$$

Here, the marginal social benefit $\frac{\partial W}{\partial x_2}$ corresponds to w'_{x_2} and, in the optimal scenario, the marginal social benefit equals the marginal social cost:

$$w'_{x_2} = \frac{\partial W}{\partial x_2} = (1 + \lambda) \left[\frac{\partial C}{\partial x_2} + 4\rho\sigma_2^2(2x_2 + rx_1) \right] \quad (16)$$

$$w'_{x_2} = (1 + \lambda)(2x_2 + rx_1) + (1 + \lambda)4\rho\sigma_2^2(2x_2 + rx_1) = (1 + \lambda)k_2(+4\rho\sigma_2^2),$$

$$\text{That is, } k_2^* = \frac{w'_{x_2}}{(1 + \lambda)(1 + 4\rho\sigma_2^2)} \quad (17)$$

Likewise, based on the aforementioned conditions and the characteristics of the numerator and denominator of the expression k_2^* , it is observed that as the marginal social return of data security assurance w'_{x_2} increases, k_2^* increases. As the marginal cost of public resources, $1 + \lambda$ increases and k_2^* decreases. Similarly, we obtained

$$\frac{\partial k_2^*}{\partial \rho} = -\frac{4\sigma_2^2(1 + \lambda)w'_{x_2}}{((1 + \lambda)(1 + 4\rho\sigma_2^2))^2} < 0 \quad (18)$$

$$\frac{\partial k_2^*}{\partial \sigma_2^2} = -\frac{4\rho(1 + \lambda)w'_{x_2}}{((1 + \lambda)(1 + 4\rho\sigma_2^2))^2} < 0 \quad (19)$$

It is evident that as the absolute risk aversion of the data exchange platform, ρ , and the uncertainty of data security assurance, σ_2^2 , increase, the optimal incentive related to data security, k_2^* , actually decreases.

4. Results and Discussion

4.1. Main Findings

The analysis reveals that the factors influencing the optimal incentive mechanism in the data market include the marginal cost of public resources ($1 + \lambda$), the uncertainty of data security assurance σ_2^2 , the absolute risk aversion coefficient of the data exchange platform ρ , and the marginal social benefit of data security assurance w'_{x_2} . Table 5 analyzes the variations in the specific parameters involved in the aforementioned equations and their differing impacts on the direction of changes in the optimal incentive mechanism.

Table 5. The impact of varying parameters on the optimal incentive mechanism in the data market.

Parameter	Description	Change Direction	k_1^* (Incentive for Data Circulation)	k_2^* (Incentive for Data Security)
$1 + \lambda/\lambda$	The marginal cost of public resources	↑	↑	↓
σ_2^2	The uncertainty associated with data security	↑	↓	↓
ρ	The absolute risk aversion of the data exchange platform	↑	↓	↓
w'_{x_2}/v	The marginal social benefit derived from data security	↑	↓	↑

Based on the table above, we observe that the efforts implemented for data security assurance involve a degree of uncertainty (σ_2^2). The presence of these uncertainties hinders the incentives for both data circulation and data security tasks, negatively impacting the enhancement of social welfare. Especially when high uncertainty in data security coincides with marginal social returns, it could even lead to negative incentives for data circulation. At this point, the incentive mechanisms in the data market become meaningless. However, we must also recognize that even without incentive mechanisms, there can still be positive efforts associated with data circulation and data security that relate to minimum social benefits. We assume these levels of effort to be $x_{\min 1}$ and $x_{\min 2}$. Even near-zero uncertainty

in data security cannot necessarily guarantee the feasibility of incentive mechanisms for the data exchange platform, as this is also related to $x_{\min 1}$ and $x_{\min 2}$.

Overall, k_1^* and k_2^* exhibit a negative correlation with σ_2^2 . Therefore, when perfect data security information conditions exist ($\sigma_2^2 = 0$), k_1^* and k_2^* become $k_1^* = 1$ and $k_2^* = \frac{v}{(1+\lambda)}$, respectively. We know that under the assumption of substitutive efforts, the maximum possible value for k_1^* is 1, which indicates that the highest level of data circulation incentives leads to maximized social welfare. However, as previously mentioned, such a scenario is difficult to achieve in the current data market. The limitations imposed by technological and economic costs related to data security protection and detection, compatibility issues among different platforms and technical standards, human factors such as data theft and leakage, and the lagging development of relevant legal frameworks and unified data security regulatory standards contribute to a series of information asymmetry issues. Consequently, a comprehensive data security evaluation system is lacking and perfect data security information does not exist. These factors collectively contribute to the complexity and challenges of data security. In conditions of incomplete information ($\sigma_2^2 > 0$), $k_1^* < 1$. This implies that, under typical circumstances, optimal incentive measures revolve around the balance and distribution of interests between the data market regulatory agency and the data exchange platform in the context of data circulation. Although measuring data security presents practical difficulties, establishing an integrated data market requires enhanced safeguards and regulatory mechanisms for data security.

