agriculture

Article

Digital Literacy and the Livelihood Resilience of Livestock Farmers: Empirical Evidence from the Old Revolutionary Base Areas in Northwest China

Xuefeng Ma [1], Liang Cheng [1], Yahui Li [1] and Minjuan Zhao [1,2,*]

[1] College of Economics and Management, Northwest A&F University, Xianyang 712100, China; xuefengma@nwafu.edu.cn (X.M.); 2022051428@nwafu.edu.cn (L.C.); 2023056512@nwafu.edu.cn (Y.L.)
[2] College of Economics and Management, Xi'an University of Finance and Economics, Xi'an 710100, China
* Correspondence: minjuan.zhao@nwsuaf.edu.cn

Abstract: Enhancing the livelihood resilience of livestock farmers in the old revolutionary base areas helps them to cope with the increasingly complex external risk shocks of recent years and promotes the sustainable development of regional agriculture. This study is based on survey data from 1047 livestock farmers in the Ningxia and Gansu provinces of the northwest old revolutionary base area. It incorporates the characteristics of livestock farmers and the elements of psychological capital into the sustainable livelihood analysis framework to construct a livelihood resilience index system. After measuring livelihood resilience, this paper uses a general linear regression model and a probit model to explore the impact and mechanism of digital literacy on the livelihood resilience of livestock farmers. The results show the following: (1) digital literacy has a significant positive effect on the livelihood resilience of livestock farmers, and the impact of different dimensions of digital literacy on different dimensions of livelihood resilience also varies. Additionally, this effect also shows the heterogeneity in different village clustering forms and different income groups. In areas inhabited by ethnic minorities and among moderate-income groups, the role of digital literacy on the livelihood resilience of livestock farmers is more significant. (2) The improvement of digital literacy has a significant positive impact on livelihood resilience through three different pathways: the "differential mode of association", learning channels, and types of income. (3) Digital literacy has led to the psychological aspects of rural hollowing-out problems among livestock farmers, which is particularly evident in families with only one type of caregiving burden (either only left-behind elderly people or only left-behind children). This problem is more evident. Therefore, this paper poses that the advancement of agricultural and rural economic development in China should not only focus on the cultivation of farmers' digital literacy but also accelerate the construction of digital infrastructure to ensure the long-term effective mechanism of improving digital literacy. At the same time, in the process of promoting digital rural areas, attention should be paid to the psychological isolation issues that the network era brings to farmers.

Keywords: digital literacy; livelihood resilience; livestock farmers; old revolutionary base area

Citation: Ma, X.; Cheng, L.; Li, Y.; Zhao, M. Digital Literacy and the Livelihood Resilience of Livestock Farmers: Empirical Evidence from the Old Revolutionary Base Areas in Northwest China. *Agriculture* **2024**, *14*, 1941. https://doi.org/10.3390/agriculture14111941

Academic Editor: Agata Malak-Rawlikowska

Received: 11 October 2024
Revised: 25 October 2024
Accepted: 28 October 2024
Published: 31 October 2024

1. Introduction

Livestock farming is a pillar industry of the agricultural economy and an important component of the national economy. Livestock products and services play a significant role for humanity [1]. Globally, the livestock sector occupies about 26% of ice-free land, with one-third of its arable land dedicated to the production of feed. Livestock production contributes nearly 40% to the global agricultural Gross Domestic Product (GDP), and this sector provides 33% of the world's protein and 17% of its caloric intake. The "14th Five-Year Plan for National Animal Husbandry and Veterinary Industry Development" released by the Ministry of Agriculture and Rural Affairs of China in 2021 pointed out that during the "13th Five-Year Plan" period, China's livestock industry made significant progress

in the supply capacity of livestock products, industry quality, product quality, and green development. It played a crucial role in the sustainable development of agriculture and rural areas, the construction of agricultural modernization, and the implementation of green and low-carbon development goals.

However, in recent years, the frequent occurrence of livestock epidemics such as swine fever, natural disasters like rainstorms and flooding, public health events like COVID-19, and policy changes in the utilization of manure resources have all brought significant external risks and shocks to animal husbandry. Data from the "National Compilation of Agricultural Cost and Benefit Data" (Compiled by the National Bureau of Statistics of China and the Compilation Committee of National Agricultural Cost and Benefit Data. These data mainly come from surveys and statistics from pricing authorities and agricultural departments at all levels, which typically use sampling methods to select representative farmers or agricultural production units as survey objects, and collect data on their production costs, output, sales prices, and other aspects) show that from 2020 to 2022, the net profit per kilogram of pigs, cattle, and sheep for livestock farmers decreased from CNY 11.05, CNY 8.31, and CNY 4.42 to CNY 1.00, CNY 8.18, and CNY 2.16, respectively, putting considerable pressure on livestock farmers. The negative impacts caused by multiple shocks, whether short-term or long-term, can change exponentially, being more than 50% more severe than the sum of a single external shock [2], making it difficult for breeder households to operate and relieve difficulties. This is especially true for areas in the northwest of China, such as the Shaanxi-Gansu-Ningxia revolutionary base, which, although having made significant contributions to the country's development due to their unique geographical features, are also subject to broader and deeper risk impacts due to poor geographical conditions, traditional production models, a lack of modern technology, and the weak livelihood capital of its villagers [3]. For livestock farmers who are recovering production, high restoration costs undermine their enthusiasm for production recovery and restocking [4], and some livestock farmers are unable to actively resume production and exit the breeding sequence [5,6]. This exposes the problem of low livelihood resilience among livestock farmers; that is, their ability to cope with short-term changes and adapt to long-term shocks is insufficient. Improving the livelihood resilience of livestock farmers in the northwest revolutionary base areas can not only prevent structural imbalances in the supply of animal husbandry but also ensure the effective implementation of policies such as the consolidation of poverty alleviation achievements and green agricultural development.

Existing research on livelihood resilience in the field of economics mainly revolves around three aspects. First, from a theoretical level, there is an expansion or reconstruction of the livelihood analysis framework, for example, combining the vulnerability framework with the resilience framework [7,8], and introducing adaptation and transformation as two major mechanisms into the livelihood system [9]. Second, on a quantitative level, livelihood resilience is quantified based on different measurement methods and frameworks, and the level of livelihood is calculated. This is a key research direction in the current field of livelihood resilience, which mainly includes two measurement methods: first, livelihood resilience is seen as a welfare characteristic or normative condition (such as various types of household income, total assets, consumption, etc.) [10,11]. When the welfare level indicators of farmers are above a certain threshold, it represents a higher level of livelihood resilience, and vice versa. Therefore, this method is more dependent on the setting of welfare characteristics or normative conditions and the selection of threshold values; second, based on Speranza's livelihood resilience analysis framework [12], a multi-dimensional livelihood resilience evaluation system is constructed to comprehensively calculate the level of livelihood resilience from the three dimensions of farmers' buffering capacity, self-organization ability, and learning ability. Therefore, this method is more dependent on the selection basis of different dimensions' indicators and theoretical combing. Third, in the research on the influencing factors and pathways of livelihood resilience, most scholars focus on exploring how to improve farmers' livelihood resilience through exogenous development, such as exploring the impact and pathways of transfer payments [13],

poverty alleviation relocation [14], precision poverty alleviation [15], land consolidation and rectification [16], etc., on livelihood resilience. However, exogenous development is too dependent on external forces and is prone to dilemmas, and the sustainability of this method is increasingly questioned [17]. Some scholars have begun to focus on how to stimulate farmers' endogenous motivation, such as endogenous development methods like insurance purchasing, participation in cooperatives, and participation in e-commerce. However, according to the new endogenous development theory, exploring a growth process centered on oneself is a long-term process that requires a combination of external factors and internal forces [18,19]. This article poses that, against the backdrop of agricultural modernization, intelligentization, and scientific and technological advancement, there is a lack of discussion on how new quality productive forces act as endogenous growth motivation in the process of improving the livelihood resilience of livestock farmers.

It is worth noting that the "52nd Statistical Report on Internet Development in China", released by the China Internet Network Information Center in 2023, indicates that the Internet penetration rate in China has reached 76.4%, with a rural Internet penetration rate of 60.5%, and the number of rural Internet users has reached 301 million [20]. With the integration of digital economy characteristics such as networking, informatization, and digitalization into rural areas, traditional agriculture has embraced the intelligent and precise integration of technologies like the Internet of Things (IoTs), artificial intelligence, big data analysis, and blockchains [21]. Digital factors are gradually becoming the core driving force of modern economic growth. Amidst the acceleration of smart rural construction and the elevation of the strategic status of digital villages, to stimulate the endogenous development momentum of farmers, it is necessary to fully develop rural digital resources and comprehensively enhance the digital literacy of farmers. The "Digital Rural Development Action Plan (2022–2025)" issued by ten departments in 2022 emphasizes "focusing on improving the digital literacy and skills of farmers. . . to provide strong support for promoting new progress in rural revitalization, new steps in the modernization of agriculture and rural areas, and new achievements in the construction of Digital China". Improving the digital literacy of farmers can optimize the allocation of human capital elements and is conducive to promoting the sustainable development of digital rural areas [22]. However, from the literature, there is little discussion on the relationship between digital literacy and livelihood resilience, and only a few documents have sorted out and interpreted the relationship between the two from a theoretical perspective. There is a lack of systematic, structured, and quantitative research on the possibility of digital literacy for livestock farmers as an endogenous engine to enhance their livelihood resilience.

The literature indicates that, on one hand, there is a lack of systematic research on the livelihood resilience of livestock farmers in specific regions; on the other hand, although some of the literature has begun to focus on how to stimulate farmers' endogenous motivation to enhance their livelihood resilience, the endogenous role of farmers' digital literacy in their livelihood resilience under the modern agricultural development goal that emphasizes new quality productive forces remains to be clarified. In summary, this paper takes livestock farmers in the northwest revolutionary base areas as an example to explore the impact of farmers' digital literacy on their livelihood resilience and further investigate the influencing mechanisms based on this. The marginal contributions of this paper are as follows: first, this paper aims to construct a sustainable livelihood analysis framework that is more characteristic of Chinese livestock farmers and integrates psychological capital into the framework to measure the level of livelihood resilience; second, based on the constructed indicators of livestock farmers' livelihood resilience, this paper discusses the role of digital literacy in promoting their livelihood resilience and considers the potential negative impacts of digital literacy in the rural development process; third, from the aspects of "differential mode of association", learning channels, and types of income, this paper explores the pathways and mechanisms of the role of digital literacy in livestock farmers' livelihood resilience, providing theoretical and policy references for the endogenous devel-

opment of livestock farmers' livelihood resilience in the context of modern agriculture in the new era.

