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The Impact of Digital Inclusive Finance on the Sustainable Growth of Income of Herdsmen in China's Pastoral Areas

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Abstract: The sustainable growth of income for farming households in pastoral areas represents a crucial challenge not only for China but also for other developing nations in the process of transition to ecologically friendly models. The scarcity of assets available for collateral, along with vulnerable production conditions and developmental shortcomings, pose significant barriers to the consistent expansion of herdsmen's income. This paper analyzes the impact of digital financial inclusion on the income of herdsmen in ethnic minority regions using panel data models from nine major pastoral provinces in China from 2011 to 2022. Through a fixed-effects model approach, the analysis delves into the influence of digital financial inclusion and subjects it to multi-dimensional and robustness tests to ensure the reliability of the findings. Furthermore, the research explores the underlying mechanisms through which digital financial inclusion contributes to income enhancement for herdsmen in these areas, employing mediation effect techniques to provide deeper insights into the relationship between digital financial services and economic upliftment in remote ethnic communities. The research findings indicate that digital financial inclusion has a positive impact on the income of herdsmen in ethnic minority regions. The breadth of coverage, depth of usage, and level of digitalization of digital financial inclusion all play a significant role in enhancing the income levels of herdsmen. In terms of the degree of influence, the impact of digital finance on the income of ethnic minorities follows this order: depth of usage > degree of digitalization > breadth of coverage. Notably, through financial backing that catalyzes a shift in herdsmen's production methodologies and propels industrial upgrading, there is a profound potential to increase herdsmen's output efficiency. This, in turn, alleviates the ecological strain on China's environmentally delicate zones. Moreover, financial backing can condense the breeding periods for herdsmen, thereby ameliorating the ecological degradation associated with excessive grazing in pastoral regions. A mediating-effect analysis reveals that digital financial inclusion can boost economic development in ethnic minority regions by increasing wage income, raising per capita GDP levels, and promoting industrial structure upgrading. This, in turn, leads to an improvement in the income of herdsmen in these regions. This is particularly pertinent in China, where the eco-fragility of pastoral regions coincides with the modest income of herdsmen, underscoring the critical importance of herdsmen's finance. To foster sustainable progress in these regions, financial backing is imperative to elevate herdsmen's income and to induce a transformative shift in production approaches and industrial layout, paving the way for the sustainable development of these pastoral regions.

Keywords: digital financial inclusion; ethnic minority regions; China's pastoral ecological areas; sustainable growth of income; fixed-effects model

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1. Introduction

The sustainable growth of income for farming households in pastoral areas represents a crucial challenge not only for China but also for other developing nations in the process of transition to ecologically friendly models. The scarcity of assets available for

collateral, along with vulnerable production conditions and developmental shortcomings, pose significant barriers to the consistent expansion of herdsmen's income. Digital financial inclusion, as a novel model of financial service with universal outreach, can effectively alleviate the financial exclusion faced by vulnerable groups. It provides convenient and equitable financial services to low-income populations and remote pastoral communities, reducing the transaction costs of financial services and enhancing the income levels of herdsmen in distant ethnic minority regions. Currently, the profound development of digital information technology in the financial sector continuously propels the integration and coordinated advancement of technological and financial innovation. This synergy has given rise to new types of digital financial services, exemplified by digital inclusive finance, which are gradually permeating all aspects of residents' lives [1,2]. Capital naturally gravitates towards wealth rather than poverty, resulting in financial services that display a marked bias. This bias leads to a disproportionate concentration of premium financial resources in urban centers and among affluent demographics, conversely sidelining rural communities and those living in poverty [3–5]. Leveraging its attributes of being low-cost, having extensive reach, and a user-friendly interface, digital inclusive finance substantially mitigates financing constraints arising from information asymmetry in financial markets. It forms a complementary relationship with traditional financial services, addressing their limitations, and effectively boosts the inclusivity of financial services. This enhancement ensures that financial services become more equitable, stable, efficient, and accessible to a broader population [2]. Digital finance, serving as a bridge between modern technology and economic development, is gradually becoming an important driver for the income growth of farmers in ethnic minority regions. The application of digital inclusive finance can break the shackles of geographical location and plays a positive role in overcoming the financial exclusion phenomenon commonly found in traditional financial markets [6]. The proliferation of digital inclusive finance creates new development opportunities for farmers in ethnic minority regions, serving as an important tool to narrow the urban–rural income gap and enhance the income of ethnic minority farmers [3,7]. With the advancement of digital technology, the promising vision of boosting the income growth of farmers in pastoral and ethnic minority regions through digital inclusive finance is gradually being realized [8,9]. Many scholars recognize the inclusivity of digital inclusive finance as a crucial characteristic, arguing that its three dimensions—breadth of coverage, depth of usage, and degree of digitalization—have a direct impact on promoting the growth of agricultural income levels [10]. Firstly, in terms of breadth of coverage, digital inclusive finance can reduce the cost of rural financial services, expand the scope of financial activities, and enhance the flexibility of financial services [11]. Secondly, regarding depth of usage, digital inclusive finance effectively reduces information asymmetry in financial services, improving the accessibility of financial services for low-income rural groups [12]. Lastly, from the perspective of digitalization, digital inclusive finance strengthens the economic resilience of rural financial services and increases the convenience of financial services through digital technologies such as digital payments and internet banking [13]. Digital inclusive finance comprehensively bolsters the income expansion of farmers in pastoral regions in three dimensions, thereby mitigating the issue of relative poverty in these areas. Additionally, digital inclusive finance notably enhances the family income of farmers by offering inclusive lending funds, which have a more significant impact on improving the income of rural vulnerable groups [14].