According to the research results, the incentive mechanism design of the data market needs to comprehensively consider factors such as the uncertainty of data security risks, the risk avoidance characteristics of data exchange platforms, the marginal cost of public resource allocation, and the social marginal benefits of data security. The core findings include the following.

(1) The increase in the marginal cost of public resources ($1 + \lambda/\lambda$) will strengthen the incentive for data circulation but weaken the incentive for safety, indicating that policymaking needs to balance public investment efficiency and risk management;

(2) The uncertainty of data security (σ_2^2) and the platform risk aversion coefficient (ρ) have a negative impact on both types of incentives, verifying the importance of information transparency and risk-sharing mechanisms. The improvement of information transparency (reducing σ_2^2) can alleviate the effort suppression of data exchange platforms.

(3) The increase in the marginal social benefits (w'_{x_2}/v) of data security will suppress circulation incentives and highlight the inherent conflict between the goals of “security circulation”. Nonlinear compensation needs to be achieved through institutional design.

This study provides methodological innovation for the design of incentive mechanisms in the field of data markets and the conclusions of the study are both in alignment and at variance with the existing literature. Research has found that an increase in the risk aversion level (ρ) of data exchange platforms and the uncertainty related to data security (σ_2^2) will simultaneously weaken both types of incentives. This is consistent with classic conclusions such as “the increase in risk cost leads to weakened incentives” and “the negative correlation between task uncertainty and incentive intensity” in the theories of information asymmetry and multitask principal–agent models. The increase in σ_2^2 (such as policy risks, technical vulnerabilities, etc.) will amplify the agent’s ρ , thereby suppressing the principal’s incentive intensity for both types of tasks. This is consistent with the findings of Zhu et al. [48] in the study of major engineering risk models, which found that contractors with higher risk aversion levels also have poorer incentive effects and, the higher the uncertainty of the environment, the lower the incentive intensity that should be adopted. In existing research, the cost factors involved in promoting efficient data sharing and exchange in the data market through incentive measures mostly belong to

direct costs such as network bandwidth and energy consumption, which directly affect the willingness of market participants to participate as well as private costs that need to be considered in decision-making [14]. This study reveals the mechanism by which public resource costs affect incentive structures through nonlinear paths in a multitask principal–agent framework by introducing the parameterization of λ . In addition, this article emphasizes the inhibitory effect of marginal social benefits of data security on data circulation incentives. This differs from the proposition of Kong et al. [20], who stated that the optimal economic efficiency goal and efficiency priority should be pursued for market-oriented data allocation, indicating that a single-goal-oriented policy may lead to systemic imbalances.

4.2. Extended Analysis

Considering that changes in different parameters in the incentive mechanism of the data market may affect the interest matrix of participants in the market, this may lead to changes in the behavioral strategies of data market participants. The static model is expanded into a dynamic game and a time dimension t is introduced. In order to further verify the rationality and effectiveness of the incentive mechanism proposed in this study, we conducted scalability verification through dynamic evolutionary game analysis and parameter sensitivity analysis based on the previously set parameters and models.

As mentioned earlier, this article focuses on the bilateral strategic interaction between the data market regulatory agency (principal) and the data exchange platform (agent). Therefore, we use adaptive learning dynamics to study their behavioral patterns in adjusting strategies in the game process [49]. Considering that the effort level (x_1, x_2) of the data exchange platform is a continuous variable, that is, the strategy space presents continuity, as shown in Equation (20), the asymptotic adjustment of the strategy is characterized by a differential equation.

$$\frac{dx_i}{dt} = \beta x_i [U_i(x) - \bar{U}(x)] \quad (20)$$

Here, x_i represents the proportion of strategy i selected by the data exchange platform (such as high effort/low effort), $U_i(x)$ represents the expected return corresponding to strategy i , $\bar{U}(x)$ is the average return, and β represents the adjustment speed coefficient of the strategy (set to 0.1 to ensure a relatively moderate adjustment speed). According to Equations (1) and (2) in the multitask principal–agent model mentioned earlier, the payoff functions, participant strategies, and their definitions for the data market regulatory agency (P) and the data exchange platform (A) have been determined, as shown in Tables 6 and 7.

