Perspective

Digital Technology-and-Services-Driven Sustainable Transformation of Agriculture: Cases of China and the EU

Tianyu Qin [1,2], Lijun Wang [3], Yanxin Zhou [3], Liyue Guo [1], Gaoming Jiang [1,2,*] and Lei Zhang [3,*]

[1] State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China; qintianyu@ibcas.ac.cn (T.Q.); guoliyue@ibcas.ac.cn (L.G.)

[2] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

[3] School of Environment and Natural Resources, Renmin University of China, Beijing 100872, China; lijunwang@ruc.edu.cn (L.W.); sheylla@ruc.edu.cn (Y.Z.)

[*] Correspondence: jgm@ibcas.ac.cn (G.J.); leizhang66@ruc.edu.cn (L.Z.)

Abstract: China's sustainable development goals and carbon neutrality targets cannot be achieved without revolutionary transitions of the agricultural sector. The rapid development of digital technologies is believed to play a huge role in this revolution. The ongoing prevention and control of COVID-19 has greatly boosted the penetration of digital technology services in all areas of society, and sustainable transformation driven by digital technologies and services is rapidly becoming an area of innovation and research. Studies have shown that the rapid advancement of digitalization is also accompanied by a series of new governance challenges and problems: (1) unclear strategic orientation and inadequate policy and regulatory responses; (2) various stakeholders have not formed a sustainable community of interest; (3) information explosion is accompanied by information fragmentation and digital divide between countries and populations within countries. Meanwhile, current research has focused more on the role of digital services in urban governance and industrial development and lacks systematic research on its role in sustainable agricultural and rural development. To address the realities faced by different stakeholders in the process of digital transformation of agriculture, this paper aims to propose an inclusive analytical framework based on the meta-governance theory to identify and analyze the demand, supply, actor networks, and incentives in the digital technology-and-services-driven sustainable agricultural transformation, starting from the goals and connotations of sustainable agricultural and rural transformation and the interactions among different stakeholders in governing information flows. This analytical framework is further applied to analyze the cases of China and the EU. Although China and the EU represent different development phases and policy contexts, the framework is valid for capturing the characteristics of information flows and actor networks along the flows. It is concluded that a common information platform based on the stakeholder network would benefit all stakeholders, help reach common framing of issues, and maintain a dynamic exchange of information. Depending on the country context, different types of stakeholders may play different roles in creating, supervising, and maintaining such platforms. Digital infrastructures/products as hardware and farmers digital capacity as 'software' are the two wings for digital sustainable transformation. Innovative incentives from different countries may inspire each other. In any case, farmers' actual farming behavior changes should be an important criterion for evaluating the effects and effectiveness of digital transition governance.

Keywords: digital technology; meta-governance theory; agriculture; SDGs; stakeholders; information flow

1. Introduction

1.1. Digital Empowerment for Sustainable Agricultural Transformation

The contemporary agricultural development model faces multiple economic and environmental challenges [1]. Although chemical agriculture has increased grain production

and ensured the absolute security of China's food rations in the near and medium to long term [2–4], it has also led to many agricultural areas presenting increasingly serious ecological and environmental problems such as declining groundwater levels and soil fertility and increased pollution from agricultural processes [5–7]. The sustainable development of the agricultural sector is one of the keys to achieving the Sustainable Development Goals (SDGs) [8,9], SDG 1, 2, 6, 8, 12, 13, 14, and 15 in particular. Improving the performance of the SDGs related to agriculture contributes to achieving the region's commitment to economic transformation and improving the wellbeing of the region [10,11] and the carbon neutrality that China pledged.

Digital technology and services offer new opportunities for sustainable transformation of the agricultural sector [12,13]. Digital technologies, represented by 5G, the Internet of Things (IoT), and cloud computing have been increasingly integrated into all aspects of agricultural development as a focus of future technological development that can improve efficiency and sustainability [14–18]. Digital technology and services can reduce environmental pollution and ensure the safety of agricultural products. Digital technology and services enable the development of agricultural databases, dynamically maintain the balance between crop growth needs and agricultural production inputs, regulate the interaction between soil, cultivation management patterns, and climate, achieve resource conservation and environmental friendliness, and contribute to carbon neutrality [19,20]. In addition, digital regulation and intelligent sorting build digital grading standards for agricultural products, provide the technical conditions for strict product certification and labeling systems, raise consumer concerns about social and environmental sustainability, and promote sustainable agricultural development [21,22]. Thus, many believed that digital agriculture would deliver a step change in efficiency, productivity, and sustainability at the farm level and across the value chain [23,24].