Currently, a multitude of scholars, both domestic and international, have confirmed that the application of digital inclusive finance notably propels the growth of farmers' economic income [15,16]. By expediting the free circulation and logical distribution of capital, information, and digital resources, digital inclusive finance offers accessible and equitable financial services to low-income and remote pastoral populations, playing a pivotal role in fostering rural economic development within ethnic minority regions. The mechanism through which digital inclusive finance boosts farmers' income primarily functions by diminishing production and operational expenses, fostering efficient connections

between farmers and markets, and amplifying financial backing. These elements have a direct bearing on the income of farmers in ethnic minority regions [5,17,18]. Simultaneously, by spurring economic expansion in ethnic minority regions, driving the industrial advancement of pastoral areas, and augmenting non-agricultural employment prospects for rural farmers, thereby escalating their wage-based income, it indirectly furthers the income growth of farmers [19]. Digital inclusive finance is instrumental in advancing the level of regional economic progress, which consequently elevates the economic income tier of farmers in ethnic minority locales [20,21]. Heterogeneous analysis has uncovered that digital inclusive finance exerts a significant influence on stimulating economic growth in the central and western regions of China, exhibiting a relatively milder impact on the eastern areas. Furthermore, its growth effects are more evident in regions with a lower urbanization rate when contrasted with those characterized by a higher urbanization rate [22]. In the context of digital inclusive finance aiding in increasing farmers' income, augmenting farmers' wage-based income is notably a crucial mediating factor. The use of digital inclusive finance opens doors for rural inhabitants to a broader spectrum of non-agricultural job opportunities, resulting in a rise in the non-agricultural income of farming communities and elevating the wage income for those who venture into non-agricultural employment [23–25]. Digital inclusive finance catalyzes an increase in farmers' income through the mechanism of industrial upgrading [4,26]. The elevation of regional industrial structures acts as a partial mediator in the correlation between digital inclusive finance and the growth of farmers' income, suggesting that digital inclusive finance indirectly spurs the rise in farmers' income via regional industrial advancement, with this facilitation being more pronounced in non-impoverished counties than in impoverished ones [27]. The influence of digital inclusive finance on industrial upgrading is characterized by regional heterogeneity, with the most significant impact seen in western ethnic minority territories, followed by central and eastern regions [28]. In consideration of the analyses presented, this paper utilizes the "Digital Inclusive Finance Index" released by the Institute of Digital Finance, Peking University, to empirically assess the impact of digital inclusive finance on the income of farmers in ethnic minority regions. Furthermore, it delves into the relationship between digital inclusive finance and the income levels of farmers in these regions.

This study innovatively designs an analytical framework to examine the impact of digital inclusive finance on the income levels of herdsmen, with the main objective of revealing how digital inclusive finance affects their income. The second part of this paper is the theoretical analysis and research hypotheses, the third part covers research methods and data sources, the fourth part presents empirical results analysis and mediating effect tests, and the final section consists of conclusions and discussions. Through rigorous analysis, this study finds that digital inclusive finance can improve the income levels of farmers, and has a more significant income-increasing effect on low-income farmers in distant ethnic minority regions. The three sub-dimensions of digital inclusive finance have a positive effect on the income level of farmers. The level of regional economic development, farmers' entrepreneurial and employment behavior, and promoting industrial structure upgrading are positively moderating.

2. Theoretical Mechanism and Research Hypotheses

Farmers in ethnic minority regions, representing vulnerable populations, often face challenges in accessing traditional financial products and services due to their limited financial means and insufficient payment capabilities, resulting in a "threshold effect". Moreover, these individuals frequently encounter credit discrimination and financial exclusion based on their inherent characteristics [29]. Digital inclusive finance, which amalgamates traditional finance with contemporary information technology, introduces digital technologies and other financial technologies into the arena of inclusive finance. This integration is typified by attributes such as sharing, convenience, cost efficiency, and accessibility, effectively mitigating financing obstacles and accelerated financing for disadvantaged groups including destitute farmers and small to micro-sized enterprises. It also ameliorates the adverse realities of information asymmetry and uneconomical scaling in ethnic minority regions

that hinder financial progression. At present, buoyed by policy support and advancements in digital infrastructure, the influence of digital inclusive finance on the income of farmers is on the rise, primarily functioning through direct and indirect mechanisms of impact.

2.1. The Direct Influence of Digital Inclusive Finance on Farmers' Income

Digital inclusive finance can directly increase farmers' income in three aspects. Firstly, it enhances the breadth of coverage. Digital inclusive finance empowers the financial sector through digital technology, addressing the issue of traditional financial services being concentrated in economically developed areas. It expands the reach of financial services, ensuring that they extensively cover minority regions where herders reside, thereby improving the accessibility of financial services. This overcomes the economic and geographical barriers of traditional financial outlets, increases the coverage rate of financial institutions, and enhances the convenience for herders to access digital inclusive financial services [30]. Secondly, it enhances the depth of usage. Digital inclusive finance can provide farmers with an array of financial services such as agricultural insurance, credit operations, and investment management, broadly fulfilling the diverse financial service needs of herders. This significantly mitigates the issue of financial exclusion in ethnic minority regions, amplifies the depth of usage of digital inclusive finance, and grants more herders the opportunity to access financial services [31]. Thirdly, it deepens the degree of digitalization. Through digital means, digital inclusive finance enables vulnerable groups like herders, who have long been excluded from financial services, to enjoy formal financial services in a cost-effective and sustainable manner. This lowers the barriers and capital costs of financial services and enhances the ability of herders in ethnic minority regions to participate in financial activities [32]. Based on this, the following research hypothesis is proposed:

Hypothesis 1 (H1). *Digital inclusive finance positively impacts the income level of farmers.*