Table 6. Participants' strategies.

Participant	Strategy	Definition
Regulator (P)	Strong Regulation (s1)	Maximize social welfare by enforcing strict data security and circulation rules
	Weak Regulation (s2)	Minimize public resource costs with baseline compliance
Platform (A)	High Effort (a1)	Allocate resources to both data circulation (x_1) and security (x_2)
	Low Effort (a2)	Minimize efforts to reduce operational costs

Table 7. Payoff matrix.

Regulator (P) \ Platform (A)	High Effort (a1)	Low Effort (a2)
Strong Regulation (s1)	(U_P^{s1a1}, U_A^{s1a1})	(U_P^{s1a2}, U_A^{s1a2})
Weak Regulation (s2)	(U_P^{s2a1}, U_A^{s2a1})	(U_P^{s2a2}, U_A^{s2a2})

This study assigned values to key parameters based on the literature, such as studies by Markowitz [43], Dahlby [46], Holmstrom and Milgrom [36], with the main parameters set as follows: marginal cost of public resources ($\lambda = 0.3$), risk avoidance coefficient ($\rho = 0.8$), and task substitutability ($r = 1.2$). We used the MATLAB R2024b software for dynamic evolutionary game theory analysis and the results obtained are shown in Figure 4.

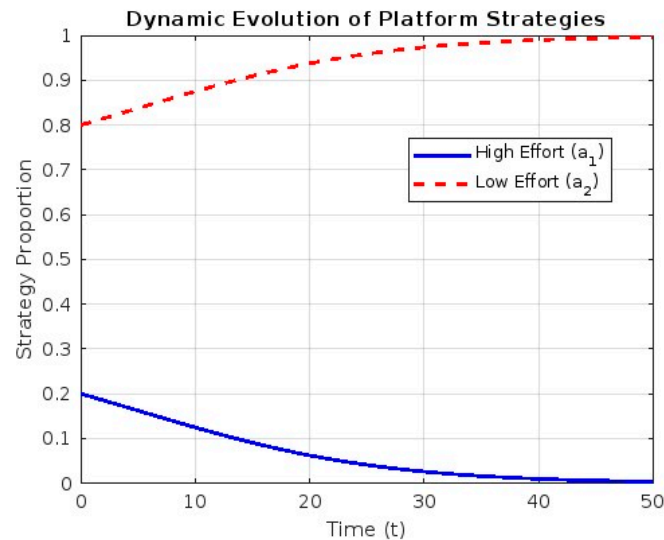


Figure 4. Dynamic evolution of platform strategies.

From the trend of strategy evolution shown in Figure 4, it can be seen that the data exchange platform gradually reduces the adoption of high-effort strategies and shifts more toward low-effort strategies in the dynamic game process. This indicates that under the current incentive mechanism, platforms are more inclined to choose low-effort strategies, which is possibly because low-effort strategies are more cost effective or have lower risks in the long run. This result indicates the need to re-examine and optimize the incentive mechanism of the data market. Regulatory agencies can reduce the cost and risk of platforms adopting high-effort strategies by providing more policy support and incentive measures, guiding platforms to adopt more proactive strategies, and promoting the sustainable development of the data market. This is consistent with our original intention of building an incentive mechanism model for the data market.

Due to the constraints on manuscript length and the accessibility of authentic data within the real data market, we conducted a sensitivity analysis to examine the influence of parameter variations on the optimal incentive intensity k_1^* . The corresponding results are depicted in Figure 5. It can be seen that, as ρ increases from 0 to 1, the height of the surface (k_1^*) gradually decreases. This indicates that, as ρ increases, k_1^* decreases. Similarly, k_1^* decreases with an increase in σ_2^2 . This indicates that the optimal circulation incentive is highly sensitive to the degree of risk avoidance and uncertainty of data security on the platform and this needs to be considered in the design of incentive mechanisms. That is to say, in high-uncertainty environments, platforms may reduce their efforts in data circulation and need to promote data circulation by reducing uncertainty or providing additional incentives. The numerical simulation results show that they are completely consistent with the theoretical predictions derived from the previous equations (such as Equations (11)–(13)), further verifying the rationality and effectiveness of the incentive mechanism in this study.