2. Concept Definition and Theoretical Foundation

2.1. Concept Definition

The term "livelihood resilience" is a combination and evolution of the words "livelihood" and "resilience". The academic study of livelihoods originated from the conceptualization of the concept of livelihood, which is an ongoing process with varying interpretations and definitions by researchers at different times. A more systematic and comprehensive discussion of livelihoods stems from the 1980s research on poverty issues in developing countries, such as that from Chambers and others who proposed that livelihoods in rural sustainable development manifest as making a living that integrates capabilities, assets, and activities [23]; Elis further proposed that an important characteristic of this definition is the various actions taken by farmers to improve income levels to meet the basic needs for survival [24]. Subsequent discussions on livelihoods have revolved more around the specific meanings of capabilities, assets, and activities, and has gradually explored different analytical methods, that is, based on human natural and social attributes, to investigate what kind of livelihood indicator system other intangible or tangible assets besides money and food could generate. In the past 20 years, various institutions and international organizations in different countries have integrated discussions on livelihood analysis methods by pioneers such as Chambers and Conway, and have proposed a variety of livelihood analysis frameworks, among which the Sustainable Livelihoods Analysis Framework (SLA) formulated by the UK Department for International Development (DFID) has been widely recognized by the academic community [25].

The term "resilience" originally comes from the field of physics, where it refers to the ability of a material to recover and bounce back after being disturbed or impacted, undergoing plastic deformation or rupture. In 1973, Holling introduced the concept into the field of ecology to describe the ability of ecosystems to continue functioning in the face of change. Since then, the concept of resilience has been applied to numerous disciplines, including economics, engineering, disaster studies, and psychology. Although the etymology of resilience comes from the Latin word "resilire", and its meaning may vary slightly within the field, the core meaning of "the ability to recover from impact" has remained unchanged. In the field of economics, the concept of resilience has been studied along the lines of the aforementioned views. For example, Simmie defined resilience from a macro perspective as the adaptability of a regional economy under external shocks [26], while Barrett defined it from a micro-household perspective as the ability of a household to avoid falling into poverty for a period of time after being subjected to various external pressures and impacts [27]. Early studies only qualitatively regarded resilience as a post-event coping ability, but in recent years, more and more scholars tend to view resilience as a capability that runs through pre-event prevention, in-event response, and post-event recovery [10]. The evaluation and measurement of resilience have also shifted from a single dimension and single standard to a composite indicator system that considers various types of capital and multiple capabilities. On this basis, researchers have begun to incorporate multidimensional resilience analysis into the sustainable livelihoods analysis framework, using factor analysis and other clustering methods to examine the ability of households to maintain and recover their livelihoods based on a diversified combination of their own resources in response to pre-event risk exposure and impacts—that is, livelihood resilience [28].

In the current quantitative research on livelihood resilience, the analytical framework for livelihood resilience constructed by Speranza et al., which includes buffering capacity, self-organizing capacity, and learning capacity, has been widely recognized and applied. Among them, buffering capacity refers to the ability of farmers to cope with tolerable risk impacts and maintain their own livelihood functions and structural levels unchanged [29]; self-organizing capacity refers to the ability of farmers to obtain assistance through so-

cial structures and human behaviors before and after the occurrence of risk impacts [30]; learning capacity refers to the ability of farmers to create, acquire, disseminate, and store knowledge and skills, as well as the ability to transform knowledge into action [12]. Furthermore, existing studies have conducted a relatively comprehensive analysis of how household characteristics and individual traits affect livelihood resilience. For instance, factors such as family size and site conditions (SC) within household characteristics have a positive impact on livelihood resilience; individual traits like the decision-maker's gender and health status also positively influence livelihood resilience [31,32].

2.2. The Direct and Indirect Effects of Digital Literacy on the Livelihood Resilience of Farmers

Digital literacy is a collection of qualities and capabilities that citizens should possess in the increasingly prosperous environment of the digital age, including the ability to acquire, create, use, evaluate, interact with, share, and create digital information. The emergence of this concept has put forward new requirements for traditional livelihood resilience research in the context of rural digitalization, intelligence, and informatization. The underlying logic of the impact of digital literacy on the livelihood resilience of livestock farmers is that by understanding, mastering, and being proficient in modern digital information technology, livestock farmers can enrich their total amount of family resources, optimize the allocation of multiple elements, and thereby enhance their livelihood resilience [33]. Therefore, the impact of digital literacy on the livelihood resilience of livestock farmers is reflected in its direct effect on livelihood capital and elements and the indirect effect on the diversity of livelihood strategies.

On the one hand, the direct effect of digital literacy on livestock farmers' livelihood assets and elements is based on the ability of digital information technology to break through spatial and temporal limitations and information barriers:

First, transcending spatial and temporal boundaries: Rural development heavily relies on geographical location characteristics, but traditional rural areas in China face issues such as remote areas, complex terrain, unstable climate, inconvenient transportation, and lagging circulation facility construction, forming obvious spatial and temporal limitations. Especially for areas deeply affected by geographical, historical, and political factors, such as the old revolutionary base areas in the northwest, the situation is even more severe. The development of smart rural and digital villages has objectively provided soil for rural areas to blur the physical distance of space and time. On this soil, the most direct manifestation of livestock farmers' improvement in digital literacy is to narrow social distance and reduce communication costs [34]. Specifically, livestock farmers have not only shortened the distance for obtaining life and production resources, that is, optimizing transportation convenience, improving the efficiency of urban and rural travel, and reducing living costs; they have also strengthened and expanded their social networks, that is, increasing their contact with acquaintances, enriching their social circles, and enhancing their possibility and quantity of obtaining economic assistance from social groups; they have also improved social participation, that is, expanding the depth and breadth of participation in public affairs, enhancing attitudes towards social relations, and raising subjective social status;

Second, breaking information barriers [35,36]: Compared to urban areas, rural areas often have lower levels of infrastructure construction, constrained by objective conditions such as the total area of hardened road pavement, the number of signal towers, and the coverage rate of network communication projects, leading to problems in information asymmetry, information inequality, and excessive information search costs, forming information barriers. The continuous transformation from traditional paper media to electronic media to digital media has restructured the way information is transmitted in rural areas. The promotion of such digital technology is easier for livestock farmers with high levels of digital literacy to search for, receive, analyze, and process information permeating all aspects of life and production [37]. Specifically, livestock farmers have not only achieved an increase in agricultural profits, that is, reducing the purchase cost of production factors, expanding sales channels, and increasing agricultural sales income; they have also optimized

their quality of life, that is, ensuring good health, efficiently supplementing their family's required living materials, and enhancing their life satisfaction; they have also weakened the financial exclusion of the long-tail group [38], that is, promoting a variety of financial asset allocation and stimulating the willingness to purchase financial services [39]. Theoretical analysis shows that improving digital literacy among livestock farmers can transcend spatial and temporal boundaries and break information barriers, directly bringing changes to the overall level of family livelihood resilience from multiple aspects and perspectives. Based on this, this paper proposes the following research hypothesis:

H1. *The improvement of digital literacy has a positive effect on the livelihood resilience of livestock farmers.*

On the other hand, digital literacy indirectly affects the diversity of livestock farmers' livelihood strategies through three pathways: the "differential mode of association", learning channels, and types of income:

First, disrupting the "differential mode of association": Chinese rural society has characteristics of being closed and stable, forming a distinct "differential mode of association" in rural areas, where livestock farmers' decisions on life and production are often first considered in terms of social relationships constituted by blood and geographical relationships [40]. This leads to livestock farmers and their family members also being influenced by the "differential mode of association", where irrational "human sentiment" factors often make it difficult for livestock farmers to achieve the diverse and efficient allocation of family elements. The improvement of livestock farmers' digital literacy effectively helps them form new types of social connections, disrupting traditional living—"differential mode of associations"—and production—"differential mode of associations"—and promoting livestock farmers to achieve the optimal allocation and maximum benefit of family elements as assumed in the "rational economic person" hypothesis;

Second, expanding learning channels: Schultz's human capital theory points out that workers with more skills can achieve higher professional success and labor incomes, meaning that learning more knowledge has a positive impact on livestock farmers' livelihood resilience [41]. For a long time, the education level of rural indigenous people has been generally lower than that of urban residents, especially for livestock farmers in remote areas, who often can only obtain knowledge from the compulsory education stage. Indeed, this is related to the lack of sufficient funds for livestock farmers to support their family's educational expenses, but it is also closely related to the lack of channels for livestock farmers to learn outside of the compulsory education stage. By improving digital literacy, livestock farmers can expand learning channels on the Internet, obtain agricultural and non-agricultural knowledge through various learning platforms or technical training videos, and promote the improvement of personal technical levels, achieving the diversification of livelihood strategies;

Third, enriching types of income: In rural areas far from urban areas, even if there is a demand for "Type I pluralism" and "Type II pluralism", it is not enough to ensure that livestock farmers have job opportunities in various fields by simply improving their education level and vocational skills. The higher the level of digital literacy among livestock farmers, the more capable they are of using social media, such as WeChat and TikTok, to skillfully search for effective information on non-agricultural employment and entrepreneurship [42]. A variety of income types helps livestock farmers to diversify their sources of income (such as wage income, commercial and industrial income, and operational income), thereby increasing the total family income. In addition, this is also of great help in narrowing the income gap between livestock farmers of different income levels, alleviating income inequality among livestock farmers, and improving the income distribution pattern.

Based on this, this paper proposes the following research hypotheses:

H2. *The improvement of digital literacy is beneficial in disrupting the "differential mode of association" faced by livestock farmers, thereby enhancing the level of livelihood resilience;*

H3. *The improvement of digital literacy is beneficial in expanding the learning channels lacking for livestock farmers, thereby enhancing the level of livelihood resilience;*

H4. *The improvement of digital literacy is beneficial in enriching the types of income needed by livestock farmers, thereby enhancing the level of livelihood resilience.*

3. Data and Methodology

3.1. Data Source

The data come from field research conducted by the project team in Ningxia Province and Gansu Province from November 2023 to January 2024. Considering factors such as population size, breeding situation, and the county-wide promotion of livestock and poultry manure resource utilization, stratified random sampling and simple random sampling methods were adopted. In each province, 1 city was selected, 2–3 districts or counties were drawn from each city, 3–4 townships were drawn from each district or county, and 4 natural villages were drawn from each town. From each natural village, 13–15 farmer households were selected. These data cover aspects of livestock farmers' planting and breeding production, manure resource utilization, the organizational level of livestock farmers, the digital literacy of livestock farmers, and the basic situation of livestock farmers. A total of 1100 questionnaires were distributed, and after excluding samples with inconsistencies and missing important data, a total of 1047 valid questionnaires were obtained, with a questionnaire validity rate of 95.18%.