2.2. The Indirect Influence of Digital Inclusive Finance on Farmers' Income

The indirect impact of digital inclusive finance on the income of farmers encompasses three primary dimensions: Firstly, it fosters the advancement of the per capita economic development level. Digital inclusive finance effectively mitigates the issue of financial exclusion confronting farmers in ethnic minority regions, diminishes barriers and reduces the costs associated with financial services, enhances the accessibility of these services, and stimulates an increase in farmers' income. Secondly, there is a rise in wage-based income. Digital inclusive finance alleviates financing constraints for small and micro-enterprises within ethnic minority regions, thereby augmenting the employment rate and stability of farmers' labor force; concurrently, it catalyzes the emergence of novel industries such as rural e-commerce, offering occupational opportunities in ethnic minority areas for e-commerce practitioners, logistics transporters, among others. These two facets can bolster farmers' wage-based income through a trickle-down effect [33–36]. Thirdly, it facilitates the upgrading of agricultural industrial structure. Digital inclusive finance can offer financial support to vulnerable groups such as farmers in ethnic minority regions, refine resource allocation [37,38], enhance production efficiency, and attain a rationalized and advanced industrial structure. This promotes an increase in farmers' income through economies of scale and improvements in breeding facilities [34–40]. Based on the aforementioned indirect effects, the following hypotheses are put forward:

Hypothesis 2 (H2). *Digital inclusive finance enhances farmers' income by elevating the regional per capita economic development level.*

Hypothesis 3 (H3). *Digital inclusive finance boosts farmers' income by farmers' entrepreneurial and employment behavior, raising wage-based income.*

Hypothesis 4 (H4). *Digital inclusive finance augments farmers' income by fostering the upgrading of agricultural industrial structure.*

In summary, the impact mechanism of digital inclusive finance on the income of rural farmers is divided into direct and indirect impact mechanisms. Although these two mechanisms emphasize different aspects in the process of increasing farmers' income, they are closely interlinked and complementary. Together, they form the mechanism by which digital inclusive finance improves the income level of farmers, as illustrated in Figure 1.

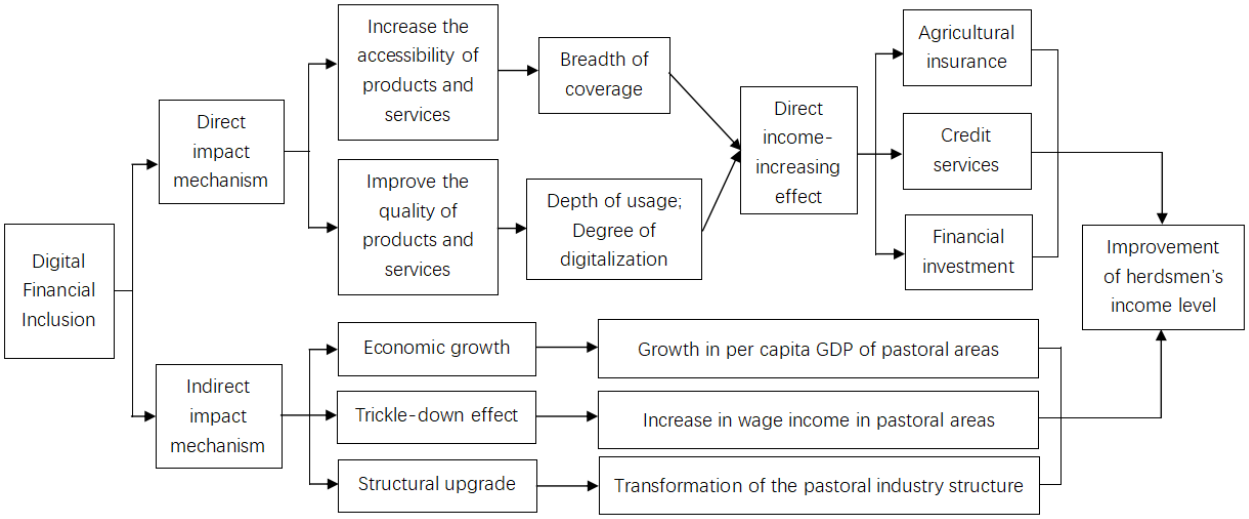

Figure 1. Mechanism of digital inclusive finance's impact on farmers' income level.

3. Research Design

3.1. Variable Selection

Based on a comprehensive consideration of existing research findings in related fields and the availability of data, the variables and their measurement methods selected for this study are presented in Table 1.

Table 1. Definition of variables.

Variable Type	Variable Name	Units	Definition and Calculation Method
Explained variable	Income of farmers (Y)	Ten thousand RMB	Per capita disposable income of farmers in primary pastoral regions
Explanatory variable	Digital Inclusive Finance Index (DFI)	--	Comprehensive index of digital inclusive finance formulated by Peking University. This index is further categorized into three sub-dimensions: breadth of coverage index (COV), depth of usage index (DEP), and the degree of digitalization index (DIG).
Control variables	Traditional financial development index (TFI)	--	Regional year-end balance of deposits and loans from financial institutions/local GDP
	Urbanization rate (UR)	%	Local urban population/total regional population
	Fiscal expenditure on agriculture (ARG)	%	Expenditures on agriculture, forestry, and water affairs/total local government expenditures
	Per capita arable land area (RJS)	Hectare/person	Per capita arable land area of rural residents
	Per capita livestock product output (Q)	Kilogram/person	Per capita livestock product quantity of residents in pastoral areas
	Fiscal expenditure on education (EDU)	%	Regional fiscal education expenditure/total fiscal expenditure
	Regional credit constraints (LOAN)	%	Year-end balance of various RMB loans from financial institutions/GDP
Intermediary variables	Wage income of farmers (WI)	%	Wage income/total income of farmers
	Level of economic development (RGDP)	Ten thousand RMB/person	Per capita GDP
	Industrial structure upgrading	%	Rationalization of industrial structure (RIS) and Advancement of industrial structure (AIS)

3.2. Model Specification

To investigate the influence of digital inclusive finance advancement on the income level of farmers, as well as the economic development level and agricultural labor productivity, the analysis is performed employing the classic ordinary least squares (OLS), random-effects, and fixed-effects models. The pertinent model specifications are as follows:

$$\ln Y = \alpha + \beta \ln DFI + \gamma Con + \varepsilon \tag{1}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \varepsilon_{it} \tag{2}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{3}$$

Through the F-test, LM-test, and Hausman test for model identification, it is found that the fixed-effects model, namely, model (3), is more suitable for the analysis of this study's data.