1.2. Digital Agricultural Transformation around the World

Given the merits of digital technologies, to ensure that agriculture meets the needs of the world's future population, the world's leading economies are accelerating the development of digital agricultural transformation [25]. The United States is vigorously promoting the spread of 5G technology in agriculture, with $9 billion planned to be invested in 5G for rural America over the next decade [26]. The UK's agricultural information technology project was started earlier, and agriculture faces the problems of smaller arable land areas, larger individual farms, and a small agricultural workforce, and they are currently working on a comprehensive 5G rural testbed project [27]. Japan has introduced a series of policies to promote agricultural informatization and intelligence since 1993 due to its small and aged agricultural workforce. The Japanese government is promoting Cross-ministerial Strategic Innovation Promotion Program (SIP) and building a WAGRI in phases to connect various data sources and services to promote cooperation between different actors in the agricultural sector [28]. India is a typical agricultural country, with a large agricultural workforce, but the development of agricultural information technology has been slow. In 2015, it proposed a "Digital India" strategy to establish 250,000 village-level public service centers to solve the problem of indiscriminate access for rural residents, while actively developing e-commerce for agricultural products [27]. Since 2013, the Common Agriculture Policy (CAP) has issued a series of regulations to promote sustainability and innovation in agriculture, supporting the digital transformation of European Union (EU) agriculture and rural areas, and 24 EU countries also agreed to cooperate on digital agriculture in 2019 [29]. Since its introduction in the 1990s, China's agricultural informatization has seen rapid development of information technologies such as mobile internet, cloud computing, big data, and the IoT, providing a good foundation and realistic conditions for the development of digital technology and services in agriculture [30].

The promotion of digital technology and services is an inevitable trend in the development of agricultural modernization, the basis for the development of digital agriculture, and an important means of intelligent agriculture [31]. Countries are experimenting with

the application of digital technology in agriculture, but the following problems have been widely observed [32]: (1) policies and legislations lag behind the development of digital technology and services [30,33]; (2) developmental goals and interests of stakeholders may conflict with each other; (3) lack of inclusive and meta-governance of information flows; (4) uneven access to infrastructure and information between urban and rural populations, making it difficult for farmers to fully engage with digital transformation; (5) lack of effective incentives and regulations for market mechanism to play a full role; (6) farmers' perspectives on digital technologies and services are under studied [17,34,35].

1.3. Research Objectives

To accelerate the sustainable transformation of agriculture with the aid of digital technology and services, an analytical framework that enables a systematic and comprehensive identification of needs and problems is needed. Therefore, in response to the above-mentioned issues, this study aims to address the following questions: (1) What are government policies and programs that promote the adoption of digital technologies in the agriculture and food sectors? How are the factors influencing technology adoption by different stakeholders considered in policy process? (2) What are the perceived changes, challenges, and uncertainties facing the sustainable transformation of agriculture? (3) What needs be reformed and reinvented among different stakeholders in governing information flows?

To answer the questions above, from an integrated and interdisciplinary perspective [36], we aim to develop an inclusive analytical framework based on the meta-governance theory [37], which is helpful for capturing the complexity of digitalization, the dynamic interactions between stakeholders and their networks, the relevance of policy contexts in which these networks operate, and the leverages for changes. This analytical framework was then applied to analyze the cases of China and the EU, where multi-level governance exist and meta-governance is needed [29,33].

2. Analyzing Digitalized Transformation of Agriculture

2.1. Defining Digital Technologies and Services

In this study, digital technology and services refer to the application of digital technology for the digital industrialization of agriculture by various subjects with a certain level of affordability, education, and institutional support, on the basis of hardware with network coverage, internet access, electricity supply, and mobile terminals [25].

Digital technology and services are divided into two types: data and services. In this paper, data is classified according to Scown's classification of policies and practices for sustainable agricultural land systems [38], and services refer to those such as agricultural digital technology promotion, agricultural production and marketing solutions, environmental monitoring and management, advice on agriculture-related laws and regulations, and farming technologies and know-hows. The ultimate goal of digital technology and services is to realize the sustainable development of agriculture.

Digitalization-driven transformation of agriculture goes beyond agriculture as a sector and farmers as rural population. It requires integration of hardware and software, rural and urban, and collaboration of governments, businesses, and societal actors.

2.2. The Relevance of Meta-Governance Theory

The complexity of digitalized transformation means that there is a need to consider how different stakeholders should cooperate at various stages of the information flow [37]. The difficulty lies in the multiplicity of subjects and the complex structure of this process. There are often conflicts of interests, unclear obligations, negotiation-based rule-making, and dynamics of technology development [37,39–41]. Thus, digitalized agricultural transformation is a typical meta-issue.

Meta-governance is one of the representative theories of pluralistic cooperation, which can effectively address the complexity of sustainability governance [37]. "Meta-governance",

also known as "governance of governance", is a higher-level approach to the integration of hierarchical, market, and network governance models, organizing and coordinating the governance mechanisms of government, market, and society. It has the advantage of anchoring different governance models in broader contexts in which the role of meta-governor can be discussed [41–44].