Additionally, we selected several case data to corroborate the model presented in this study. According to the 2023 China Data Transaction Market Research and Analysis Report released by the Shanghai Data Exchange, the future development trend of the data

exchange is expected to “reduce data security uncertainty through technological upgrades and provide greater data security assurance.” This indicates a decline in the uncertainty associated with data security ($\sigma_2^2 \downarrow$). The report also points out that the global data exchange market size of USD 906 billion in 2022 is projected to grow to USD 1445 billion by 2025, and is anticipated to reach USD 3011 billion by 2030 ($k_1^* \uparrow$). The aforementioned case data, through dynamic data changes, verify the impact of key parameters in the model on data circulation incentive mechanisms, which is consistent with the theoretical derivation within the multitask principal–agent framework.

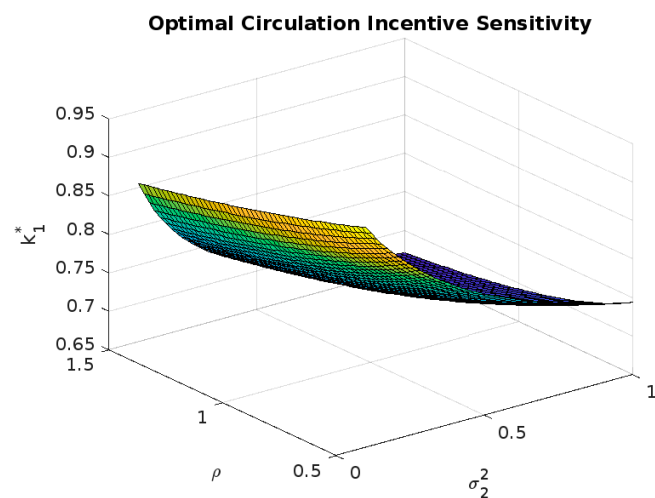


Figure 5. Optimal circulation incentive sensitivity.

To some extent, we should also grasp the mainstream trends of the current international development situation of the data market and data exchange. China’s large-scale data exchange platforms are generally established with government approval or supported by state-owned holdings, in contrast to platforms in other countries, which are more market oriented, diversified businesses and more active market entities. For example, OpenPrise, as a provider of a data orchestration platform, began to attempt to unify and standardize data from multiple sources in August 2017, launching its “Data Marketplace”, which interfaces with third-party data and allows data to be automatically accessed in different systems.

From the perspective of data market laws, regulations, and institutional frameworks worldwide, the EU General Data Protection Regulation (GDPR) and the Digital Services Act have enhanced data transparency and the protection of personal data. The United States, which once lacked federal-level legislation, is addressing the illegal collection and abuse of data by data brokers as well as the proliferation of unregulated underground data markets. Regarding this, the US has launched data legislation processes such as the American Data Privacy and Protection Act (ADPPA) and the American Privacy Rights Act (APRA), which are regarded as the American version of the GDPR, aimed at strengthening data security and establishing a unified data protection standard and unified federal model to reduce data risks. It is evident that other economic entities also place a strong emphasis on data circulation and data security, demonstrating greater market-oriented and flexible approaches.

5. Conclusions and Implications

5.1. Essential Conclusions

This study is based on a multitask principal–agent model and innovatively provides an analytical framework for data market incentive mechanisms that involve balancing data circulation and data security at the theoretical level. The study delves into the dynamic im-

part of factors such as marginal social benefits of data security, absolute risk aversion of data exchange platforms, uncertainty of data security, and marginal costs of public resources on data market incentives. Regulators should adjust incentive policies and regulatory strategies based on the actual conditions of data circulation and risk assessments. Establishing a continuous feedback loop between the data market regulator and the data exchange platform will enhance the scientific, adaptive, and return efficiency of the data market's incentive mechanisms, ensuring the maximization of long-term social welfare. Overall, an optimized nationwide integrated data market and corresponding incentive mechanisms will ultimately be established through long-term tracking, continuous evaluation, and dynamic adjustments.