To further examine the trickle-down effect of digital inclusive finance, and its indirect impact on farmers' income through wage income and the economic development level of pastoral areas, the models are set as follows after introducing mediating effects based on model (3):

Introducing the indicator of the proportion of farmers' wage income:

$$\ln WI_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{4}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \lambda_1 \ln WI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{5}$$

Introducing the indicator of per capita economic development level:

$$\ln RGDP_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{6}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \lambda_2 \ln RGDP_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{7}$$

Introducing the indicator of industrial structure upgrading:

① Rationalization of industrial structure:

$$\ln RIS_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{8}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \lambda_2 \ln RIS_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{9}$$

② Advancement of industrial structure:

$$\ln AIS_{it} = \alpha + \beta \ln DFI_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{10}$$

$$\ln Y_{it} = \alpha + \beta \ln DFI_{it} + \lambda_2 \ln AIS_{it} + \gamma Con_{it} + \mu_i + \varepsilon_{it} \tag{11}$$

In the model, *lnY* represents the disposable income of farmers, *lnDFI* symbolizes digital inclusive finance, *lnWI* indicates the proportion of farmers' wage income, *lnRGDP* respectively, represent the rationalization and advancement of the industrial structure. The term α denotes a constant, *Con* stands for control variables, β, λ, and γ represent the regression coefficients of the variables, i indicates the ith province, t represents the tth year, μ is the individual effect term, μ_i indicates the individual differences across provinces that do not vary over time, and ε_{it} represents the random disturbance term.

3.3. Data Sources

The Digital Inclusive Finance Index (*DFI*) utilized in this research is derived from the Digital Inclusive Finance Index compiled by the research team at the Peking University Internet Finance Research Center, which meticulously organized data from nine principal pastoral provinces in China over the period of 2011 to 2022. Data for the other research variables are obtained from the "China Statistical Yearbook" and the "China Rural Statistical Yearbook" spanning the years 2012 to 2023. Furthermore, to counteract the effects of heteroscedasticity in the dataset, a logarithmic transformation was applied to certain variables.

3.4. Summary Statistics

This paper focuses on indicators such as the income of farmers and the Digital Inclusive Finance Index from nine provinces in China's primary ethnic minority pastoral regions from 2011 to 2022, yielding 108 observations, as presented in Table 2.

Table 2. Statistical description of variables.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Income of farmers (Y)	108	10,047.04	3494.146	4278	18,672.4
Digital Inclusive Finance Index (DFI)	108	220.276	99.975	16.22	380.76
Traditional financial development index (TFI)	108	3.652	0.892	2.551	6.667
Urbanization rate (UR)	108	48.864	9.718	22.71	66.34
Fiscal expenditure on agriculture (ARG)	108	0.143	0.023	0.097	0.204
Per capita arable land area (RJS)	108	4.194	1.848	2.026	9.763
Per capita livestock product output (Q)	108	54.537	17.453	24.3	97.7
Fiscal expenditure on education (EDU)	108	0.154	0.027	0.095	0.212
Regional credit constraints (LOAN)	108	130.552	71.788	1.16	264.86
Wage income of farmers (WI)	108	32.71	7.861	1.99	47.6
Level of economic development (RGDP)	108	10.596	0.341	9.706	11.327
Rationalization of industrial structure (RIS)	108	0.243	0.085	0.095	0.451
Advancement of industrial structure (AIS)	108	1.247	0.268	0.685	1.808

As shown in Table 2, notable disparities exist in the levels of the development of digital inclusive finance across China's principal pastoral areas, with values ranging from a minimum of 16.220 to a maximum of 380.760, exhibiting substantial differences between these extremes. The explained variable, per capita disposable income for farmers, also exhibits marked variability across regions, typically falling within the range of 4278.000 to 18,672.400. Similarly, the discrepancies between the minimum and maximum values for other indicators are also evident, underscoring the imbalanced development patterns across different ethnic minority regions.

4. Empirical Analysis

4.1. Regression Analysis of Direct Impact

4.1.1. Overall Regression Analysis

Regression analyses were conducted using the classic OLS, fixed-effects, and random-effects models, with the outcomes presented in Table 3.

Table 3. Regression results.

Variable	Classic OLS	Fixed Effects	Random Effects
	lnY	lnY	lnY
lnDFI	0.180 ***	0.078 ***	0.180 ***
	(3.85)	(4.76)	(3.85)
TFI	−0.003	−0.049 ***	−0.003
	(−0.23)	(−8.02)	(−0.23)
lnUR	0.382 ***	2.326 ***	0.384 ***
	(3.39)	(27.08)	(3.39)
ARG	−0.718 *	−0.502 ***	−0.718 *
	(−1.68)	(−3.08)	(−1.68)
RJS	0.006	0.009 *	0.006
	(1.37)	(1.96)	(1.37)
lnQ	0.219 ***	0.089	0.219 ***
	(3.98)	(1.42)	(3.98)
EDU	−1.029 ***	−1.045 ***	−1.029 ***
	(−3.08)	(−5.15)	(−3.08)
lnLOAN	0.174 ***	0.043 ***	0.174 ***
	(4.70)	(2.98)	(4.70)
N	108	108	108
R^2	0.8447	0.9822	0.8447

Notes: * and *** denote statistical significance at 10% and 1%, respectively. Figures in parentheses represent t values.

The regression results reveal that the impact of digital inclusive finance on farmers' income levels is significant at the 1% level across all three panel regression models, thereby confirming H1. Digital inclusive finance can enhance the income levels of farmers in ethnic minority regions. Upon testing the relevant models, the fixed-effects model proved to be superior among the three, leading to its selection for detailed analysis. The intermediate process values of this model are presented in Table 4.