Meta-governance has three important attributes: firstly, it is a multiplicity of subjects, i.e., there are many actors such as government, enterprises and the public; secondly, it is a complex structural relationship, i.e., there are strong and weak structural relationships between subjects, which are not fully unified; thirdly, it has a "governor who governs", similar to the relationship of "peer elders", which enables government, market, and society to work together efficiently by creating a situation of coordination among multiple actors in information flow [37,39–41,45]. These three attributes make it flexible and powerful for addressing the realities of digital technology and services in agricultural transformation. (Table S1).

2.3. Analytical Framework from Meta-Governance Perspective

The meta-governance theory provides a new space of governance in which all the three types of actors (governments, market participants, and societal actors) are presented, and the functions of potential meta-governor are analyzed (Figure 1). All these actors and their networks are engaged in the generation, collection, analysis, disclosure and application, and impact of information flows. Depending on the characteristics of specific data and information, the capabilities and resources they possess, the interactions within and between different networks, and the policy and market contexts in which they operate, each of these actors can be potential suppliers, users, supervisors, or meta-governors [46–48]. To be more specific, in this analytical framework, governments include central and local governments, market participants refer to businesses and services, societal actors include farmers, farmers' organizations, social organizations, associations, research institutions, and media. It must be stressed that both the information flows as a result of digitalization and the institutional contexts in which actors networks operate are dynamic. Factors such as policy and institutional changes and technological advances can either constrain or enable digitalization. The effects and effectiveness of the meta-governance also depend on its ability to adapt to changes.
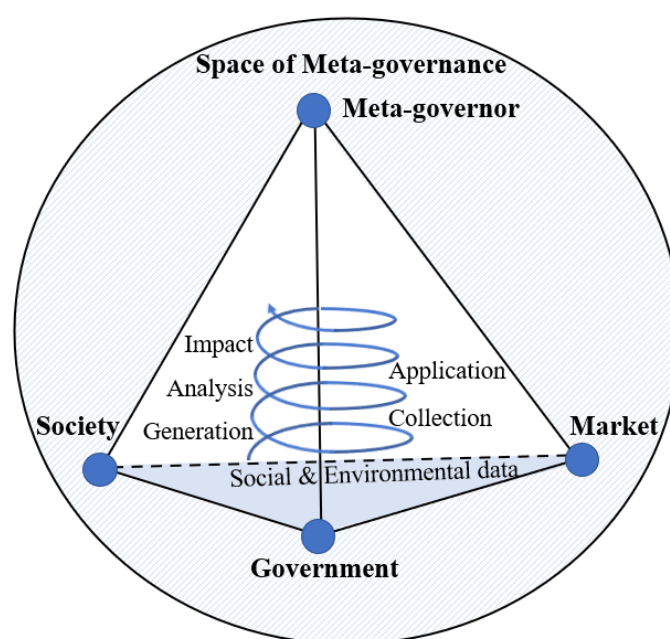
Figure 1. Meta-governance-based analytical framework for digitalization-driven agriculture transformation.

3. Case of China and the EU

Case studies on China and the EU serve two purposes: to test the relevance of the established analytical framework and to generate knowledge on the digitalization-driven agricultural transformation in China and the EU. Guided with the analytical framework, China and the EU are compared with regard to policy context, stakeholders involved, governments and governance modes, and roles of market actors and societal actors.

Both China and the EU have experimented with government-led digital technology service platforms. The EU set up Farm Sustainability Tool (FaST) based on the CAP to provide agricultural, environmental, and administrative simplification to farmers, EU member state payment agencies, farm advisors, and researchers through a user-friendly experience [49]. China's digital technology facilities are at a rapid stage of penetration, with provinces and cities setting up information platforms for farmers to connect farmers, farmer organizations, enterprises, consumers, and government departments through an online platform and offline outlets [13,17].

3.1. Policy Evolution

China and EU provide important experiences to draw from for validating the analytical framework in this study. However, as their initial platforms were not set up with the explicit goal of achieving sustainable transformation of agriculture, it is necessary to dig deeper into the evolution of their policy context. There are certain similarities and differences in the evolution of policies in China and the EU. For similarities, a top-down governance model can be observed in both cases. A central-local data sharing system exists in China and Europe. The Chinese central government has been continuously improving the top-level design of China's agricultural digital development. A three-in-one policy framework of "speed-breadth-quality" for agricultural digital technology has been formed [30]. In comparison, the EU's effort to establish inter-regional agricultural databases when the EU's CAP has changed the EU's original development model of promoting economic growth in agriculture [50].