The characteristics of the individuals in this survey are as follows: the male to female ratio is 4:1, with an average age of 50 years, an average of 6 years of education, an average of 17 years of livestock farming experience, and an average of 29 years of crop cultivation experience. The characteristics of the sampled households are as follows: the average household population is 4 people, the average disposable income per household is CNY 83,700, the average per capita disposable income is CNY 16,800, the average number of cattle per household is 18, and the average scale of farmland operation per household is 31 mu. Overall, the characteristics of the sampled farmers reflect the current reality of older age, lower education levels, and combined cultivation and breeding operations in rural China. The economic data are consistent with local statistical yearbook information, indicating that the sample has a certain level of representativeness.

3.2. Variable Selection

3.2.1. The Dependent Variable: Livelihood Resilience

The core dependent variable of this paper is the livelihood resilience of livestock farmers. Considering that this variable cannot be directly obtained, this paper refers to the methods of measuring farmers' livelihood resilience by Speranza et al. and Quandt et al. [12,25], and combines the actual characteristics of livestock farmers in the research area to construct a livelihood resilience index system based on three dimensions: buffering capacity, self-organization capacity, and learning capacity. In addition, some scholars have pointed out that resilience research also concerns the perception at the individual psychological level [43]; that is, the introduction of psychological capital helps to more comprehensively portray the livelihood resilience of livestock farmers, so variables that can characterize psychological capital are introduced into the construction of the index system. When calculating a livelihood resilience score, ensuring the scientific nature of the weights of each indicator and each dimension is of the utmost importance. The existing methods of weighting at home and abroad include the entropy method, the equal weight method, the Principal Component Analysis method, etc.; each method has its own characteristics and advantages. To prevent the bias of subjective weighting and ensure the objectivity and reliability of the empirical results, this paper refers to the mainstream literature [44], uses the entropy method for weighting in the baseline regression, and further tests with the Principal Component Analysis method and the equal weight method in the robustness test. The selection of variables for each dimension, attributes, and weights are shown in Table 1.

Table 1. Evaluation Index System for livestock farmers' Livelihood Resilience.

Dimension Layer	Indicator Layer	Attribute	Weight
Buffering Capacity	The ease of seeking help during financial difficulties	+	0.0280
	Expenditures on gift money in social interactions	+	0.0301
	Friends and relatives living in the city	+	0.0500
	The number of friends and relatives who are civil servants or have public institution positions	+	0.0753
	Labor force participation rate	+	0.0082
	Per capita annual household income	+	0.0939
	Cultivated land area	+	0.0206
	Scale of breeding	+	0.0268
	Credit difficulty	−	0.0481
	Means of production value	+	0.0470
	Means of subsistence value	+	0.0240
	Per capita medical expenses	-	0.0003
	Life satisfaction	+	0.0050
Self-organizing Capacity	Whether it is a village for the resource utilization of manure pollution	+	0.0411
	Whether to participate in collective public affairs of the village	+	0.0055
	Transparency of collective public affairs in the village	+	0.0035
	The degree of contact among relatives and friends	+	0.0267
	Regular contacts	+	0.0510
	Distance to the county town	−	0.0034
	Transport accessibility	+	0.0019
	Whether to participate in social organizations or e-commerce	+	0.0942
	Subjective social status	+	0.0047
	Attitudes toward social relationships	+	0.0143
Learning Capacity	Head of household education level	+	0.0146
	Annual household education expenditure	+	0.0453
	Whether to participate in breeding training	+	0.0255
	Whether to have participated in the resource utilization of manure pollution	+	0.0893
	The environmental protection capability of manure pollution resource utilization	+	0.0051
	The income-generating capacity of manure pollution resource utilization	+	0.0069
	The number of information acquisition channels when encountering breeding difficulties	+	0.0363
	Income from working outside the home village	+	0.0646
	The ability to discern the impact of participating in the resource utilization of manure pollution on life	+	0.0087

3.2.2. The Explanatory Variable: Digital Literacy

The core explanatory variable in this article is the digital literacy of livestock farmers. The academic community generally believes that the development of digital literacy is for addressing the "digital divide" caused by the asynchronous application of digital technology and social change. Some studies divide the "digital divide" into "first-level digital divide" and "second-level digital divide" (some studies also add a "third-level digital divide"), while others categorize it into "access gap", "usage gap", and "creation gap". Since the quantification and concept of digital literacy have significant correspondence with the "digital divide", this article draws on the relevant literature of "digital divide" index construction and refers to the "Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Safety and Problem" indicators proposed by the European Union's "Digital Competence Framework for Citizens" and the "Equipment and Software Operation, Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Digital Security, Problem Solving, and Occupation-Related Literacy" indicators published by UNESCO's "Global Digital Literacy Framework". A total of 6 dimensions and 12 variables were selected to form an Evaluation Index System for livestock farmers' digital literacy, including "Equipment and Software operation Literacy", "Information and Data Literacy", "Communication and Collaboration Literacy", "Digital Content Creation Literacy", "Problem Solving Literacy", and "Occupation-Related Literacy". The score of digital literacy was also weighted and calculated using the entropy method, and the selection of variables for each dimension is shown in Table 2.

Table 2. Digital literacy Evaluation Index System.

Dimension Layer	Indicator Layer	Attribute	Weight
Equipment and Software Operation Literacy	Whether you and your family use smartphones	+	0.0022
	Whether the family has been connected to broadband, the Internet, or a wireless network	+	0.0660
Information and Data Literacy	Whether you have accessed agricultural information through the Internet	+	0.0150
	Whether you have purchased agricultural supplies through the Internet	+	0.1111
Communication and Collaboration Literacy	Whether you have joined social media groups for agricultural production communication	+	0.0523
	Whether you have joined a social media group for village affairs in your village	+	0.0097
Digital Content Creation Literacy	Whether you have sold agricultural products through the Internet	+	0.1810
	Whether you have engaged in digital credit through the Internet	+	0.1871
Problem Solving Literacy	Whether you search the Internet for information to solve problems when encountering difficulties	+	0.1122
Occupation-Related Literacy	Whether cost reduction and efficiency enhancement have been achieved through the use of agricultural ICT technology	+	0.0466
	Whether agricultural labor has been released through the use of agricultural ICT technology	+	0.0936
	Whether the ecological environment has been improved through the use of agricultural ICT technology	+	0.1231

3.2.3. Control Variables

To prevent interference from other potential confounding factors in the regression results, this article draws on mainstream research related to livelihood resilience [45], combined with the specific circumstances of the survey area, and uses family characteristics, individual characteristics, and regional dummy variables as control variables. Specifically, family characteristics include the "proportion of agricultural income", "family consumption", "actual family members", "land transfer", "whether it is a demonstration household for breeding", and "whether it is a family farm"; individual characteristics include the "gender of the decision-maker", the "age of the decision-maker", the "health status of the decision-maker", and "whether the decision-maker is an ethnic minority"; the addition of regional dummy variables is to control for characteristics that do not change over time and are unobservable. After preliminary research and consultation with experts and government workers, it was found that there are many unobservable differences at the county level in the survey area. Therefore, this article focuses on the regional fixed effects at the county level.

3.2.4. Mediating Variables

The theoretical analysis in the previous text involves three mechanism variables: the "differential mode of association", learning channels, and types of income. First, the variable of the "differential mode of association" is divided into the life "differential mode of association" (identified based on the questionnaire "Whether you mainly rely on the help of relatives in economic difficulties in life") and the production "differential mode of association" (identified based on the questionnaire "Whether you mainly rely on surrounding livestock farmers and merchants when purchasing feed in production"); secondly, the variable of learning channels is based on the questionnaire "How many channels you mainly use to obtain Internet information for learning" (including agricultural software, short video software, social software, shopping software, and search engine software), with the total number of types ranging from 1 to 5, and the larger the value, the more learning channels it represents; finally, the variable of income types is based on the types of income sources obtained by livestock farmers in the questionnaire (operational income, wage income, commercial and industrial income, property income, and transfer income), ranging from 1 to 5, and the larger the value, the more learning channels it represents.

Table 3 reports the definitions of the main variables and their descriptive statistical results.

Table 3. Variable definition and descriptive statistical results.

Variables	Definition	Mean	Std. Dev.
Digital literacy	Based on the livelihood resilience index system calculated from Table 1	0.162	0.069
Livelihood Resilience	Based on the digital literacy index system calculated from Table 2	0.175	0.129
Proportion of agricultural income	The percentage of the total agricultural output value to the total family income	0.581	0.336
Family consumption	The percentage of family consumption expenditure to the total family income	0.785	2.703
Actual family members	The number of members actually living in the household	4.284	1.678
Land transfer	Has the land been transferred?: 1 = Yes; 0 = No	0.523	0.500
Whether it is a demonstration household for breeding	1 = Yes; 0 = No	0.202	0.402
Whether it is a family farm	1 = Yes; 0 = No	0.109	0.312
Gender of the decision-maker	1 = Male; 0 = Female	0.802	0.398
Age of the decision-maker	Age	49.585	10.004
Health status of the decision-maker	1 = Healthy; 2 = Frail; 3 = Chronic illness; 4 = Serious illness; 5 = Disabled	1.305	0.737
Whether the decision-maker is an ethnic minority	1 = Yes; 0 = No	0.534	0.499
Living "differential mode of association"	Whether to mainly rely on relatives for help when encountering economic difficulties in life: 1 = Yes; 0 = No	0.770	0.421
Production "differential mode of association"	Whether the purchase of feed materials in production mainly depends on surrounding farmers and merchants: 1 = Yes; 0 = No	0.387	0.487
Learning Channels	1 = Agricultural software; 2 = Short video software; 3 = Social media software; 4 = Shopping software; 5 = Search engine software	1.615	1.215
Income Types	1 = Operating income; 2 = Wage income; 3 = Business and industrial income; 4 = Property income; 5 = Transfer income	3.105	0.933

3.3. Econometrics Model

The dependent variable in this article is the livelihood resilience of livestock farmers, which is a continuous variable. Therefore, a linear regression model was selected to explore the impact of digital literacy on the livelihood resilience of livestock farmers. The specific regression model is set up as follows:

$$res_i = \alpha_0 + \alpha_1 digital_i + \beta Control_i + \varepsilon_i \quad (1)$$

In this model, res_i represents the livelihood resilience level of the i-th farmer, $digital_i$ is the independent variable representing digital literacy, and $Control_i$ represents the control variables. α_0 is the constant term, α_1 is the regression coefficient for the core explanatory variable of digital literacy's impact on livelihood resilience, and β are the regression coefficients for the control variables.

In this paper, the endogeneity test section employed the Propensity Score Matching (PSM) method to address potential sample selection bias and model specification bias issues. Before proceeding with the PSM test, the digital literacy levels were categorized into a high-level group and low-level group based on whether they exceeded the average value, and dummy variables were created accordingly.