Table 4. Intermediate process values of the fixed-effects model.

lnY	Coef.	Std. Err	t	*p*	95% CI
lnDFI	0.078 ***	0.016	4.76	0.000	0.045~0.109
TFI	−0.049 ***	0.006	−8.02	0.000	−0.061~−0.037
lnUR	2.326 ***	0.086	27.08	0.000	2.156~2.497
ARG	−0.502 ***	0.163	−3.08	0.003	−0.826~−0.178
RJS	0.009 *	0.004	1.96	0.053	−0.000~0.018
lnQ	0.089	0.063	1.42	0.160	−0.036~0.214
EDU	−1.045 ***	0.203	−5.15	0.000	−1.448~−0.642
lnLOAN	0.043 ***	0.014	2.98	0.004	0.014~0.071

Notes: * and *** denote statistical significance at 10% and 1%, respectively.

From the table above, it can be seen that the Digital Inclusive Finance Index is significant at the 0.01 level ($t = 4.76$, $p = 0.000 < 0.01$), with a regression coefficient of $0.078 > 0$, indicating that it has a significant positive impact on the income levels of farmers in ethnic minority regions. The traditional finance development index has a more significant negative impact on the income levels of farmers in ethnic minority regions, which is due to the "poor-disdaining and rich-favoring" development characteristics of traditional finance posing considerable obstacles to the development of financial services in economically underdeveloped ethnic minority regions. The urbanization rate has a significant impact on farmers' income levels, mainly because as urbanization progresses, the economic development level of cities and towns rapidly improves, attracting a large number of rural populations to continuously flow into cities, increasing non-agricultural employment opportunities for farmers, thereby enhancing their wage income and increasing the disposable income of farmers. Fiscal expenditure on agriculture is significant at the 0.01 level ($t = -3.08$, $p = 0.003 < 0.01$), with a regression coefficient of $-0.502 < 0$, indicating a significant negative impact on the income levels of farmers, contrary to the anticipated direction of the effect. Upon organizing the data, it was observed that although the overall amount of fiscal expenditure by pastoral governments shows an upward trend, the proportion of fiscal payments in pastoral areas has been continuously declining. In this paper, the ratio of fiscal expenditure allocated to agriculture serves as a control variable, and it was discovered that there is a significant negative correlation between this expenditure and the income levels of farmers in ethnic minority regions. Nevertheless, the overall volume of fiscal expenditure on agriculture demonstrates a positive correlation with the income levels of farmers within these areas. The per capita arable land area positively affects the income levels of farmers at the 0.1 significant level, reflecting the status of feed crop cultivation. Feed is a primary food source for livestock and directly relates to the production output of animal products in pastoral areas, indirectly influencing income positively. The p value of educational expenditure is $0.000 < 0.01$, with a regression coefficient of $-1.045 < 0$, indicating a significant negative impact on the income levels of farmers in ethnic minority regions. This paper also uses proportional indicators for educational expenditure, finding a significant negative correlation between the proportion of fiscal educational spending and the income levels of farmers in ethnic minority regions. The regional credit level has a significant positive impact on farmers' income and is significant at the 0.01 level, as a higher regional credit level leads to better economic development quality, which is conducive to increasing the income of farmers in pastoral areas.

4.1.2. Dimensional Analysis

The Digital Inclusive Finance Index (DFI) compiled by the research team from the Internet Development Research Institution of Peking University's is a comprehensive indicator that measures the widespread adoption of financial services in the digital age. This index reflects the development status of digital inclusive finance through three dimensions: breadth of coverage (COV), depth of usage (DEP), and the degree of digitalization (DIG). In a bid to enhance the accuracy and depth of this research, the influence of each dimension on the income levels of farmers was separately assessed, as illustrated in Table 5. The data from Table 5 reveal that the breadth of coverage, depth of usage, and degree of digitalization pertaining to digital inclusive finance all exert a significant positive effect on the income of farmers. This suggests that, driven by digitalization, the widespread adoption and in-depth development of financial services play a crucial and undeniable role in significantly improving the income of farmers. When examined in detail, the usage depth of digital inclusive finance exerts the most substantial influence on the income levels of farmers. A 1% increase in usage depth results in a 0.087% rise in farmers' income. The degree of digitalization within digital inclusive finance has the next greatest impact. For every 1% advancement in digitalization, there is a corresponding 0.059% increase in farmers' income. The breadth of coverage of digital inclusive finance has a comparatively milder effect on farmers' income levels. For each 1% expansion in coverage, farmers' income sees an uptick of 0.039%. Upon a comprehensive comparison of the regression coefficients across the various dimensional indicators, it becomes evident that the depth of usage of digital inclusive finance wields the most profound impact on the income levels of farmers, trailed by the degree of digitalization, with the breadth of coverage exerting the least influence. This revelation underscores the imperative to concentrate on increasing the tangible engagement and frequency of financial service utilization among farmers as digital inclusive finance progresses. Furthermore, it highlights the necessity to bolster the widespread accessibility and digitization of financial services, thereby maximizing digital inclusive finance's potential in fostering rural economic growth and enhancing farmers' income.

Table 5. Dimensional regression results.

Variable	Breadth of Coverage Index (COV) (1)	Depth of Usage Index (DEP) (2)	Degree of Digitalization Index (DIG) (3)
lnY	0.039 ***	0.087 ***	0.059 ***
	(3.49)	(4.22)	(4.28)
TFI	−0.047 ***	−0.048 ***	−0.048 ***
	(−7.42)	(−7.72)	(−7.74)
lnUR	2.410 ***	2.405 ***	2.413 ***
	(28.07)	(28.93)	(29.25)
ARG	−0.533 ***	−0.478 ***	−0.465 ***
	(−3.10)	(−2.87)	(−2.80)
RJS	0.009 *	0.009 *	0.009 *
	(1.97)	(1.89)	(1.89)
lnQ	0.102	0.102	0.111 *
	(1.54)	(1.59)	(1.74))
EDU	−1.139 ***	−0.940 ***	−1.026 ***
	(−5.28)	(−4.52)	(−4.96)
lnLOAN	0.0495 ***	0.021	0.059 ***
	(3.25)	(1.17)	(4.44)
N	108	108	108
R^2	0.9804	0.9814	0.9815

Notes: * and *** denote statistical significance at 10% and 1%, respectively. Figures in parentheses represent t values.