For differences, in terms of policy starting points, the EU has been calling for the establishment of an agricultural database since 1992 through the reform measures of the CAP, well before China's initiative in 2015 [29]. In terms of policy objectives, China's digital agriculture development is designed to increase yields and incomes, agricultural modernization, and rural revitalization, with the transformation focusing on the means of production and technological development rather than on laborers. The EU's development is underpinned by the goal of farmers' income and rural development. In terms of the policy process, China has issued policies at a fast pace, with seven relevant documents issued in just four years from 2015–2019, especially in 2017, when the Ministry of Agriculture issued the Implementation Opinions on Promoting the Development of Big Data in Agriculture and Rural Areas, calling for the establishment of a global agricultural data center by 2025. In contrast, EU policies have been slower to advance, requiring a great deal of time to justify each policy as it progresses (Table S2).

3.2. Multiple Stakeholders in Agricultural Digital Transformation

In theory, all stakeholders can be potential providers and users of data and information. Different stakeholders have diverse roles and functions that can expand the application scenarios and technological innovations of digital technology services and promote sustainable transformation in agriculture. The role of stakeholders is mainly reflected in the flow of information. In China and the EU, for example, the government is able to standardize information standards, promote information sharing, integrate resources from all parties, and establish support platforms in the process of information collection. In the process of analysis and use, the government makes scientific decisions based on agricultural information. The diversity of social actors leads to the differentiation of different actors. Farmers and farmers' organizations upload data in the process of information collection, improve efficiency in the process of information use, and promote professionalization of

labor and functionalization of decision-making. Scientific research institutions develop key technologies and supervise research data in the process of information collection. In the process of analysis, they establish analytical models to support government management and deepen research and provide development ideas. Social organizations and the media convey the needs of multiple parties in the process of information analysis, breaking the problem of information silos of various subjects. Market players integrate data and provide value solutions in the process of information analysis, ultimately realizing the mining of agricultural value and expanding business models.

We therefore need meta-governance theory to build an institutional framework for collaborative development and develop appropriate incentive mechanisms based on the needs of different subjects, to provide research support funding to improve farmers' returns, to promote market development and change government management, and to promote project incubation and implementation to achieve collaboration. Achieving sustainable development relies on the cooperation of government, markets, and farmers to build an innovation ecosystem that takes into account the drivers of different actors. Due to the complex linkages between different actors, sustainable agricultural development can only be achieved if they develop together [24,46,50] (Table S3).

3.3. Cases Studies

3.3.1. Government

China

Hierarchical decision making is particularly important in the Chinese governance model, in which central government provides top-level design and coordinates between different regions, while local governments are responsible for implementation and innovation. As a core part of the hierarchical governance model, the central government provides legal safeguards and oversees the process of the sustainable transformation of agriculture in a polycentric governance system, supporting and coordinating sustainable agricultural development [46]. However, the barriers to the property rights system for the flow of various resources and information in rural areas lead to poor information flow and prevent effective interaction between various stakeholders [51]. Besides, consultations generally take place only between governments, and it is difficult for other stakeholders to participate in the process [52]. As a result, it is difficult for the government to obtain a rapid response from the market and society to promote new technologies [41]. This dilemma is present in the diffusion of digital agricultural technology services [53]. On the other hand, the implementation of new governance models in China is generally based on local policy experiments with special central government interventions, relying on entrepreneurship, adaptation, and learning facilitated [40]. There are huge disparities in the economic development, natural conditions, and resource endowments of different regions in China. In order to facilitate information supply and demand coordination, local governments need to understand local agricultural production and farmers' needs [51]. Government departments therefore need to reconcile the top-level design of the transformation process of digital technology services with the different needs of local practice. The existence of a unified top-level design and local differences makes central and local coordination extremely important [30].

The government needs to build information communication channels with different stakeholders. For the promotion of digital technology and services among farmers in information collection, the central government should establish a unified system and channel, such as the "Information Platform for Farmers", in the hope of aggregating agricultural information to meet farmers' needs and the government's decision-making needs. For local governments, on the one hand, they need to implement the policies of the central government; on the other hand, they need to carry out innovative practices based on local information resource endowment and learning ability. In this way, the government's ability to recruit is a central element in the formation of information flow [53]. Currently, differences in digital technology endowment in terms of information

investment, information equipment, and information capacity in different regions of China have resulted in huge disparities in the application of digital technology in agriculture across regions [54]. For example, the digital agriculture and rural development in Zhejiang province's counties is leading the country, with a development level twice as high as the national average, but there are still some provinces in slow digital transformation [55].

In information processing and analysis, China's agricultural science and technology innovation system consists of an agricultural research system, an agricultural technology extension system, and an agricultural science and technology intermediary organization, developed from the top down and categorized as part of the government. In the past 20 years, the number of funding inputs, topics, scientific papers, publications, and agricultural knowledge and innovation achievements in the field of agricultural science and technology have all been on the rise [56]. Research institutions also apply for a large number of variety rights and agriculture-related patents, and the index of intellectual property creation is much higher than that of corporate institutions [57].