Firstly, this paper uses a Logit model to estimate the conditional probability fitting value; that is, the expression for the propensity score value is

$$PS_m = \Pr(R_m = 1|X_m) = E(R_m = 0|X_m) \quad (2)$$

In Equation (2), PS_m represents the propensity score, R_m = 1 indicates the high level of the digital literacy group; R_m = 0 indicates the low level of the digital literacy group; and X_m represents the observable household characteristics and individual characteristics.

Secondly, the treatment group was matched with the control group. To verify the robustness of the matching results, this paper selects K-nearest neighbor matching, radius matching, and kernel matching to perform the matching, respectively.

Finally, the difference in livelihood resilience between the treatment group and the control group of farmers was calculated, that is, the Average Treatment Effect on the Treated

(ATT), to obtain the impact of digital literacy on the livelihood resilience of farmers. The expression for ATT is as follows:

$$ATT = E(Y_{1m}|R_m = 1) - E(Y_{0m}|R_m = 1) = E(Y_{1m} - Y_{0m}|R_m = 1) \quad (3)$$

In Equation (3), Y_{1m} represents the livelihood resilience of farmers in the high level of the digital literacy group; Y_{0m} represents the livelihood resilience of farmers in the low level of the digital literacy group.

Drawing on the methods of intermediary mechanism testing from other scholars [46], this study solely explores the impact of digital literacy on mechanism variables, while the relationship between the mechanism variables and the explained variables was proven through existing literature. According to the different types of mechanism variables in this paper, probit and ordered probit (oprobit) models were used for analysis. The specific regression model settings were as follows:

$$m_i = \gamma_0 + \gamma_1 digital_i + \gamma_2 Control_i + \sigma_i \quad (4)$$

In this model, mi represents the mechanism variable (including "differential mode of association", learning channels, and types of income), γ_1 is the regression coefficient for the impact of digital literacy on the mechanism variable, and σ_i is the error term. Other variables are the same as in Equation (1).

4. Empirical Results

4.1. Benchmark Regression Results

Before conducting the regression, a test for multicollinearity was performed first. All the variables had Variance Inflation Factor (VIF) test values significantly below 5, and the results were consistent with expectations, indicating that there is no multicollinearity issue in the model.

Table 4 presents the baseline regression results of the impact of livestock farmers' digital literacy on livelihood resilience. Column (1) represents the direct impact of digital literacy on livelihood resilience, and column (2) represents the impact of the six different dimensions of digital literacy on livelihood resilience. It can be seen that digital literacy positively affects the livelihood resilience of livestock farmers at the 1% significance level. This result indicates that after livestock farmers bridge the "digital divide" commonly found in today's digital economy and enhance their digital literacy in specific dimensions, their level of livelihood resilience will also increase accordingly. The above results also validate theories suggesting that the Internet enhances temporal and spatial flexibility, thereby weakening constructs such as occupational and gender segregation [47], as well as urban–rural disparities [48]. Therefore, hypothesis H1 is validated.

Table 4. Regression results of the impact of digital literacy on the resilience of livestock farmers.

Variable	Livelihood Resilience	Livelihood Resilience
	(1)	(2)
Digital Literacy	0.145 ***	
	(0.016)	
Equipment and software operation literacy		0.122 **
		(0.060)
Information and data literacy		0.031
		(0.046)
Communication and collaboration literacy		0.595 ***
		(0.072)
Digital content creation literacy		0.249 ***
		(0.034)

Table 4. *Cont.*

Variable	Livelihood Resilience	Livelihood Resilience
	(1)	(2)
Problem solving literacy		0.229 ***
		(0.046)
Occupation-related literacy		−0.022
		(0.028)
Proportion of agricultural income	0.012 *	0.007 *
	(0.006)	(0.006)
Family consumption	−0.001 *	−0.001 *
	(0.001)	(0.001)
Actual family members	0.001	0.001
	(0.001)	(0.001)
Land transfer	0.001	0.000
	(0.004)	(0.004)
Whether it is a demonstration household for breeding	0.016 ***	0.015 ***
	(0.005)	(0.005)
Whether it is a family farm	0.046 ***	0.040 ***
	(0.007)	(0.007)
Gender of the decision-maker	0.015 ***	0.013 ***
	(0.005)	(0.005)
Age of the decision-maker	−0.000	0.000
	(0.000)	(0.000)
Health status of the decision-maker	0.006 **	0.005 *
	(0.003)	(0.003)
Whether the decision-maker is an ethnic minority	−0.016 **	−0.012 *
	(0.008)	(0.008)
Xigui County	−0.001	−0.014
	(0.009)	(0.009)
Jingyuan County	−0.001	−0.011
	(0.010)	(0.010)
Pengyang County	−0.023 **	−0.028 ***
	(0.009)	(0.009)
Ganzhou District	−0.011 **	−0.014 ***
	(0.006)	(0.006)
Constant term	0.137 ***	0.134 ***
	(0.015)	(0.015)
Amount of observed data	1047	1047
R-squared	0.219	0.288

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

"Equipment and Software Operation Literacy", "Communication and Collaboration Literacy", "Digital Content Creation Literacy", and "Problem Solving Literacy" all have significant positive impacts on livelihood resilience. The possible reasons are as follows:

"Equipment and Software Operation Literacy" represents the basic conditions of digital equipment that livestock farmers possess. Livestock farmers with better digital hardware conditions often have better standards of living and higher livelihood resilience;

"Communication and Collaboration Literacy" represents the quality of livestock farmers' transformation in communication methods and forms amidst digital and network development. The stronger the ability to use information exchange platforms such as WeChat for information dissemination, the better the expansion of human capital and social capital, thereby crossing the "second-level digital divide" to achieve endogenous development [49];

"Digital Content Creation Literacy" and "Problem Solving Literacy" represent the ability of livestock farmers to use digital devices to overcome practical problems, produce digital content, and transform individual endowments into tangible outputs such as materials and economy. Livestock farmers with the above two types of literacy are more likely

to efficiently apply digital elements, a new type of factor of production, to production and business activities, giving full play to their income-increasing effect, and obtaining higher livelihood resilience [42].

Additionally, "Information and Data Literacy" and "Occupation-Related Literacy" did not pass the test. This may be because the above two types of literacy test the livestock farmers' ability to identify, accept, and understand new information and new technologies. In reality, due to their own or their family's experience and cognitive characteristics, livestock farmers may sometimes accurately filter out accurate and effective information, make correct processing choices, and bring positive results, and sometimes do the opposite, bringing negative results. Both types of results often exist simultaneously, making the impact insignificant.

4.2. Endogeneity Tests

In consideration of the endogeneity issues that may arise from omitted variables and reverse causality, to ensure the reliability and credibility of the results, this paper employs the instrumental variable method for regression analysis. The instrumental variables are as follows: the topographical characteristics of the village and the average digital literacy of other the livestock farmers in the same village (The topographical characteristics of the village were derived from the questionnaire question "What are the topo-graphical characteristics of your village: 1 = plain; 2 = mountains; 3 = hills; 4 = plateau; 5 = basin"; the average digi-tal literacy of the other livestock farmers in the same village was calculated by taking the mean of the digital litera-cy of all the other livestock farmers residing in the same village as the surveyed subject). Specifically, the topographical characteristics of the village are geographically based instrumental variables. Drawing on relevant studies [50], the more rugged the geographical terrain, the greater the difficulty in building digital infrastructure, the lower the convenience for livestock farmers to access related technologies, and thus their digital literacy is affected, meeting the relevance requirement of the instrumental variable. Moreover, the topographical characteristics at the village level are naturally occurring geographical phenomena with clear exogeneity, and they do not directly affect the livelihood resilience of livestock farmers [51]. The other is a village-level instrumental variable—the average digital literacy of other livestock farmers in the same village. Drawing on research related to the digital economy [52], the average level of digital literacy of the other members in the village to some extent reflects the current state of the village's infrastructure, economic development, and social environment, and it influences an individual's digital literacy, meeting the relevance requirement of the instrumental variable. Furthermore, the average level of digital literacy in the village reflects the overall situation of the village, has clear exogeneity, and does not affect the livelihood resilience of a single farmer.

The Two-Stage Least Squares (2SLS) method was used for regression estimation, and the results are shown in Table 5. It can be observed that in column (1) of the first stage regression, the F-value is 21.39, which is greater than the critical value of 19.93 proposed by Stock and Yogo [53], thus rejecting the null hypothesis of weak instruments; the Sargan statistic is 2.2463 (p = 0.1339), and the Basmann statistic is 2.2146 (p = 0.1367), which means we cannot reject the null hypothesis of the exogeneity of the instruments. At the same time, the geographical terrain characteristics of the village and the average digital literacy of other livestock farmers in the same village both significantly affect digital literacy at the 5% and 1% levels, respectively. The regression coefficients are −0.014 and 0.573, respectively. The former represents that the more rugged the terrain of the village, the lower the individual digital literacy level of the livestock farmers; the latter represents that the higher the average digital literacy level of other livestock farmers in the same village, the higher the individual digital literacy level of the livestock farmers. The regression results are consistent with the theoretical analysis. In column (2) of the second stage regression, it can be seen that under the regression using the instrumental variable method, digital literacy still significantly

affects the livelihood resilience of livestock farmers at the 1% level, which is consistent with the baseline regression results.

Table 5. Regression results using instrumental variables method.

Variable	Digital Literacy	Livelihood Resilience	Digital Literacy	Livelihood Resilience
	(1)	(2)	(3)	(4)
Digital literacy		0.366 ***		0.672 ***
		(0.085)		(0.160)
Topographical characteristics of the village	−0.014 **		−0.019 ***	
	(0.006)		(0.006)	
The average digital literacy of the other farmers in the village	0.573 ***			
	(0.112)			
The collective financial income of the village where the farmer resides			0.004 **	
			(0.002)	
Control variables	Controlled	Controlled	Controlled	Controlled
County-level dummy variable	Controlled	Controlled	Controlled	Controlled
Constant term	0.144	0.086 ***	0.250 ***	0.015
	(0.038)	(0.025)	(0.031)	(0.043)
Amount of observed data	1047	1047	1047	1047
R-squared	0.137	0.067	0.105	0.023

Notes: *** $p < 0.01$, ** $p < 0.05$.