4.1.3. Robustness Test

In conducting a robustness test, the paper substituted the explained variable, replacing the per capita disposable income of farmers in primary pastoral regions with the Consumer Price Index (CPI)-based per capita consumer expenditure level of these farmers. Per capita consumer expenditure represents the average consumption level within a household, which increases in tandem with disposable income. Typically, as disposable income among residents increases, their consumer expenditure also rises accordingly. There is a significant positive correlation between rural per capita disposable income and rural per capita consumer expenditure. The regression analysis findings, as depicted in Table 6, adopted an approach of gradually incorporating control variables to explore the connection between digital inclusive finance and the per capita consumer expenditures of farmers in pastoral regions. The analysis revealed a significant positive correlation between the Digital Inclusive Finance Index and the per capita consumer expenditure levels of farmers in these areas. This indicates that a higher degree of digital inclusive finance corresponds to increased per capita consumer spending among farmers, thereby exerting a more substantial influence on both income and quality of life, aligning with the conclusions drawn earlier in the paper.

Table 6. Regression results of robustness test.

Variable	Cpi (1)	Cpi (2)	Cpi (3)	Cpi (4)	Cpi (5)	Cpi (6)	Cpi (7)	Cpi (8)
lnDFI	1.057 ***	1.027 ***	0.289 ***	0.305 ***	0.305 ***	0.293 ***	0.304 ***	0.321 ***
	(20.59)	(15.20)	(6.71)	(7.01)	(6.98)	(6.36)	(7.22)	(6.55)
TFI		0.033	−0.058 ***	−0.059 ***	−0.059 ***	−0.058 ***	−0.056 ***	−0.056 ***
		(0.70)	(−2.93)	(−2.97)	(−2.96)	(−2.88)	(−3.05)	(−3.04)
lnUR			5.775 ***	5.826 ***	5.835 ***	5.850 ***	5.882 ***	5.944 ***
			(22.11)	(22.45)	(22.08)	(22.03)	(24.31)	(23.00)
ARG				−0.091 *	−0.890 *	−0.822	−1.019 **	−0.919 *
				(−1.84)	(−1.77)	(−1.61)	(−2.18)	(−1.87)
RJS					−0.003	−0.008	−0.008	−0.008
					(−0.20)	(−0.52)	(−0.61)	(−0.61)
lnQ						0.162	0.142	0.173
						(0.80)	(0.77)	(0.91)
EDU							−2.728 ***	−2.710 ***
							(−4.49)	(−4.44)
lnLOAN								−0.030
								(−0.70)
N	108	108	108	108	108	108	108	108
R^2	0.8122	0.8131	0.9693	0.9704	0.9704	0.9706	0.9759	0.9760

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1%, respectively. Figures in parentheses represent t values.

4.2. Regression Analysis of Indirect Impact

We conduct a mediation effect test to verify the indirect impact of digital inclusive finance on farmers' income levels. The analysis primarily focuses on three aspects: the increase in farmers' wage income, the growth of per capita GDP, and the transformation and upgrading of pastoral industry structure. The test examines whether the aforementioned variables can serve as mediating variables. The results are presented in Tables 7–10. Columns 1 and 3 both use farmers' income as the explained variable, while column 2 employs the selected three mediating variables as the explained variables.

Table 7. Results of the test on effect of farmers' wage income.

Variable	lnY (1)	lnWI (2)	lnY (3)
lnDFI	0.078 ***	−8.039 ***	0.075 ***
	(4.76)	(−2.75)	(4.42)
TFI	−0.049 ***	−2.413 **	−0.049 ***
	(−8.02)	(−2.22)	(−7.89)
lnUR	2.326 ***	54.549 ***	2.343 ***
	(27.08)	(3.54)	(25.46)
ARG	−0.502 ***	30.338	−0.493 ***
	(−3.08)	(1.04)	(−2.99)
RJS	0.009 *	2.626 ***	0.009 **
	(1.96)	(3.30.)	(2.01)
lnQ	0.089	−10.319	0.086
	(1.42)	(−0.91)	(1.36)
EDU	−1.045 ***	112.282 ***	−1.011 ***
	(−5.15)	(3.08)	(−4.72)
lnLOAN	0.043 ***	0.016	0.043 ***
	(2.98)	(0.01)	(2.97)
lnWI			0.000
			(−0.51)
N	108	108	108
R^2	0.9822	0.3403	0.9823

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1%, respectively. Figures in parentheses represent t values.

Table 8. Results of the test on effect of per capita GDP.

Variable	lnY (1)	lnRGDP (2)	lnY (3)
lnDFI	0.078 ***	0.238 ***	0.037 **
	(4.76)	(5.72)	(2.14)
TFI	−0.049 ***	−0.159 ***	−0.021 ***
	(−8.02)	(−10.27)	(−2.64)
lnUR	2.326 ***	5.720 ***	1.343 ***
	(27.08)	(26.09)	(5.94)
ARG	−0.502 ***	−1.042 **	−0.323 **
	(−3.08)	(−2.50)	(−2.12)
RJS	0.009 *	−0.007	−0.009 **
	(1.96)	(−0.64)	(2.48)
lnQ	0.089	0.284 *	0.040
	(1.42)	(1.77)	(0.70)
EDU	−1.045 ***	−0.436	−0.969 ***
	(−5.15)	(−0.84)	(−5.27)
lnLOAN	0.043 ***	−0.125 ***	0.064 ***
	(2.98)	(−3.41)	(4.67)
lnRGDP			0.172 ***
			(4.63)
N	108	108	108
R^2	0.9822	0.9705	0.9857

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1%, respectively. Figures in parentheses represent t values.