5.2. Academic Implications

Compared to the existing literature, this study advances the theoretical boundaries in the following areas: (1) the traditional principal–agent model often focuses on single-task scenarios. This study quantifies the impact mechanism of dual-task collaboration and conflict on incentive intensity, which more comprehensively reflects the complexity of the data market. (2) This study specifically focuses on the impact of uncertainty in data security risks on incentive mechanisms, which is less explored in existing research. By introducing the uncertainty of data security risks, this study is closer to the operational environment of the actual data market. (3) This study reveals the structural constraints of policy objective functions by introducing social welfare functions, providing a new paradigm for multiobjective optimization of data market incentives.

5.3. Managerial Implications

This study proposes specific incentive mechanism design suggestions from the perspective of policymaking. Multiple parameters of the model in the article can be monetized according to actual situations, allowing policymakers to analyze the incentive mechanisms of the data market and the social and economic benefits that it brings more clearly. Based on this, a performance evaluation system for data security circulation can be established and differentiated incentive mechanisms can be designed. This provides operational guidelines for regulatory agencies and data exchange platforms. In contrast, existing research has mostly focused on the construction and analysis of theoretical models, with relatively insufficient guidance for policy practice. The research conclusions suggest that regulatory authorities should carefully design incentive mechanisms to balance the competitive goals between data security and circulation.

5.4. Policy Implications

To achieve effective incentives and efficient governance in the data market, this study proposes the following policy options.

- (1) Designing a flexible incentive structure and establishing a risk-sharing fund.

A dynamic and flexible regulatory environment should be established to adapt to the constantly evolving data market. During an economic downturn ($\lambda \uparrow$), the weight of circulation incentives can be temporarily increased ($k_1^* \uparrow$) but a safety bottom line should be set (such as $k_2^* \geq k_2$, $\min k_2^* \geq k_2$). During high-incidence periods of data breaches (with a sudden increase in σ_2^2), it is advisable to moderately reduce the performance weight of security incentives and instead diversify risks through technology outsourcing or insurance mechanisms. Encourage data exchange platforms to actively participate in proactive risk management, with the government taking the lead in establishing a data market risk-sharing fund (a special fund funded by fiscal appropriations and platforms in proportion to exchange volume to compensate for direct circulation losses caused by data security

incidents, such as data leakage compensation), will reduce the absolute risk aversion (ρ) of data exchange platforms. Platforms should be made to bear higher risks under the same incentive intensity, thereby alleviating the dual decay of k_1^* and k_2^* .

(2) Using a dynamic trade-off framework for heterogeneous incentives.

Relevant regulatory agencies can incentivize data exchange platforms to increase data circulation investment through tax incentives (reducing $1 + \lambda$) and introduce social capital through PPP models to share public costs ($\lambda \downarrow$). Public policies should be utilized to enhance the marginal benefits of data security investment while considering the heterogeneity of risk aversion among different platforms and designing incentive contracts for data markets in a differentiated manner. From the perspective of differences in risk aversion, data exchange platforms with high risk aversion require lower security incentives. Small and medium-sized platforms usually have weak risk resistance capabilities. Providing security subsidies to small and medium-sized platforms can improve their actual k_2^* , compensate for their risk-taking, and optimize the overall task allocation efficiency of the data market. From the perspective of the marginal cost difference in public resources, data exchange platforms in environments with a high marginal cost of public resources should prioritize responding to circulation incentives (k_1^*) to quickly monetize through data product innovation while building their compliance funds as a buffer against security risks. A data exchange platform in an environment with a low marginal cost of public resources can balance resource allocation and use government subsidies to build a positive cycle of circulation security.

(3) Improving the transparency of data market information and the “security premium”.

The marginal cost of public resources affects the efficiency of balancing data circulation and data security goals through asymmetric paths and one important cause is information asymmetry. It is possible to establish an audit system for the efficiency of public resource utilization and regularly evaluate the dynamic changes in the marginal cost of public resources. Measurement standards for data market regulatory costs should be established based on the standard cost model (SCM). All sectors must work together, strengthen cooperation and innovation, and promote the standardization, normalization, and innovation of the market. By increasing the cost transparency of the data market, we can avoid the accumulation of hidden costs. The standardization of data formats and interface standards should be promoted, the flow friction caused by technological heterogeneity should be reduced, and the effectiveness of k_1^* should be indirectly enhanced. Referring to the EU GDPR’s “Data Protection Seal” system, a data security certification standard system (reducing σ_2^2) should be established and the platform’s data security performance should be rated and publicly disclosed to alleviate information friction and asymmetry. Platforms with high credit ratings for data security, priority qualifications, and tax exemptions (reduced by $1 + \lambda$) will be granted high-value data exchange, forming a data market incentive mechanism of a “security premium”. Establishing a sustainable feedback loop between data market regulatory agencies and data exchange platforms will enhance the scientificity, adaptability, and return efficiency of data market incentive mechanisms, ensuring the maximization of social welfare and sustainable development.