It is particularly worth mentioning that there may be doubts and difficulties in proving exclusivity when using "The average digital literacy of other farmers in the village" as an instrumental variable. Therefore, considering potential unobserved economic conditions and other factors, this paper replaces "The average digital literacy of other farmers in the village" with "The collective financial income of the village where the farmer resides". 2SLS regression is then conducted again to ensure the robustness of the instrumental variable method. The collective financial expenditure of the village represents the economic conditions of the entire village. The better the economic conditions of the village, the higher the level of development of digitalization and networking (such as fiber optic coverage, digital services), which will affect the digital literacy of individual farmers, meeting the relevance requirement. Moreover, the collective financial income of the village will not directly affect the livelihood resilience of a particular household, nor will it be directly affected by the digital literacy of a particular farmer, meeting the requirements of exclusivity and exogeneity. The specific regression results can be seen in columns (3) and (4) of Table 5. It can be observed that "The collective financial income of the village where the farmer resides" significantly and positively affects the digital literacy of the farmers, with a regression coefficient of 0.004. In subsequent tests, the F-statistic was 10.32, which is greater than 10, rejecting the null hypothesis of a weak instrumental variable; the Sargan statistic was 3.2841 ($p = 0.0700$), and the Basmann statistic was 3.2410 ($p = 0.0718$), which means we cannot reject the null hypothesis of the exogeneity of the instrumental variable.

Through the aforementioned analysis, we can find that regardless of which instrumental variable is used, it can pass the endogeneity test in the baseline regression, consistent with the results of the baseline regression.

To address potential endogeneity issues due to selection bias and model specification errors in the regression model, this paper further employs the Propensity Score Matching (PSM) method to test the results. Since digital literacy is not a dummy variable but a continuous variable, this paper follows mainstream research by treating digital literacy as a dummy variable and then uses the PSM method for regression [54]. The specific steps are as follows: first, digital literacy is divided into high-level group (assigned a value of 1) and low-level group (assigned a value of 0) based on the overall average value, setting up the experimental group and the control group; second, the propensity score of the sample is calculated using the control variables from the baseline regression, and the experimental group and control group samples are matched in four different ways to calculate the treatment effect, and the regression results are shown in Table 6. It can be seen that the results of the four matching methods all prove that the livelihood resilience

of the high-level group of digital literacy is higher than that of the low-level group, thus confirming the reliability of the baseline regression results.

Table 6. Regression results of Propensity Score Matching.

Matching Method	ATE	Standard Error	*t*-Test
Nearest neighbor matching (k = 1)	0.034	0.006	6.04 ***
Nearest neighbor matching (k = 4)	0.029	0.005	6.01 ***
Radius matching (radius = 0.01)	0.029	0.005	6.41 ***
Kernel matching	0.03	0.004	6.59 ***

Notes: *** $p < 0.01$.

4.3. Robustness Tests

1. Replace the calculation method of the dependent variable. Considering the different calculation logic and weights of different calculation methods, this paper uses Principal Component Analysis (PCA) (The results of Cronbach's Alpha reliability test for the dimensions of livelihood resilience in this paper are 0.7094, which is greater than 0.7, indicating good reliability; the KMO and Bartlett's test results are 0.715, which is also greater than 0.7, indicating good validity) and equal weighting methods to recalculate the livelihood resilience level of livestock farmers and perform regression. The results are shown in columns (1) and (2) of Table 7. It can be seen that digital literacy positively affects the livelihood resilience of livestock farmers at the 1% significance level;

Table 7. Regression results of robustness test.

Variable	Livelihood Resilience	Livelihood Resilience	Livelihood Resilience (Incorporating Vulnerability)	Livelihood Resilience (1% Winsorized)	Livelihood Resilience (5% Winsorized)
	(1)	(2)	(3)	(4)	(5)
Digital Literacy (Principal Component Analysis Method)	0.028 *** (0.004)				
Digital Literacy (Equal Weighting Method)		0.145 *** (0.015)			
Digital Literacy (Entropy Method)			0.140 *** (0.016)	0.139 *** (0.015)	0.125 *** (0.014)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled
County-Level Dummy Variable	Controlled	Controlled	Controlled	Controlled	Controlled
Constant Term	0.100 *** (0.019)	0.097 *** (0.017)	0.140 *** (0.015)	0.140 *** (0.015)	0.142 *** (0.014)
Amount of Observed Data	1047	1047	1047	1047	1047
R-Squared	0.186	0.227	0.217	0.218	0.205

Notes: *** $p < 0.01$.

2. Replace the dependent variable. The existing sustainable livelihood framework finds it difficult to comprehensively grasp the full picture of livelihood resilience. This paper draws on the theory of livelihood resilience's counterpart–vulnerability research to include the vulnerability variables of farmers into the livelihood resilience index system (The resilience of farmers is closely related to vulnerability. In this section, the vulnerability variables are the degree of the farmers' production reduction due to natural disasters and the degree of land fragmentation. The former is obtained through the question "What is the proportion of your production reduction due to natural disasters in the previous year?", and the latter is calculated by dividing the total cultivated land area by the total number of cultivated land plots. These are included in the evaluation value system of livelihood resilience, and the final level of livelihood resilience is calculated using the entropy method), re-measure the level of livelihood resilience [55], and conduct regression analysis. The results can be seen in

column (3) of Table 7. It can be observed that digital literacy still positively affects the livelihood resilience of farmers at the 1% level of significance;

3. Winsorizing treatment: Considering the potential outliers of the dependent variable and their adverse effects on regression, this paper performs 1% and 5% winsorizing treatment on the dependent variable and performs regression. The results are shown in columns (4) and (5) of Table 7. It can be seen that digital literacy positively affects the livelihood resilience of livestock farmers at the 1% significance level.

From the above robustness test results, it is known that digital literacy has a significant positive impact on the livelihood resilience of livestock farmers; that is, the baseline regression is obviously robust.

4.4. Heterogeneity Tests

From the analysis above, it is evident that digital literacy indeed has a positive impact on the livelihood resilience of livestock farmers. It is noteworthy that some scholars have pointed out that the enhancement of livestock farmers' livelihood resilience exhibits heterogeneity in terms of groups and structures. Therefore, does the impact of digital literacy on livestock farmers' livelihood resilience show group and structural differences? This paper conducts grouped regression analyses for livestock farmers with different village aggregation forms and income groups, attempting to explore the potential heterogeneity issues that may exist.

Heterogeneity forms in village aggregation. As a multi-ethnic country, China often sees distinct beliefs, cultures, and social characteristics emerging in areas populated by ethnic minorities, which differ significantly from those in non-ethnic minority areas. Compared to the central and eastern regions, the western region is more prominently influenced by historical legacies and modernization development, making ethnic issues more pronounced. For livestock farmers living in ethnic minority villages and non-ethnic minority villages in the old revolutionary base areas of the northwest, there is bound to be a difference in digital literacy to some extent, and the degree of its impact on livelihood resilience varies. In this section, based on the list of ethnic minority villages provided by local governments during field research, the data are divided into ethnic minority villages and non-ethnic minority villages, and the regression results are shown in columns (1) and (2) of Table 8. These results show that digital literacy has a positive impact on the livelihood resilience of livestock farmers in both groups at the 1% significance level, and it has a greater impact on the livelihood resilience of livestock farmers living in ethnic minority villages. This may be because livestock farmers in ethnic minority villages, due to their unique views on clans and culture, have a stronger dependence on social networks, and digital literacy is more conducive to helping livestock farmers in these areas maintain and expand their social capital, thereby enhancing livelihood resilience.

Table 8. Regression results of village agglomeration patterns and ethnic heterogeneity of family decision-makers.

Variable	Non-Ethnic Minority Dominated Village	Ethnic Minority Concentrated Village	Decision-Maker Is Not the Hui Ethnicity	Decision-Maker Is the Hui Ethnicity
	(1)	(2)	(3)	(4)
Digital literacy	0.136 ***	0.182 ***	0.113 ***	0.164 ***
	(0.017)	(0.037)	(0.024)	(0.020)
Control variables	Controlled	Controlled	Controlled	Controlled
County-level dummy variable	Controlled	Controlled	Controlled	Controlled
Amount of observed data	917	130	759	288
R-squared	0.214	0.424	0.186	0.233

Notes: *** $p < 0.01$.

Additionally, there are more ethnic minority family decision-makers from the Hui ethnicity in this study area, and significant differences exist between the Hui ethnicity and other ethnicities (especially the Han ethnicity) in aspects such as diet (Hui people

follow Muslim dietary laws), attire, and beliefs [56]. The aforementioned issues may lead to different cultural influences permeating every aspect of family farming, ultimately resulting in significant differences in the role of digital literacy on livelihood resilience. This paper discusses the heterogeneity of baseline regression based on whether the family decision-maker is of the Hui ethnicity, with the results shown in columns (3) and (4) of Table 8. The results indicate that digital literacy has a positive impact on the livelihood resilience of both groups of farmers at the 1% significance level, and the impact on the livelihood resilience of families with Hui decision-makers is greater. This may be because the Islamic community possesses strong cultural resilience, and the decision-maker's intervention in their family is entirely contingent upon strong cultural attributes, such as the so-called "Arranged cohabitation" phenomenon [57]. Therefore, digital literacy can significantly break down these cultural barriers in such families, with a positive effect on livelihood resilience that is markedly higher than in non-Hui families.

In regard to income group heterogeneity, a large number of studies have pointed out that income differences can lead to digital inequality [58], which in turn causes the impact of digital literacy on various types of household capital to vary among livestock farmers of different income groups. However, most studies only divide the income group into low-income and high-income groups, ignoring the largest existing middle-income group from a definitional perspective. In this part, we followed the research on income levels and divided the low- [59], middle-, and high-income groups based on the total family income at the 33rd, 66th, and 99th percentiles, respectively, and performed a regression analysis. The results are shown in columns (1), (2), and (3) of Table 9. The results show that digital literacy has a positive impact on the livelihood resilience of livestock farmers in all three groups at a significance level of 1%, with the greatest impact on the middle-income group and a similar impact on the low-income and high-income groups. This may be because of the following reasons: ① for the low-income group, although there is significant room for improvement in livelihood resilience and digital literacy can significantly enhance it, the lack of innate resource endowment makes it difficult to fully convert digital literacy into actual improvement in livelihood resilience; ② for the high-income group, although there is sufficient support for improving digital literacy, the room for improvement in livelihood resilience is smaller compared to other income groups; ③ for the middle-income group, this group has both sufficient room for improvement in livelihood resilience and certain resource endowments as a support, hence the effect of digital literacy on livestock farmers' livelihood resilience is the highest.

Table 9. Regression results of income groups and gender heterogeneity of family decision-makers.

Variable	Total Family Income			Decision-Maker Is Male	Decision-Maker Is Female
	(1) 0~33%	(2) 33~66%	(3) 66~99%	(4)	(5)
Digital literacy	0.117 ***	0.187 ***	0.107 ***	0.162 ***	0.069 **
	(0.027)	(0.027)	(0.027)	(0.017)	(0.038)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled
County-level dummy variable	Controlled	Controlled	Controlled	Controlled	Controlled
Amount of observed data	345	345	345	840	207
R-squared	0.157	0.276	0.209	0.225	0.071

Notes: *** $p < 0.01$, ** $p < 0.05$.