Table 9. Results of the test on effect of rationalization of industrial structure.

Variable	lnY (1)	lnRIS (2)	lnY (3)
lnDFI	0.078 ***	−0.056 ***	0.089 ***
	(4.76)	(−2.72)	(5.47)
TFI	−0.049 ***	0.005	−0.049 ***
	(−8.02)	(0.67)	(−8.46)
lnUR	2.326 ***	−0.819 ***	2.504 ***
	(27.08)	(−7.56)	(23.61)
ARG	−0.502 ***	−0.934 ***	−0.299 *
	(−3.08)	(−4.54)	(−1.72)
RJS	0.009 *	0.0128 **	0.006
	(1.96)	(2.28)	(1.35)
lnQ	0.089	−0.159 **	0.124 **
	(1.42)	(−2.00)	(1.99)
EDU	−1.045 ***	−0.159	−1.010 ***
	(−5.15)	(−0.62)	(−5.14)
lnLOAN	0.043 ***	0.047 **	0.033 **
	(2.98)	(2.59)	(2.27)
lnRIS			0.216 ***
			(2.69)
N	108	108	108
R^2	0.9822	0.8163	0.9836

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1%, respectively. Figures in parentheses represent t values.

Table 10. Results of the test on effect of advancement of industrial structure.

Variable	lnY (1)	lnAIS (2)	lnY (3)
lnDFI	0.078 ***	0.309 ***	0.077 ***
	(4.76)	(2.67)	(4.55)
TFI	−0.049 ***	0.044	−0.049 ***
	(−8.02)	(1.02)	(−7.93)
lnUR	2.326 ***	0.607	2.326 ***
	(27.08)	(0.99)	(26.78)
ARG	−0.502 ***	1.520	−0.502 ***
	(−3.08)	(1.31)	(−3.04)
RJS	0.009 *	0.025	0.009 *
	(1.96)	(0.80)	(1.94)
lnQ	0.089	−0.184	0.089
	(1.42)	(−0.41)	(1.41)
EDU	−1.045 ***	−4.744 ***	−1.043 ***
	(−5.15)	(−3.29)	(−4.83)
lnLOAN	0.043 ***	−0.157	0.043 ***
	(2.98)	(−1.54)	(2.93)
lnAIS			0.000
			(0.03)
N	108	108	108
R^2	0.9822	0.4088	0.9822

Notes: * and *** denote statistical significance at 10%, 5% and 1%, respectively. Figures in parentheses represent t values.

Table 7 shows the impact of digital inclusive finance on the income levels of farmers and the mediating role played by wage income. The results in column 1 indicate that digital inclusive finance significantly contributes to the growth of farmers' income levels. This finding confirms that the promotion and application of digital inclusive finance have a positive stimulating effect on the economic growth of farmers. The findings in column 2 demonstrate that digital inclusive finance significantly boosts the wage income of farmers. This further highlights the crucial role of digital inclusive finance in fostering the growth of

wage-based income. The results shown in column 3 indicate that, even after introducing the mediating variable of farmers' wage income, both digital inclusive finance and wage income maintain a significant impact on farmers' income levels. This verifies the mediating role of wage income between digital inclusive finance and farmers' income levels, suggesting that digital inclusive finance indirectly increases farmers' income by stimulating the growth of their wage-based income. Furthermore, the coefficient of digital inclusive finance decreased from 0.078 in column 1 to 0.075 in column 3. This change indicates that enhancing farmers' wage income is an important mechanism through which digital inclusive finance promotes the income growth of farmers.

The results in column 1 of Table 8 demonstrate that digital inclusive finance can significantly foster the growth of farmers' income levels. This outcome indicates that the implementation of digital inclusive finance stimulated income growth among farmers. Column 2 shows that digital inclusive finance can enhance the level of economic development at a 1% significance level, suggesting that digital inclusive finance plays a vital role in improving the regional economic development level. The findings in column 3 reveal that, after incorporating the mediating variable of economic development level, both digital inclusive finance and economic development level still have a significant impact on farmers' income levels, thus confirming H3, substantiating the mediating effect of economic development level. In other words, digital inclusive finance indirectly enhances farmers' income levels by elevating the per capita GDP. Meanwhile, the coefficient for digital inclusive finance diminished from 0.078 in column 1 to 0.037 in column 3. This shift suggests that, with the mediating effect of level of economic development taken into account, the direct influence of digital inclusive finance on farmers' per capita GDP has intensified, as a result, fostering an increase in the per capita GDP emerges as an effective channel through which digital inclusive finance can stimulate income growth among farmers.

The results in column 1 of Table 9 demonstrate that digital inclusive finance can significantly foster the growth of farmers' income levels. This outcome reveals that the effective implementation and widespread application of digital inclusive finance have played a significant role in driving income growth among the farmer community. The findings in column 2 indicate that digital inclusive finance can promote the rationalization of agricultural industrial structure at a 1% significance level. This suggests that digital inclusive finance plays a crucial role in facilitating the rationalization of industrial structure and can drive its development. The results shown in column 3 demonstrate that, after introducing the mediating variable of rationalization of industrial structure, both digital inclusive finance and rationalization of industrial structure still have a significant impact on farmers' income levels. This confirms the validity of H4, substantiating the mediating effect of rationalized agricultural industrial structure. In other words, digital inclusive finance indirectly enhances farmers' income levels by advancing the rationalization of industrial structure. Concurrently, the coefficient of digital inclusive finance increases from 0.078 in column 1 to 0.089 in column 3. This change indicates that promoting the rationalization of industrial structure is a powerful means for digital inclusive finance to boost farmers' income levels.