5.5. Limitations and Outlook

It should be pointed out that although this study has made progress in theoretical modeling and policy design, there are still several limitations. Firstly, this study mainly conducts a descriptive analysis of the development of data markets and related incentive policies in other countries. In the future, the research scope can be expanded to cross-border comparisons to explore the differences in and adaptability of data market incentive mechanisms against different cultural and policy backgrounds. Secondly, the model does not

cover the impact of data pricing mechanisms on incentive intensity. In the future, models such as bilateral auctions can be introduced to analyze the moderating effect of price signals. Thirdly, policy recommendations need to further refine the implementation path, such as the specific fundraising ratio of relevant funds, technical details of certification standards, etc., which can be jointly tackled by multidisciplinary teams, such as those involving experts in the fields of law and computer science. In summary, as a tentative theoretical analysis of data market incentive mechanisms, this article is a holistic exploration of the construction of data market incentive mechanisms in the fields of economics, management, and policy research. Its full implementation still requires continuous collaboration and iterative innovation from academia, industry, and regulatory agencies.

Author Contributions: Conceptualization, Y.M. and N.J.; methodology, Y.M. and N.J.; validation, Y.M. and N.J.; formal analysis, Y.M. and N.J.; investigation, Y.M.; resources, Y.M. and N.J.; data curation, Y.M. and N.J.; writing—original draft preparation, Y.M. and N.J.; writing—review and editing, Y.M. and N.J.; visualization, Y.M.; supervision, N.J.; project administration, N.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by “The National Natural Science Foundation of China,” grant numbers 72274137 and 71874122 as well as by “The Special Fund for Basic Scientific Research Business Expenses of Central Universities”, grant number 22120230346.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zheng, J.; Li, E.; Liu, T. From Web2.0 to Web5.0: The Psychological Belongingness of Gen-Z in the Context of Digital Diversification. *Int. J. Human Computer Interact.* **2024**, *40*, 7924–7940. [CrossRef]
2. Wang, S.; Jiang, X.; Khaskheli, M.B. The Role of Technology in the Digital Economy’s Sustainable Development of Hainan Free Trade Port and Genetic Testing: Cloud Computing and Digital Law. *Sustainability* **2024**, *16*, 6025. [CrossRef]
3. Frost & Sullivan Consulting (Beijing) Co., Ltd.; LeadLeo Information Technology Nanjing Co., Ltd.; National Engineering Laboratory for Big Data Distribution and Exchange Technologies; Shanghai Data Exchange. 2023 China Data Transaction Market Research and Analysis Report; 2023; pp. 1–45. Available online: <https://voe-static.chinadep.com/group1/voe/9fa6c6c32831457997d47751a46e2a9d.pdf> (accessed on 3 December 2024).
4. Su, Y.; Yu, Y. Dynamic Early Warning of Regional Atmospheric Environmental Carrying Capacity. *Sci. Total Environ.* **2020**, *714*, 136684. [CrossRef] [PubMed]
5. Perera, A.; Iqbal, K. Big Data and Emerging Markets: Transforming Economies Through Data-Driven Innovation and Market Dynamics. *J. Comput. Soc. Dyn.* **2021**, *6*, 1–18.
6. Su, Y.; An, X.L. Application of Threshold Regression Analysis to Study the Impact of Regional Technological Innovation Level on Sustainable Development. *Renew. Sustain. Energy Rev.* **2018**, *89*, 27–32. [CrossRef]
7. Hossin, M.A.; Du, J.; Mu, L.; Asante, I.O. Big Data-Driven Public Policy Decisions: Transformation Toward Smart Governance. *Sage Open* **2023**, *13*, 21582440231215123. [CrossRef]
8. Luo, J. Data-Driven Innovation: What Is It? *IEEE Trans. Eng. Manag.* **2023**, *70*, 784–790. [CrossRef]
9. Zhang, M.; Beltrán, F.; Liu, J. A Survey of Data Pricing for Data Marketplaces. *IEEE Trans. Big Data* **2023**, *9*, 1038–1056. [CrossRef]
10. Quix, C.; Chakrabarti, A.; Kleff, S.; Pullmann, J. Business Process Modelling for a Data Exchange Platform. In Proceedings of the CAiSE 2017 Forum and Doctoral Consortium, Essen, Germany, 12–16 June 2017.
11. Sakr, M. A Data Model and Algorithms for a Spatial Data Marketplace. *Int. J. Geogr. Inf. Sci.* **2018**, *32*, 2140–2168. [CrossRef]
12. Zeng, Z.; Wang, L. The Fundamental Institutions of the Data Factor Market: Main Obstacles and the Ways to Remove. *Macroeconomics* **2021**, 85–101. [CrossRef]
13. Zhang, L.; Lu, Q.; Huang, R.; Chen, S.; Yang, Q.; Gu, J. A Dynamic Incentive Mechanism for Smart Grid Data Sharing Based on Evolutionary Game Theory. *Energies* **2023**, *16*, 8125. [CrossRef]
14. Liu, L.; Han, M. Data Sharing and Exchanging with Incentive and Optimization: A Survey. *Discov. Data* **2024**, *2*, 2. [CrossRef]
15. Biswas, S.; Jung, K.; Palamidessi, C. An Incentive Mechanism for Trading Personal Data in Data Markets. In Proceedings of the Theoretical Aspects of Computing—ICTAC 2021, Nur-Sultan, Kazakhstan, 8–10 September 2021.