In relation to gender heterogeneity, some studies have indicated that there is a significant gap in digital literacy between different gender groups [47]. This paper divides the baseline regression into two groups based on the gender of the decision-maker and conducts a heterogeneity test. The results are shown in columns (4) and (5) of Table 9. The results show that when the decision-maker is male, digital literacy significantly and positively affects livelihood resilience at the 1% significance level, with a regression coefficient of 0.162; when the decision-maker is female, digital literacy significantly and positively

affects livelihood resilience at the 5% significance level, with a regression coefficient of 0.069. This may be because, under the current social environment, men have a higher utilization rate of digital technology compared to women, such as in job searching and interpersonal interactions. Especially for decision-makers within the family, this advantage is amplified, leading to the greater impact of digital literacy on livelihood resilience in the male group.

Resilience in livelihoods is characterized by three dimensions: buffering capacity, self-organizing capacity, and learning capacity. This paper examines whether there is heterogeneity in the impact of digital literacy and its various dimensions on these three dimensions of livestock farmers' livelihood resilience. The results of the regression analysis, as shown in Table 10, indicate that digital literacy significantly and positively affects all three dimensions of livelihood resilience. Specifically, ① the "equipment and software operation literacy" and "digital content creation literacy" dimensions of digital literacy significantly and positively influence buffering capacity. This suggests that livestock farmers with better basic digital conditions and those who can transform more outputs through digital means are more likely to have a positive impact on the comprehensive level of human and physical capital. ② The "equipment and software operation literacy", "communication and collaboration literacy", and "digital content creation literacy" dimensions of digital literacy significantly and positively influence self-organizing capacity. This implies that livestock farmers with better basic digital conditions, stronger abilities to disseminate information through digital networks, and those who can transform more outputs through digital means are more likely to use social networks to enhance their self-recovery capabilities. ③ The "information and data literacy", "communication and collaboration literacy", and "problem-solving literacy" dimensions of digital literacy significantly and positively influence learning capacity. This indicates that livestock farmers who are more capable of processing information when collecting, identifying, and transmitting it, and those with higher levels of digital problem-solving skills, are more likely to acquire and transform knowledge to improve their self-learning abilities. It can be observed that the self-organizing and learning capacities within livestock farmers' livelihood resilience are more significantly affected by digital literacy, with higher demands for the use and creation of digital literacy.

Table 10. Heterogeneous impact of digital literacy on different dimensions of livelihood resilience.

Variable	Buffering Capacity	Buffering Capacity	Self-Organizing Capacity	Self-Organizing Capacity	Learning Capacity	Learning Capacity
	(1)	(2)	(3)	(4)	(5)	(6)
Digital Literacy	0.009 ** (0.004)		0.069 *** (0.010)		0.067 *** (0.010)	
Equipment and Software Operation Literacy		0.028 * (0.017)		0.070 * (0.038)		0.024 (0.040)
Information and Data Literacy		0.006 (0.013)		−0.037 (0.029)		0.061 * (0.031)
Communication and Collaboration Literacy		−0.006 (0.020)		0.328 *** (0.046)		0.274 *** (0.048)
Digital Content Creation Literacy		0.016 * (0.010)		0.223 *** (0.022)		0.010 (0.023)
Problem Solving Literacy		0.015 (0.013)		−0.006 (0.029)		0.220 *** (0.031)
Occupation-Related Literacy		0.001 (0.008)		−0.021 (0.018)		−0.002 (0.019)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
County-Level Dummy Variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant Term	0.038 *** (0.004)	0.039 *** (0.004)	0.037 *** (0.010)	0.037 *** (0.009)	0.063 *** (0.010)	0.059 *** (0.010)
Amount of Observed Data	1047	1047	1047	1047	1047	1047
R-Squared	0.150	0.153	0.132	0.232	0.131	0.179

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.5. Mechanisms Analysis

In the previous analysis, it was found that digital literacy has different impacts on the various dimensions of livestock farmers' livelihood resilience. The discussion in the theoretical analysis section suggests that this is obviously due to the different pathways of the mechanisms at play. In light of this, this paper further uses an econometric model to confirm whether the mechanisms proposed in the theoretical section exist. The regression results are shown in Table 11.

Table 11. The impact mechanism of digital literacy on the livelihood resilience of livestock farmers.

Variable	Living "Differential Mode of Association"	Production "Differential Mode of Association"	Learning Channels	Income Types
	(1)	(2)	(3)	(4)
Digital Literacy	−1.206 ***	−0.819 **	3.101 ***	1.718 ***
	(0.341)	(0.330)	(0.276)	(0.276))
Control Variables	Controlled	Controlled	Controlled	Controlled
County-Level Dummy Variable	Controlled	Controlled	Controlled	Controlled
Amount of Observed Data	1047	1047	1047	1047
R-Squared	0.040	0.025	0.211	0.115

Notes: *** $p < 0.01$, ** $p < 0.05$.

1. The disruption of the "differential mode of association": Columns (1) and (2) of Table 11, respectively, present the regression results of digital literacy on daily life and agricultural production "differential mode of associations", showing that digital literacy significantly negatively affects both types of "differential mode of associations". On one hand, livestock farmers can use digital communication software to break through spatial and temporal limitations, expanding their social circles beyond blood relations, thereby disrupting the "differential mode of association" at the level of daily life. On the other hand, livestock farmers rely on cloud platforms to build online agricultural product sales markets and broaden the channels for purchasing agricultural raw materials, thus disrupting the "differential mode of association" at the level of production. Further, existing studies have proven that disrupting the "differential mode of association" can significantly enhance livestock farmers' life happiness [60], expand social networks, and improve land use efficiency, effectively strengthening the buffering capacity and self-organizing capacity within livestock farmers' livelihood resilience. Therefore, the mechanism of action is confirmed to exist;
2. Expansion of learning channels: Column (3) of Table 11 presents the regression results of digital literacy on learning channels, showing that digital literacy significantly positively affects information channels. This means that livestock farmers, relying on the rapid development of various application softwares such as social media, news apps, and short video platforms, can obtain knowledge from a wide range of information sources that is several times greater than that from traditional media. This, in turn, broadens their self-learning channels and enhances the efficiency of education. The benefits to livestock farmers from the aforementioned results include reduced educational expenses and increased cultural levels, which significantly improve the learning capacity within livestock farmers' livelihood resilience. Therefore, the mechanism of action is confirmed to exist;
3. Enrichment of income types: Column (4) of Table 11 displays the regression results of digital literacy on income types, indicating that digital literacy significantly positively impacts income types. This means that livestock farmers, by leveraging various online information channels to obtain employment information or expand their professional skills, can enrich their income types and increase their sources of income. For example, some livestock farmers can use short video software to learn about industries such as food delivery, sales, and education; they can also access job information online, which in the past could only be obtained by entering the city or relying on traditional

media; some livestock farmers have even started their own businesses through digital means. Scholars both domestically and internationally have pointed out that an increase in income types and sources can significantly increase the various types of household income and total income, which in turn strengthens the buffering capacity and learning capacity of livelihood resilience [61]. Therefore, the mechanism of action is confirmed to exist.

4.6. Further Discussion

The previous analysis examined the positive impact of digital literacy on the livelihood resilience of livestock farmers from the perspectives of group, spatial, and dimensional heterogeneity, as well as the mechanisms of action. However, some of the literature has pointed out the "double-edged sword" effect of digital technology in the process of farmers improving their digital literacy and bridging the "digital divide". That is, farmers may experience "digital poverty" due to a lack of feasible capabilities as they integrate into the development of digital villages. This "digital poverty", rooted in the "digital divide", forms a unique superimposed state in the digital age—digital inequality—and gives rise to farmers' feelings of alienation and cognitive anxiety [62]. Therefore, against the backdrop of severe rural population loss and prominent hollowing-out issues worldwide, does this negative effect have a significant impact on the evolution of rural social forms? Based on Fei Xiaotong's definition of traditional rural forms and related quantitative research [40], this paper measures rural hollowing-out as the dependent variable and divides it into objective and subjective hollowing-out indicators (The objective hollowing-out indicator is calculated by the number of family members who have been out all year round/household registered population × 100%; the subjective hollowing-out indicator is obtained from the question "Is there a village regulation and agreement in this village?" in the questionnaire). A regression model was constructed to analyze the impact of digital literacy on rural hollowing-out, and the results can be seen in Table 12.

Table 12. The impact of digital literacy on rural hollowing-out.

Variable	Objective Hollowing-Out	Subjective of Rural Hollowing-Out	Subjective Indicators of Rural Hollowing-Out			
			No Caregiving Burden	Only the Elderly Care Burden	Only the Child-Rearing Burden	Dual Caregiving Burden
	(1)	(2)	(3)	(4)	(5)	(6)
Digital literacy	0.027 (0.031)	0.987 ** (0.402)	1.039 (0.852)	1.760 * (1.016)	1.172 * (0.672)	0.090 (0.981)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
County-level dummy variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant term	0.588 *** (0.031)	0.645 * (0.374)	−0.436 (1.087)	1.115 (0.936)	0.339 (0.660)	0.920 (1.038)
Amount of observed data	1047	1047	278	238	345	186
R-squared	0.144	0.239	0.083	0.102	0.052	0.249

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

It can be observed that in column (1), digital literacy does not have a significant impact on the objective hollowing-out indicator, meaning that digital literacy is not a factor leading to the objective transformation of rural areas from the traditional "acquaintance society" to a hollowed-out form. In column (2), digital literacy positively affects the subjective hollowing-out indicator at the 5% significance level; that is, digital literacy has led to farmers feeling the disintegration of the traditional "acquaintance society" structure from a subjective psychological perspective. Considering the impact of urban–rural dual development on the changes in rural forms in recent years, and the frequent occurrence of the caregiving burden in farmer households, this paper further divides livestock farmers into four groups based on family structure: no caregiving burden, only elderly care burden, only child-rearing burden, and dual caregiving burden (The elderly care burden variable was calculated as the population of people aged 60 and above divided by the number of family labor force members × 100%, and then treated as a dummy variable based on whether it was greater than zero; the child-rearing burden variable was calculated as the sum of the school-age

population and pre-school children population divided by the number of family labor force members × 100%, and then treated as a dummy variable based on whether it was greater than zero). Analyzing the heterogeneity of family structure leading to subjective hollowing-out caused by digital literacy, columns (4) and (5) of Table 12 show that in families with only elderly care burdens and those with only child-rearing burdens, digital literacy significantly impacts the subjective hollowing-out indicator. A possible reason is that these two types of families will separately present the issues of empty-nest elderly or left-behind children in rural areas. Farmers in such families often lack sensitivity to digital literacy but are highly dependent on the Internet, gradually leading to a subjective feeling of abandonment and the belief that there is a hollowing-out phenomenon in rural areas.