The data in Table 10 reveal the impact of digital inclusive finance on the growth of farmers' income levels and the mediating role of industrial structure upgrading in this process. The results in column 1 show that the coefficient of digital inclusive finance is significantly positive, indicating that digital inclusive finance can significantly promote the growth of farmers' income levels. The findings in column 2 demonstrate that digital inclusive finance also significantly propels the advancement of industrial structure. Column 3 introduces the mediating variable of advanced industrial structure, and the results show that both digital inclusive finance and the advancement of industrial structure still significantly impact farmers' income levels. This confirms the validity of Hypothesis H4, that is, advancement of industrial structure plays a mediating role between digital inclusive finance and the growth of farmers' income. More importantly, after introducing advancement of industrial structure, the coefficient of digital inclusive finance decreases

from 0.078 in column 1 to 0.077 in column 3. This change indicates that, after considering the mediating effect of advancement of industrial structure, the direct influence of digital inclusive finance on farmers' income levels is partially explained by industrial advancement. In other words, advancement of industrial structure is one of the important pathways through which digital inclusive finance promotes the income growth of farmers.

Taking into account the results of the mediation effect tests mentioned above, wage income, economic development, and advancement of industrial structure all play mediating roles in the impact of digital inclusive finance on farmers' income levels. This means that the development of digital inclusive finance can increase farmers' wage income, enhance the regional economic development level, and promote the advancement of agricultural industrial structure, thereby indirectly boosting farmers' income levels.

5. Conclusions and Recommendations

Utilizing a panel data regression model and relevant data from nine major pastoral provinces in China, this paper analyzes the impact of digital inclusive finance on the income levels of farmers in ethnic minority regions. The following conclusions are drawn:

(1) The development of digital inclusive finance has a positive promoting effect on the income levels of farmers in China's nine major pastoral provinces, aligning with theoretical hypotheses. digital inclusive finance deeply integrates digital technology with inclusive finance, driving the high-quality development of animal husbandry through expanding service coverage, enhancing accessibility, improving satisfaction, and reducing costs. This provides strong support for the growth of farmers' income and promotes an increase in local farmers' earnings.

(2) The breadth of coverage, depth of usage, and degree of digitalization of digital inclusive finance all significantly promote farmers' income, with depth of usage having the most substantial impact. These three dimensions not only resolve the issues of geographical and product-based exclusion present in traditional financial services but also, by reducing service costs, invigorate financial institutions in rural markets, enhancing their dynamism and innovative drive. This, in turn, further propels the development of rural economies and elevates farmers' income.

(3) In terms of control variables, the urbanization rate and regional credit constraints have a significant positive impact at the 0.01 significance level, while fiscal expenditure and educational expenditure have a significant negative impact at the 1% level, and the per capita arable land area has a significant negative impact at the 0.05 level. The acceleration of urbanization leads to the transfer of rural labor to cities, and the jobs that farmers engage in within towns often yield higher incomes, contributing to an overall increase in farmers' income levels. Regional credit constraints can enhance the quality of economic development and promote economic growth, thereby increasing farmers' income.

(4) Regarding mediating variables, digital inclusive finance significantly boosts the growth of wage income, improves the regional economic development, and enhances the status of industrial structure upgrading in China's nine major pastoral provinces. Moreover, after introducing these mediating variables, the impact of digital inclusive finance on farmers' income levels remains significant, confirming the indirect influence of digital inclusive finance on farmers' income levels.

The outcomes of this research diverge from the remarkable achievements observed in studies focusing on the internet and income disparity. For instance, research by Aopeng Zhang et al. demonstrated that internet usage notably reduces the income gap among rural households, with a more pronounced alleviating effect in eastern regions [41]. In contrast, such mitigating impact was absent in ethnic minority territories. The present study illuminates that the advancement of digital inclusive finance plays a pivotal role in enhancing the income levels of herdsmen in ethnic minority areas. These findings furnish empirical support and offer critical decision-making insights for the betterment of herdsmen's livelihoods and the promotion of digital inclusive finance development.

In light of the study's findings, the following policy recommendations are put forth: Firstly, intensify the promotion and educational efforts of digital inclusive finance within minority pastoral regions to raise public awareness. This involves offering specialized financial knowledge and skills training tailored for these communities, guiding them towards establishing sound financial principles. Such measures will empower farmers to harness digital inclusive finance effectively, addressing their diverse financial needs in production. Secondly, bolster the innovation of digital inclusive finance products. By pioneering new service methodologies to deepen service capabilities and by broadening the spectrum of financial options available to farmers, we can cater to the extensive financial requirements of the farmers population, thereby spurring economic growth and prosperity in minority territories. Thirdly, there is a need to upgrade the infrastructure in minority pastoral areas, enhancing network coverage and data processing capabilities. This entails continuously refining financial service facilities to deliver efficient, stable, convenient, and secure financial services to the extensive farmers population, thereby infusing new vitality into the economic prosperity of the region. Fourthly, reinforce policy support and regulatory measures. The government can implement favorable policies like tax cuts and fiscal incentives to motivate financial institutions to offer digital inclusive finance services in minority pastoral regions. Concurrently, it is essential to establish a thorough financial regulatory framework to regulate the operations of financial institutions, ensuring the compliance and resilience of digital inclusive finance services. Fifthly, promote the integrated growth of industries. We should encourage the integrated development of industries in pastoral areas, melding digital inclusive finance with sectors such as animal husbandry and tourism to create synergies and leverage complementary strengths. By backing the development of pastoral industries through financial services, we can boost farmers' incomes and foster economic flourishment in these regions.

This study employs regional digital inclusive finance data and the average income of herdsmen as explanatory and explained variables, respectively, to elucidate the influence of digital inclusive finance development on herdsmen's income. However, the study is constrained in its ability to examine the effects of inclusive finance development on distinct groups from the standpoint of individual pastoral households. A more in-depth investigation, incorporating data from micro-level pastoral households, is necessitated to further our understanding.

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