The EU

In 1962, the EU fixed its agricultural policy with the CAP through comprehensive planning, design, and coordination of various stakeholders, and it has ensured the viability and effectiveness of the policy through continuous adjustments over six decades. After three rounds of major reforms, the CAP has progressively emphasized the wisdom, flexibility, and diversification of agricultural development on the basis of ensuring food security, and it has integrated rural development such as environmental protection, climate action, and agricultural competitiveness into the policy planning of the CAP [29,58]. The present data-driven agriculture governance system of EU can be characterized as hybrid regarding governance [59]. It has been undergoing a shift from formal, hierarchical policymaking to more open and inclusive modes of governance involving actors within the government, market, and civil society at multiple levels [60]. Government and other stakeholders seem to have played quite an active and beneficial role in meta-governance to resolve conflicts due to its perceived neutrality relatively [61].

The EU government is currently at the stage where information flows are generated and collected, but the division of responsibilities between the different levels is unclear. In the information flow, Eurostat and the farm accountancy data network (FADN) collect agricultural information by means of questionnaires in cooperation with third parties; the Agricultural Council is responsible for the analysis and processing of agricultural information, the formation of global guidance, and the regulation of markets, and the Agricultural Council is also responsible for publishing relevant information. Although the full responsibility of the EU agricultural information process is clear, its multi-level governance model coupled with market-oriented reforms, the disappearance of coordinating bodies, and the limited scope for the exercise of laws in different regions have led to a high degree of complexity and heterogeneity in the operation of the institutions [62].

3.3.2. Market Actors

China

The market actors, with the main goal of profit making, play important roles in promoting rural informatization and stimulating economic growth in digital agriculture. Santoso divided the agriculture information system into nine parts and focused on farmers and production activity [21]. Liu combined China's existing information technology promotion platforms, and they can be divided into nine categories based on enterprise function points: agricultural technology, machinery, technology, tools, services, trade, policy, loans, and land transactions [63]. On top of improving the hardware of digital technology, market players focus on cultivating the soft power of farmers to accept and use digital technology. In 2020, Alibaba worked with more than 100 counties nationwide to help train 133,200 farmers and nurture 100,000 new farmer anchors [64]. In 2021, Alibaba established the "Rural Talent

Revitalization" course program through its "Taobao Education" platform to provide free digital technology training courses to farmers [65].

In terms of information collection, the main way for market players to obtain information is to establish a partnership with the government. In addition, some of the more technologically powerful companies have begun to experiment with alternative ways of collecting agricultural data. Jing Dong, another Chinese e-commerce giant, applies digital technology to build modern agricultural bases and provide comprehensive solutions, while Alibaba Cloud uses the IoT to build digital origin warehouses and dock production and marketing processes [56,57].

In terms of information processing and analysis, market players integrate data from the agricultural production chain with China's national conditions, propose more optimal solutions for the production and marketing of agricultural products with the help of statistics, model building, visualization, and intelligent analysis, promote the effective interface between digital technology and agricultural production and operation, promote the deep integration of modern information technology with various fields and links in agriculture and rural areas, develop digital productivity to improve the quality, efficiency, and competitiveness of agriculture, activate the endogenous power of rural development, and increase market potential [13,66].

In terms of information impact, the e-commerce platform provided by commercial entities has played a huge role in the development of rural e-commerce by farmers. However, 95.4% of the 474 high-quality "e-commerce villages" are located in China's six developed coastal provinces, which cannot realize the "synergy sharing" and "mutual benefit" that digital technology services should provide. "The information divide is getting deeper and deeper" [54].

The EU

Since the 1990s, the EU's private stakeholders have played important analytical and influential roles along the information flow. In 2017, 474 and 157 counterpart consultancies in 51 and 42 private institutions in Italy and Germany, respectively [67,68], which create digital agricultural solutions through a supply chain management model, connecting directly with producers and providing services across the agricultural industry chain from cultivation to marketing through hardware systems such as monitoring base stations, remote visualization equipment, central control, and supporting software support such as management modules, early warning modules, and cloud-based management. By developing new agricultural technologies, technology companies are characterized as market style in meta-governance, and they improve agricultural production efficiency and reduce operating costs, allowing agriculture to shift from crude and inefficient to a sustainable development model. By establishing partnerships with governments or working with producers and operators to obtain data, market players obtain useful information from data, analyze it in depth, and use it to effectively predict or guide decisions [9,69].