16. Liu, Z.; Lin, D. Construction of Data Infrastructure Systems from the Perspective of High Quality Development and High Level Security. *SSCC* **2024**, 54–66.
17. Taubman, A. Digital Disruption and the Reshaping of Markets for IP: What this Means for Trade & Competition Policy. CP & IP in GE 2021. Accepted. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3857808 (accessed on 3 December 2024).
18. Peng, H. The Dilemma in Data Transactions and the Resolution: A Perspective from Incomplete Contract. *J. Comp. Law*. **2023**, *2*, 172–185.
19. Odusote, A. Data Misuse, Data Theft and Data Protection in Nigeria: A Call for a More Robust and More Effective Legislation. *Beijing Law Rev.* **2021**, *12*, 1284. [\[CrossRef\]](#)
20. Kong, Y.; Liu, J.; Zhao, Z. Research on the market-oriented allocation of data elements: Connotation deconstruction, operation mechanism, and practical path. *Economist* **2021**, 24–32. [\[CrossRef\]](#)
21. Tang, Y.; Zhang, Y.; Ning, X. Uncertainty in the Platform Market: The Information Asymmetry Perspective. *Comput. Hum. Behav.* **2023**, *148*, 107918. [\[CrossRef\]](#)
22. Xiong, F.; Xie, M.; Zhao, L.; Li, C.; Fan, X. Recognition and Evaluation of Data as Intangible Assets. *SAGE Open* **2022**, *12*, 21582440221094600. [\[CrossRef\]](#)
23. Chen, Q.; Wang, X.; Jiang, Z.L.; Wu, Y.; Li, H.; Cui, L.; Sun, X. Breaking the traditional: A survey of algorithmic mechanism design applied to economic and complex environments. *Neural Comput. Appl.* **2023**, *35*, 16193–16222. [\[CrossRef\]](#)
24. Carroll, G. Robustness in mechanism design and contracting. *Annu. Rev. Econ.* **2019**, *11*, 139–166. [\[CrossRef\]](#)
25. Martimort, D.; De Donder, P.; De Villemeur, E.B. An Incomplete Contract Perspective on Public Good Provision. *J. Econ. Surv.* **2005**, *19*, 149–180. [\[CrossRef\]](#)
26. Hurwicz, L. *Designing Economic Mechanisms*, 1st ed.; Reiter, S., Ed.; Cambridge University Press: Cambridge, UK, 2006; pp. 1–356.
27. Honkapohja, S. Information and Incentives: Organizations and Markets: Editor’s Introduction. *Scand. J. Econ.* **1988**, *90*, 255–257.
28. Hurwicz, L. Incentive Aspects of Decentralization. In *Handbook of Mathematical Economics*, 2nd ed.; Kenneth, J.A., Michael, D.I., Eds.; North-Holland: Amsterdam, The Netherlands, 1986; Volume 3, pp. 1441–1482.
29. Sémirat, S.; Forges, F. Strategic Information Transmission with Sender’s Approval: The Single-Crossing Case. *Games Econ. Behav.* **2022**, *134*, 242–263. [\[CrossRef\]](#)
30. Mookherjee, D. Decentralization, Hierarchies, and Incentives: A Mechanism Design Perspective. *J. Econ. Lit.* **2006**, *44*, 367–390. [\[CrossRef\]](#)
31. Brousseau, E.; Glachant, J.-M. *The Economics of Contracts: Theories and Applications*, 1st ed.; Cambridge University Press: Cambridge, UK, 2002; pp. 1–602.