In summary, while previous criticisms of digital village construction may lack macro and objective rational evidence, it is still essential not to overlook the emotional changes that farmers experience in the current digital age. Special attention should be paid to the issues of elderly care and child-rearing in rural areas.

5. Conclusions

This paper utilizes field research from the Northwest Revolutionary Old District in 2023, based on the sustainable livelihood analysis framework, to construct an index system for livelihood resilience that incorporates psychological capital and is characteristic of Chinese livestock farmers. By measuring the level of livelihood resilience, this paper analyzes the impact of digital literacy on livestock farmers' livelihood resilience and explores the mechanisms by which digital literacy affects livelihood resilience through three different pathways: "differential mode of association", learning channels, and types of income. In subsequent discussions, this paper integrates theoretical analyses from previous studies that suggest the potential negative impacts of digital literacy and empirically test the actual effects of digital literacy on subjective and objective rural hollowing-out. It further analyzes differentiated results in situations where there are elderly care and child-rearing needs. While discussing how livestock farmers can improve their livelihood resilience by enhancing their digital literacy, this paper firmly avoids the consequences of exacerbating rural hollowing-out, which is beneficial for better achieving the goals of agricultural modernization.

This paper reaches the following conclusions: first, digital literacy significantly positively affects the livelihood resilience of livestock farmers. Specifically, the impact of different dimensions of digital literacy on different dimensions of livelihood resilience also varies. The promoting effect on learning ability is mainly reflected in the aspects of information processing and creation, while the promoting effects on buffering capacity and self-organization ability are mainly reflected in the aspects of information acquisition and processing. Additionally, this effect also shows heterogeneity in different village aggregation forms and different income groups. That is, in areas where ethnic minorities are concentrated, the role of digital literacy in livestock farmers' livelihood resilience is more significant; among medium-income groups, the role of digital literacy in livestock farmers' livelihood resilience is more significant. Second, the improvement of digital literacy can both take the path of tearing the traditional "differential mode of association" (reflected in both production and living "differential mode of association") to reduce the costs of production and living, and improve buffering capacity and self-organization ability, and can also take the path of expanding learning channels to improve knowledge reserves and education levels, thereby enhancing learning ability. It can also take the path of enriching income types (including operational income, wage income, transfer income, and property income, etc.) to increase the total family income, thereby improving buffering capacity and learning ability. Third, digital literacy will not cause objective rural hollowing-out phenomena, but it can lead to the hollowing-out problem at the psychological level of livestock farmers. After considering the current reality of the increasing pressure of elderly care and child-rearing in rural areas, it was found that in families with different types of caregiving burdens, the role of digital literacy in the subjective rural hollowing-out

index of livestock farmers shows heterogeneity; that is, when there is only one type of caregiving pressure in the family, this impact is more significant. The above conclusions have confirmed the discussion in Section 1 of this paper regarding the enrichment and expansion of the theoretical aspects related to digital literacy and livelihood resilience; that is, they have expanded the sustainable livelihood framework and improved the study of factors affecting livelihood resilience and their mechanisms of action.

Based on the above research conclusions, in order to better utilize digital literacy to promote the construction of agricultural modernization, this paper puts forward the following policy recommendations:

First, form a long-term mechanism that promotes the improvement of farmers' livelihood resilience with digital literacy as an endogenous development driving force. China's digital villages and smart rural construction have effectively narrowed the gap in information acquisition between urban and rural areas, especially for remote areas such as the old revolutionary base areas, which have significantly improved the economic level of local farmers and narrowed the income gap, injecting new production factors into the sustainable development of agriculture. Therefore, the construction of digital infrastructure in rural areas should be accelerated, and the transformation and empowerment of new quality productive forces in the animal husbandry industry in the region should be promoted. Ensure the coordinated layout of digital strategies and digital facilities, so that digital projects such as "East Data West Computing" can be smoothly implemented, and ensure that remote areas can also receive high-quality digital and intelligent services. Drive the improvement of individual farmers' digital literacy with innovative digital technologies and solid digital infrastructure, and enjoy the information dividends of the new era together, expanding the effect of digital literacy in promoting the improvement of livelihood resilience;

Second, give full play to the indirect driving effect of digital literacy on livelihood resilience through tearing "differential mode of association", enriching learning channels, and broadening income types. On the one hand, the deep-rooted "differential mode of association" in Chinese rural areas makes the consideration of personal relationships full of production and life, forming an inertial thinking of "economic irrationality". Therefore, efforts should be made to build digital information platforms to promote the flow and transparency of information in various factor markets and product markets in production and life. The government should coordinate various economic entities, and use digital technologies such as the Internet of Things, artificial intelligence, and big data to form a multi-entity collaborative market information sharing platform, thereby helping farmers break through the traditional network of personal relationships, and achieve the goal of reducing production and living costs and improving breeding efficiency. On the other hand, farmers in rural areas (especially in remote mountainous areas and marginal pastoral areas represented by the northwest revolutionary base areas) are limited by regional basic resources, industrial structure, and geographical location in terms of education level and sources of income, and it is difficult to obtain new knowledge and non-agricultural income. Therefore, a cultivation system for farmers' digital literacy should be established, and various digital technology promotion entities are suggested or urged to provide relevant training, guidance, and services to farmers through various means. Pay more attention to the cultivation and education of rural digital talents, encourage agricultural enterprises, institutions, and social service organizations to share digital resources and information, help farmers in the middle and low-income strata to improve the frequency and effectiveness of using digital technologies, and ensure that all groups can truly enjoy the dividends of digitalization, forming a virtuous development path of widespread improvement in education level and significant increase in sources of income;

Third, while playing the positive role of digital literacy, pay attention to its impact on the problem of rural hollowing-out. While rural areas enjoy the digital dividend brought by digitalization, such as the high-speed transmission of information and expansion of social networks, it inevitably leads to the problem of hollowing-out at the psychological level. Therefore, the government should pay full attention to the phenomenon of emotional

isolation and psychological estrangement that may emerge among farmers in the trend of the digital age. Encourage governments at all levels to organize various offline cultural and entertainment activities to create a warm and harmonious village collective atmosphere, especially for families where only the elderly or school-age children live alone, to provide a good community environment with "special case special treatment" and "special person special treatment". At the same time, guide "intergenerational feedback" from the family level to bridge the digital divide between the elderly or school-age children, optimize the digital participation space of the two groups, prevent the occurrence of digital marginalization, and enhance the sense of gain, satisfaction, and happiness.

This study has at least two limitations. On the one hand, due to the limitations of the survey data, although the analysis of heterogeneity mentioned that culture might have different impacts on the relationship between digital literacy and livelihood resilience in different ethnic groups, it did not deeply explore other potential aspects of cultural customs in this context; on the other hand, the construction of the digital literacy framework reflects the characteristics of livestock farmers, which may lack universality for a broader group of farmers.

Author Contributions: Conceptualization, X.M. and L.C.; methodology, X.M. and L.C.; software, X.M.; validation, X.M.; formal analysis, X.M.; investigation, X.M.; resources, X.M.; data curation, X.M.; writing—original draft preparation, X.M. and Y.L.; writing—review and editing, X.M. and Y.L.; supervision, M.Z.; project administration, M.Z.; funding acquisition, M.Z. 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 Project "Evaluation and Improvement of the Farmland Resource Protection Policy System in the Northwest Region: Multi-objective Coordination and Public Support" (72173097); and by the "National Modern Agricultural Industry Technology System (Oat and Buckwheat)" Project supported by the Ministry of Agriculture and Rural Affairs and the Ministry of Finance (CARS-07-F-1).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are available in this article.

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

References

1. Herrero, M.; Grace, D.; Njuki, J.; Johnson, N.; Enahoro, D.; Silvestri, S.; Rufino, M.C. The roles of livestock in developing countries. *Animal* **2013**, *7*, 3–18. [CrossRef] [PubMed]
2. Phillips, C.A.; Caldas, A.; Cleetus, R.; Dahl, K.A.; Declet-Barreto, J.; Licker, R.; Merner, L.D.; Ortiz-Partida, J.P.; Phelan, A.L.; Spanger-Siegfried, E.; et al. Compound climate risks in the COVID-19 pandemic. *Nat. Clim. Chang.* **2020**, *10*, 586–588. [CrossRef]
3. Wen, H.; Jiang, L. Promoting sustainable development in less developed regions: An empirical study of old revolutionary base areas in China. *Environ. Dev. Sustain.* **2024**, *26*, 12283–12308. [CrossRef]
4. Piao, S.; Jin, X.; Hu, S.; Lee, J.-Y. The Impact of African Swine Fever on the Efficiency of China's Pig Farming Industry. *Sustainability* **2024**, *16*, 7819. [CrossRef]
5. Li, J.; Li, Q.; Liu, L. Carbon emissions from smallholder pig production in China: A precise account based on farmers' survey. *Environ. Sci. Pollut. Res.* **2022**, *29*, 25651–25664. [CrossRef] [PubMed]
6. Nzeyimana, J.B.; Butore, J.; Ndayishimiye, L.; Butoyi, M. Impact of COVID-19 on livestock production chain and its consequences on food security: A review. *Agric. Sci. Dig.-A Res. J.* **2022**, *42*, 196–202. [CrossRef]
7. Lecina-Diaz, J.; Martínez-Vilalta, J.; Lloret, F.; Seidl, R. Resilience and vulnerability: Distinct concepts to address global change in forest. *Trends Ecol. Evol.* **2024**, *39*, 706–715. [CrossRef]
8. Urruty, N.; Tailliez-Lefebvre, D.; Huyghe, C. Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agron. Sustain. Dev.* **2016**, *36*, 15. [CrossRef]
9. Ackerl, T.; Weldemariam, L.F.; Nyasimi, M.; Ayanlade, A. Climate change risk, resilience, and adaptation among rural farmers in East Africa: A literature review. *Reg. Sustain.* **2023**, *4*, 185–193. [CrossRef]
10. Cissé, J.D.; Barrett, C.B. Estimating development resilience: A conditional moments-based approach. *J. Dev. Econ.* **2018**, *135*, 272–284. [CrossRef]
11. Barrett, C.B.; Ghezzi-Kopel, K.; Hoddinott, J.; Homami, N.; Tennant, E.; Upton, J.; Wu, T. A Scoping review of the development resilience literature: Theory, methods and evidence. *World Dev.* **2021**, *146*, 105612. [CrossRef]