For the promotion of the agricultural transformation of digital technology services, in terms of information generation and collection, market players are usually driven by material interests to develop a software package to obtain information from farmers through a business-company model, and an example would be Vital Fields, of Estonia. As a farm management tool, Vital Fields allows growers to record data, import maps, obtain help with compliance reporting, benchmark reports, and more. The software enables farmers to make a process of applying for European Union subsidies more efficient and automated. In terms of information analysis and application, the EU market players consist of technology and commercial companies, often working in partnership with governments and research institutions to form an independent platform. Food Valley NL, for example, is an independent platform for innovation and transformation of global food systems. Food Valley sets up a smart data system that contains all relevant and up-to-date data and knowledge, trends, and developments. It also lists the stakeholders in the food system (from investors to entrepreneurs). However, the multitude of market players has led to an

increasingly competitive environment for service organizations to offer a diversified range of services, affecting the cost of access to IT services for farmers [62,70].

3.3.3. Society Actors
China

At present, the construction and development of agricultural digital technology services are increasingly tending towards real-time application, host-client integration, and overall co-biosis [6]. A large number of agricultural workers and managers are both users and makers of big data [9,71], but China has to overcome a number of barriers for digital agriculture and rural development. Overall, the level of digital agricultural and rural development in counties nationwide in 2019 reached only 36% [55], with only 23.6% of agricultural production digitized. The average age of China's agricultural production and operation personnel is on the aged side. Their overall education level is low: 91.7% of agricultural production and operation personnel have only received education at junior high school or below in 2020, and more than half of them have only received primary school education or below [72]. China's universal Internet infrastructure has achieved 309 million Internet users in rural China and an Internet penetration rate of 55.9% in rural areas [73]. There are already realistic conditions for improving farmers' ability to use digital technology, and there is an urgent need to improve farmers' ability to use IT in the digital transformation of agriculture.

Different stakeholders are trying to connect with farmers. The central government expects to use "Information Platform for Farmers" as a carrier to extend information technology projects to every administrative village in China. However, in practice, the role of "Information Platform for Farmers" is not significant. The "Information Platform for Farmers" is generally dedicated to providing technical training to farmers (e.g., cell phone use, access to data resources, agricultural technology training) and establishing e-commerce platforms for farmers. Three years after the establishment of "Information Platform for Farmers", 48% of the respondents had hardly heard of it. In addition, only 14.5% of Information Platform for Farmers is currently profitable, while 85.5% is not profitable or losing money [74]. This is mainly due to the fact that the training courses are not designed to focus on the "applied training" that farmers are interested in. In addition, the Information Platform for Farmers is not operating well, and it is difficult to get farmers interested in their training content [75]. Market players are also trying to motivate farmers for information training. Only 13,146 farmers participated in the same type of free course offered by the aforementioned "Alibaba" company [65]. This is similar to the dilemma governments face when promoting other types of agricultural technologies—the potential gap between technology supply and technology demand makes "recruitment" difficult [53].

The EU

The societal actors in the EU are mainly farmers, various farmers' organizations as well as social organizations, and the media. The main role of farmers' organizations is to act as a bridge between government and farmers and as guarantors of their common interests. On the one hand, farmers' organizations can transmit information to all their members via the Internet, association publications, and telephone calls, and on the other hand they are also the concrete implementing bodies for strategic guidance at national or regional levels, often actively advising the state. For example, in Austria, Belgium, Denmark, Finland, France, Lithuania, Portugal, Slovenia, Spain, and Sweden, farmers' organizations are the main providers of STI services to the public [67]. Farmer cooperatives can organize farmers to learn digital technologies, improve their scientific, technological, and business management skills and enhance their innovation, democratic awareness, and cooperative spirit. Due to the different levels of knowledge and education of farmers in different countries, farmers and farmers' organizations have different levels of acceptance of digital technology services [25].

For the diffusion of digital technology services, the role of farmers has also changed from being direct payers of services for help to being collectors of information in terms of information generation and collection [70]. The main reason for this is that the EU average knowledge level of farmers is among the world leaders, with 63.8% of 15–64-year-olds having a high school education or higher in 2020 [76]. The involvement of non-governmental organizations (NGOs) can also help to overcome the last-mile barrier to the application of data technology by fully understanding the needs, capacities, and concerns of farmers' practices, often considered to be the second-most reliable source of environmental information after scientific institutions [47]. In terms of information analysis and application, a large number of agricultural workers and managers are users of big data [9,71]. Farmers rely on agricultural information platforms, where farmers can upload, store, and analyze data to monitor weather changes, crop health, soil quality, and irrigation levels [35]. In terms of information influence, the media can enhance information exchange between different subjects, update farmers' knowledge and concepts, and improve their ability to receive and feedback information [68]. As a result, the media promote the development of the agricultural economy, the process of agricultural industrialization and the restructuring of the agricultural economy, and the development of markets such as agricultural e-commerce. Media operations are the most used and central tool in the field of agricultural information analysis and dissemination, publicity, and brand communication in recent years [30,77].