32. Dawson, G.S.; Watson, R.T.; Boudreau, M.-C. Information Asymmetry in Information Systems Consulting: Toward a Theory of Relationship Constraints. *J. Manag. Inf. Syst.* **2010**, *27*, 143–178. [\[CrossRef\]](#)
33. Hoppe, E.I.; Schmitz, P.W. Contracting under Incomplete Information and Social Preferences: An Experimental Study. *Rev. Econ. Stud.* **2013**, *80*, 1516–1544. [\[CrossRef\]](#)
34. Hausken, K. Principal–Agent Theory, Game Theory, and the Precautionary Principle. *Decis. Anal.* **2019**, *16*, 105–127. [\[CrossRef\]](#)
35. Saijo, T. Incentive Compatibility and Individual Rationality in Public Good Economies. *J. Econ. Theory* **1991**, *55*, 203–212. [\[CrossRef\]](#)
36. Holmstrom, B.; Milgrom, P. Multitask Principal–Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design. *J. Law Econ. Organ.* **1991**, *7*, 24–52. [\[CrossRef\]](#)
37. Sivarajah, U.; Kamal, M.M.; Irani, Z.; Weerakkody, V. Critical Analysis of Big Data Challenges and Analytical Methods. *J. Bus. Res.* **2017**, *70*, 263–286. [\[CrossRef\]](#)
38. Li, X.Y.; Jiang, Y. Research on the Incentive Compatibility Mechanism of China’s Agricultural Land System from the Perspective of Mechanism Design. *J. Jiangxi Univ. Finance Econ.* **2022**, 108–122. [\[CrossRef\]](#)
39. Pan, F.; Xi, B.; Wang, L. Research on Incentive Mechanism of Chinese Local Government Environmental Regulation. *China Econ. Stud.* **2015**, *6*, 26–36. [\[CrossRef\]](#)
40. Sánchez Soliño, A. Sustainability of Public Services: Is Outsourcing the Answer? *Sustainability* **2019**, *11*, 7231. [\[CrossRef\]](#)
41. Holmstrom, B.; Milgrom, P. Aggregation and Linearity in the Provision of Intertemporal Incentives. *Econometrica* **1987**, *55*, 303. [\[CrossRef\]](#)
42. Liang, A.; Madsen, E. Data and Incentives. *Theor. Econ.* **2024**, *19*, 407–448. [\[CrossRef\]](#)
43. Markowitz, H. Mean–Variance Approximations to Expected Utility. *Eur. J. Oper. Res.* **2014**, *234*, 346–355. [\[CrossRef\]](#)
44. Hart, O.; Shleifer, A.; Vishny, R.W. The proper scope of government: Theory and application to prisons. *Q. J. Econ.* **1997**, *112*, 1127–1161. [\[CrossRef\]](#)
45. Eisenhardt, K.M. Agency theory: An assessment and review. *Acad. Manag. Rev.* **1989**, *14*, 57–74. [\[CrossRef\]](#)
46. Dahlby, B. *The Marginal Cost of Public Funds: Theory and Applications*; The MIT Press: Cambridge, MA, USA, 2008.

47. Barrios, S.; Pycroft, J.; Savein, B. The Marginal Cost of Public Funds in the EU: The Case of Labour Versus Green Taxes. *Fisc. Pol. Rev.* **2013**, *13*, 403–431.
48. Zhu, J.; Shi, Q.; Zhang, J.; Sheng, Z. An Incentive Model in Risk Management of Mega Project Considering Insurance Company Involved. *CMSS* **2022**, *30*, 1–10. [[CrossRef](#)]
49. Friedman, D. On Economic Applications of Evolutionary Game Theory. *J. Evol. Econ.* **1998**, *8*, 15–43. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.