12. Speranza, C.I.; Wiesmann, U.; Rist, S. An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. *Glob. Environ. Chang.* **2014**, *28*, 109–119. [CrossRef]
13. Miao, Y.; Li, Z. The poverty alleviation effect of transfer payments: Evidence from China. *Humanit. Soc. Sci. Commun.* **2023**, *10*, 910. [CrossRef]
14. Ma, L.; Zhang, Y.; Li, T.; Zhao, S.; Yi, J. Livelihood capitals and livelihood resilience: Understanding the linkages in China's government-led poverty alleviation resettlement. *Habitat Int.* **2024**, *147*, 103057. [CrossRef]
15. Cheng, X.; Yu, Z.; Gao, J.; Liu, Y.; Dai, Y.; Chen, J.; Liu, G.; Xie, Z. How to restore the livelihood resilience of the rural vulnerable? Evidence from 1, 356 households in rural China. *Environ. Dev. Sustain.* **2024**, 1–28. [CrossRef]
16. Bao, H.X.H.; Jiang, Y.; Wang, Z.; Feng, L. Social capital and the effectiveness of land use policies: Evidence from rural China. *Land Use Policy* **2024**, *139*, 107069. [CrossRef]
17. Chirwa, T.G.; Odhiambo, N.M. Exogenous and endogenous growth models: A critical review. *Comp. Econ. Res. Cent. East. Eur.* **2018**, *21*, 63–84. [CrossRef]
18. Bosworth, G.; Annibal, I.; Carroll, T.; Price, L.; Sellick, J.; Shepherd, J. Empowering Local Action through Neo-Endogenous Development; The Case of LEADER in England. *Sociol. Rural.* **2016**, *56*, 427–449. [CrossRef]
19. Ward, N. Rural development and the economies of rural areas. In *A New Rural Agenda*; Institute for Public Policy Research: Newcastle upon Tyne, UK, 2006; pp. 46–67.
20. Yang, N.; Wang, Y.; Jin, H.; Qi, Q.; Yang, Y. Impacts of Internet Information Literacy on Farmers' Relative Poverty Vulnerability: Evidence from CGSS Survey Data in China. *Soc. Indic. Res.* **2024**, 1–32. [CrossRef]
21. Nugroho, A.D. Comparing the effects of information globalization on agricultural producer prices in developing and developed countries. *Agris-Line Pap. Econ. Dev. Ctries.* **2024**, *16*, 93–107. [CrossRef]
22. Malik, P.K.; Singh, R.; Gehlot, A.; Akram, S.V.; Das, P.K. Village 4.0: Digitalization of village with smart internet of things technologies. *Comput. Ind. Eng.* **2022**, *165*, 107938. [CrossRef]
23. Chambers, R.; Conway, G. *Sustainable Rural Livelihoods: Practical Concepts for the 21st Century*; Institute of Development Studies: Brighton, UK, 1992.
24. Ellis, F. *Rural Livelihoods and Diversity in Developing Countries*; Oxford University Press: Oxford, UK, 2000.
25. Obrist, B.; Pfeiffer, C.; Henley, R. Multi-layered social resilience: A new approach in mitigation research. *Prog. Dev. Stud.* **2010**, *10*, 283–293. [CrossRef]
26. Simmie, J.; Martin, R. The economic resilience of regions: Towards an evolutionary approach. *Camb. J. Reg. Econ. Soc.* **2010**, *3*, 27–43. [CrossRef]
27. Barrett, C.B.; Constas, M.A. Toward a theory of resilience for international development applications. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 14625–14630. [CrossRef]
28. Quand, A.; Neufeldt, H.; McCabe, J.T. Building livelihood resilience: What role does agroforestry play? *Clim. Dev.* **2019**, *11*, 485–500. [CrossRef]
29. Sina, D.; Chang-Richards, A.Y.; Wilkinson, S.; Potangaroa, R. A conceptual framework for measuring livelihood resilience: Relocation experience from Aceh, Indonesia. *World Dev.* **2019**, *117*, 253–265. [CrossRef]
30. Liu, W.; Li, J.; Ren, L.; Xu, J.; Li, C.; Li, S. Exploring livelihood resilience and its impact on livelihood strategy in rural China. *Soc. Indic. Res.* **2020**, *150*, 977–998. [CrossRef]
31. Tang, L.; Xu, Y.; Wang, W.; Wang, Y. Impact of livelihood capital and rural site conditions on livelihood resilience of farm households: Evidence from contiguous poverty–stricken areas in China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 123808–123826. [CrossRef]
32. Zhao, X.; Chen, H.; Zhao, H.; Xue, B. Farmer households' livelihood resilience in ecological-function areas: Case of the Yellow River water source area of China. *Environ. Dev. Sustain.* **2022**, *24*, 9665–9686. [CrossRef]
33. Marschke, M.J.; Berkes, F. Exploring Strategies that Build Livelihood Resilience: A Case from Cambodia. *Ecol. Soc.* **2006**, *11*, 709–723. [CrossRef]
34. He, K.; Li, F.L.; Wang, H.; Ming, R.Y.; Zhang, J.B. A Low-carbon Future for China's Tech Industry. *Science* **2022**, *377*, 1498–1499. [CrossRef] [PubMed]
35. Goldfarb, A.; Tucker, C. Digital Economics. *J. Econ. Lit.* **2019**, *57*, 3–43. [CrossRef]
36. Hjort, J.; Poulsen, J. The Arrival of Fast Internet and Employment in Africa. *Am. Econ. Rev.* **2019**, *109*, 1032–1079. [CrossRef]
37. Anadozie, C.; Fonkam, M.; Cleron, J.P.; Kah, M.M. The impact of mobile phone use on farmers' livelihoods in post—Insurgency Northeast Nigeria. *Inf. Dev.* **2021**, *37*, 6–20. [CrossRef]
38. Fang, D.; Zhang, X. The protective effect of digital financial inclusion on agricultural supply Chain during the COVID-19 pandemic: Evidence from China. *J. Theor. Appl. Electron. Commer. Res.* **2021**, *16*, 3202–3217. [CrossRef]
39. Fedorova, E.A.; Nekhaenko, V.V.; Dovzhenko, S.E. Impact of Financial Literacy of the Population of the Russian Federation on Behavior on Financial Market: Empirical Evaluation. *Stud. Russ. Econ. Dev.* **2015**, *26*, 394–402. [CrossRef]
40. Barbalet, J. The analysis of Chinese rural society: Fei Xiaotong revisited. *Mod. China* **2021**, *47*, 355–382. [CrossRef]
41. Schultz, T.W. Investment in Human Capital. *Am. Econ. Rev.* **1961**, *51*, 1–17.
42. Liu, B.; Zhou, J. Digital literacy, farmers' income increase and rural Internal income gap. *Sustainability* **2023**, *15*, 11422. [CrossRef]
43. Tugade, M.M.; Fredrickson, B.L. Resilient individuals use positive emotions to bounce back from negative emotional experiences. *J. Personal. Soc. Psychol.* **2004**, *86*, 320–333. [CrossRef]

44. Lazarus, R.S. From psychological stress to the emotions: A history of changing outlooks. *Annu. Rev. Psychol.* **1993**, *44*, 1–22. [CrossRef] [PubMed]
45. Sun, Y.; Wang, Y.; Huang, C.; Tan, R.; Cai, J. Measuring farmers' sustainable livelihood resilience in the context of poverty alleviation: A case study from Fugong County, China. *Humanit. Soc. Sci. Commun.* **2023**, *10*, 75. [CrossRef] [PubMed]
46. Chen, Y.; Fan, Z.; Gu, X.; Zhou, L.-A. Arrival of young talent: The send-down movement and rural education in China. *Am. Econ. Rev.* **2020**, *110*, 3393–3430. [CrossRef]
47. Chen, Z.; Cui, R.; Tang, C.; Wang, Z. Can digital literacy improve individuals' incomes and narrow the income gap? *Technol. Forecast. Soc. Chang.* **2024**, *203*, 123332. [CrossRef]
48. Chen, H.; Chen, C.-P.; Li, Y.; Qin, L.; Qin, M. How internet usage contributes to livelihood resilience of migrant peasant workers? Evidence from China. *J. Rural Stud.* **2022**, *96*, 112–120. [CrossRef]
49. Lu, S.; Sun, Z.; Huang, M. The impact of digital literacy on farmers' pro-environmental behavior: An analysis with the Theory of Planned Behavior. *Front. Sustain. Food Syst.* **2024**, *8*, 1432184. [CrossRef]
50. Nunn, N.; Qian, N. US food aid and civil conflict. *Am. Econ. Rev.* **2014**, *104*, 1630–1666. [CrossRef]
51. Zhou, D.; Zha, F.; Qiu, W.; Zhang, X. Does digital literacy reduce the risk of returning to poverty? Evidence from China. *Telecommun. Policy* **2024**, *48*, 102768. [CrossRef]
52. Yang, C.; Ji, X.; Cheng, C.; Liao, S.; Obuobi, B.; Zhang, Y. Digital economy empowers sustainable agriculture: Implications for farmers' adoption of ecological agricultural technologies. *Ecol. Indic.* **2024**, *159*, 111723. [CrossRef]
53. Stock, J.H.; Yogo, M. *Testing for Weak Instruments in Linear IV Regression*; NBER Working Paper; National Bureau of Economic Research: Cambridge, MA, USA, 2005.
54. Agresti, A. *Categorical Data Analysis*; John Wiley & Sons: Hoboken, NJ, USA, 2012.
55. Moser, C.O. The asset vulnerability framework: Reassessing urban poverty reduction strategies. *World Dev.* **1998**, *26*, 1–19. [CrossRef]
56. Gustafsson, B.; Ding, S. Maping and understanding ethnic disparities in length of schooling: The case of the Hui minority and the Han majority in Ningxia autonomous region, China. *Soc. Indic. Res.* **2015**, *124*, 517–535. [CrossRef]
57. Mu, Z.; Qing, L.; Yu, X. Arranged cohabitation among Chinese Muslims. *Proc. Natl. Acad. Sci. USA* **2024**, *121*, e2317704121. [CrossRef] [PubMed]
58. Wei, K.K.; Teo, H.H.; Chan, H.C.; Tan, B.C. Conceptualizing and testing a social cognitive model of the digital divide. *Inf. Syst. Res.* **2011**, *22*, 170–187. [CrossRef]
59. Lei, L.I.; Zhai, S.X.; Bai, J.F. The dynamic impact of income and income distribution on food consumption among adults in rural China. *J. Integr. Agric.* **2021**, *20*, 330–342. [CrossRef]
60. Tang, Y.; Li, Q.; Wu, Y. The impact of the digital divide on rural older People's mental quality of life: A conditional process analysis. *Heliyon* **2024**, *10*, e37109. [CrossRef]
61. Dettling, L.J. Broadband in the Labor Market: The Impact of Residential High-Speed Internet on Married Women's Labor Force Participation. *ILR Rev.* **2017**, *70*, 451–482. [CrossRef]
62. Vandeursen, A.; Helsper, E.J. The third-level digital divide: Who benefits most from being online? *Stud. Media Commun.* **2015**, *10*, 29–52.