4. Discussion

China and the EU are accelerating the development of the digital agricultural transformation [25]. The government-led, market-led, and socially engaged synergistic promotion mechanism for the construction of digital agriculture and rural areas has gradually come into play, and a co-construction pattern of active input from enterprises and extensive participation by farmers and new agricultural business entities is taking shape.

4.1. Government as Meta-Governor in Digitalized Agricultural Transformation

Big data in agriculture is an inevitable trend in agricultural modernization, the basis for the development of digital agriculture, and an important means of intelligent agriculture. For the government, it should integrate the information system, emphasize demand orientation, adapt to local conditions and continuously improve the service capacity for ordinary farmers. The government should focus on public production service organizations to play a leading role in providing agricultural production services that are highly professional and technical and closely related to product quality and safety, and they should continuously improve the supply body of digital technology promotion services, integrate existing data platforms, promote government-enterprise cooperation and regional cooperation, create an integrated digital agriculture platform, build an integrated system of production, marketing, and protection, and improve the efficiency of digital technology application. The government, as a "meta-governor," needs to be involved in identifying common social goals and intervening with criteria other than purchasing power, which is a challenge for the government.

China is in the early stages of a sustainable transformation of its agriculture. The government still has a strong leading role in the development of digital agriculture. Chinese government is enabling the rapid development of China's agricultural information infrastructure, but, on the other hand, the government-led top-down governance model has been less successful in transforming into the meta-governance model needed for digital agriculture development. Some scholars argue that the existing governance model of the Chinese government is a continuation of sectional governance and does not belong to meta-governance [41], while others argue that it is a manifestation of "primus inter pares" and that the government is a responsible body that governs by "indirect-soft" means rather than a power body whose main mode is "command-and-control". For a country such as China with a strong hierarchical governance style, when the government acts as a "meta-manager", it may be necessary to clarify the boundaries of the government's role,

focus on the needs of the real beneficiaries of digital agricultural technology services, and energize the market and grid governance styles [40]. The Chinese government conducts policy experiments under a hierarchical system, and farmers still behave passively in the flow of agricultural information, lacking the awareness and ability to collect, process, and apply information. However, due to the aforementioned weaknesses in China, the capacity building of farmers will be prioritized in future [66]. Sustainable transformation of agriculture cannot be realized without the changes of farmers [78].

The digital transformation of agriculture in the EU has gone through three phases of development and has already achieved some success. Nowadays, the role of government seems to be rather flexible and pragmatic and responsive to expectations associated with a certain governance style. One example is the Finnish forest data ecosystem. To build a data platform, the Finnish Forest center (FFC), a public body that operates under the steering of the ministry of agriculture and forestry, gathers data either by purchasing it from the private sector, from the general public, or from private-sector players via crowdsourcing solutions. Legitimacy of data-sharing activities was enforced. Furthermore, they provided a portal, which connects owners with relevant third parties, including providers of forestry services. The Finnish Forest policy program for integrated spatial planning argues explicitly in favor of more cooperation between government and citizens. Instruments to link different parts of government and stakeholders from different sectors rely on cooperation and trust, not on hierarchy [79]. Another example is from the Netherlands. As the second largest exporter of agricultural products worldwide, the 'National Proeftuin Precisielandbouw' (NPPL) (National Experimental Garden for Precision Farming) project has been launched in the Netherlands. In this project, experts from Wageningen University support farmers and gardeners in the application of various methods, such as location-dependent weed control and precision fertilization. The objectives are better harvests and a lower environmental impact from agriculture, and these strategies promote network governance under government guidance. In order to address the new challenges posed by climate change and the new pandemic for the development of European agriculture and to promote sustainable agricultural development, the EU has launched the "from Farm to Fork Strategy" and the "Biodiversity strategy for 2030" as the supplement of CAP, which enhance the competitiveness and resilience in response to the food crisis [34].

4.2. Engaging Non-Governmental Stakeholders Participation

Scientific research institutions need to promote the scientific research and innovation of digital technology in agriculture-related fields. Scientific research institutions should summarize and analyze the data and information generated in practice, build models, and construct risk prevention and control mechanisms in the agricultural sector. They should promote the application of big data in conjunction with relevant scientific research in the agricultural field and target and strengthen applied development research on the integrated application of data technology and technologies to assist decision-making, providing new methods and ideas for government decision-making and the development of agriculture-related enterprises.

Farmers are both the users and the makers of big data, and the impact of digital technology services on farmers' behavior is comprehensive and far-reaching. Not only does it provide a new data base in terms of farmer behavior and other aspects (leading to a more rational and optimal allocation of agricultural resources), a gradual reduction in environmental pollution, a better agricultural service system, and rapid development of the agricultural economy, but it can also change farmers' thinking and consciousness and establish the concept of sustainable agricultural development [25,80]. Meta-governance should promote information technology awareness and training to enhance information awareness, promote professionalism, and attract young farmers; different forms of self-organizations will also play an important role in engaging farmers.

For the market players, based on market demand, dig deeper into the value of demand and promote the effective docking of technology and agricultural production. Market

players need to dig deeper into the value base of investment in the agricultural industry, promote the informatization of agricultural social service organizations, identify solutions to improve the efficiency of agricultural production by integrating data from the agricultural production chain, and promote the effective interface between digital technology and agricultural production and operation with the help of statistics, model building, and visual intelligent analysis. Market players use the new generation of digital technology to carry out the whole process of agricultural production, operation, and marketing supervision services and obtain stable investment returns to achieve their own business sustainability and social responsibility [13]. Therefore, there is a need to create a friendlier ecology of agricultural data technology services by a clear return on investment, creating enough business opportunities for them to drive solutions to technical challenges in agricultural practices [81].

In China, other stakeholders cannot be directly involved in the sustainable transformation of agriculture. Although most Chinese research institutions have tried or are providing data consultation or corresponding technical services to farmers in the process of transforming their achievements, the results are not effective. The main reasons for this include the lack of a professional service intermediary team adapted to the market mechanism, insufficient reliance on and importance attached to agricultural science and technology achievements by the stakeholders analyzed in this paper, and the inadequate design of the policy and regulatory system [82]. The media, NGOs, and farmer organizations' lack mechanisms for cooperation between different actors to participate in the digital transformation of agriculture in a sustainable or effective way [35,77]. To summarize the above, the Chinese government, with a tradition of a hierarchical governance style, moving towards more network governance seems to encounter serious obstacles with authorities.

The EU has a longer top-level design and now has some practical experience. FaST, the Copernicus, and ISA^2 provide technical support, will help EU farmers, member state paying agencies, farm advisors, and developers of digital solutions improve their respective capabilities across a host of agricultural, environmental, and sustainability-focused activities [49]. For farmers, the FaST platform helps to improve cropping management models, simplify day-to-day management, and improve economic efficiency while achieving environmental protection, in addition to facilitating communication between farmers and between farmers and other institutions about their own cropping history and overall European cropping programs. For the relevant EU institutions, the FaST platform helps to enable environmental monitoring of agricultural land, to increase two-way communication with farmers, to computerize agriculture, to simplify workflows, to develop relevant standards, and to build economies of scale. For researchers and farmer organizations, the FaST platform enables the provision of basic data and direct communication with farmers to deliver services. For policy makers, the FaST platform enables rapid retrieval of agricultural data, which helps analyze the current state of agricultural development and thus informs policy formulation. For NGOs, the FaST platform can help NGOs to connect with farmers or government agencies to reach collaboration and improve environmental action. For commercial service providers, the open-source nature of the FaST platform accepts value-added services provided by commercial service providers to farmers and helps to open up the smallholder market segment. In addition, some EU countries are also working on similar technologies for their own national contexts. In the future, in order to further promote the role of digital technologies in sustainable agricultural development, the EU needs to further promote the coverage of hardware facilities and increase the accessibility of digital technologies [83].

5. Conclusions

Digitalization is a means, not a goal. With increasing institutionalization of sustainability in policy making on agricultural development, digitalization is also increasingly being re-orientated to serve sustainable agricultural and rural transitions in both China and the EU. The EU represents a pioneer in the field of digitalized agricultural transition, while

China takes the advantage of late comer and is making a frog leap. The "fourth agricultural revolution" is on the way [84].

Digitalized agricultural transition also represents a typical case for meta-governance. Multiple goals, diverse stakeholders, conflicts of interest, uncertainties, and risks all contribute to digital politics. Without an effective meta-governor, rules of the game would not be made and followed automatically. Although market players are often the most innovative in technological development and marketing, and farmers as important end users define the success, it is the responsibilities of the government to initiate and facilitate the policy making and provide important public services. Having said this, it must be stressed that the roles of other non-governmental actors need be differentiated at different stages of information flows. The analytical framework proposed in this study recognizes the meta-issue nature of digitalization and emphasizes the importance of meta-governor. Tested in the case of China and the EU, this framework is proven inclusive and flexible to capture a holistic view and to identify similarities and differences in different countries. Future research needs to go further to explore different types of mechanisms and leverages and the conditions for them being effective.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture12020297/s1, Table S1: Difference of governance style along information flow; Table S2: Digital agriculture policies of China and EU; Table S3: The role of stakeholders in promoting sustainable transformation in agriculture in China and the EU.

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

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