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The Impact of Digital Finance on New Quality Productive Forces in Ethnic Minority Regions

Reyihanguli Yishake ^{1,2,*}, Dangchen Sui ¹ and Xinyan Lv ¹ 

¹ International Business School, Shaanxi Normal University, Xi'an 710119, China; suiuhu7672@snnu.edu.cn (D.S.); xinyanlv@snnu.edu.cn (X.L.)

² Business School, Xinjiang Normal University, Urumqi 830054, China

* Correspondence: 2024008@snnu.edu.cn; Tel.: +86-18001224721

Abstract

Cultivating new quality productive forces is pivotal for the high-quality development of China's ethnic minority regions. This study investigates how digital finance, by leveraging its capacity to overcome geographical constraints, can drive this process. Utilizing panel data from 45 ethnic minority cities from 2013 to 2023, we employ two-way fixed-effects, spatial econometric, mediation, and moderation models to examine the impact and underlying mechanisms of digital finance. The findings indicate that digital finance significantly enhances new quality productive forces in border ethnic minority regions and generates positive spatial spillover effects on neighboring areas. This impact is mediated by two pathways: technological innovation and the green, low-carbon transformation. Conversely, digital divides related to access, usage, and skills exert a significant negative moderating effect on this positive impact. Furthermore, a regional heterogeneity analysis reveals that the driving effect of digital finance is more pronounced in the Northwest region compared to the Southwest. Accordingly, we propose targeted policy recommendations centered on optimizing adaptive digital infrastructure, strengthening digital literacy, promoting green finance, and establishing collaborative regional mechanisms. The objective is to amplify the positive impacts while mitigating the existing digital divides.

Keywords: ethnic minority regions; digital finance; new quality productive forces

1. Introduction

Against the backdrop of a shifting paradigm in technological innovation and the restructuring of the global economic landscape, emerging technologies—such as Artificial Intelligence (AI), blockchain, and big data—have become the core engines driving the leapfrog development of productivity. In this context, the strategic discourse on “New Quality Productive Forces” (NQPF), alongside the mandates from the Third Plenary Session of the 20th Central Committee of the CPC regarding the “refinement of institutional mechanisms to develop NQPF according to local conditions,” has delineated a new strategic trajectory for China's coordinated regional economic development [1]. However, a significant chasm persists between this policy vision and on-the-ground realities. Border ethnic minority regions, serving as strategic bulwarks for ecological security and national unity, have long been hampered by inadequate infrastructure, low resource utilization efficiency, and lagging industrial structures [2]. As eastern regions spearhead advances into high-end, precision, and cutting-edge innovation, the question of how these border regions can cultivate their own adapted new quality productive forces by leveraging their



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unique endowments is not only a major theoretical proposition for resolving regional development imbalances but also a practical imperative for revitalizing border areas and achieving common prosperity.

Essentially, new quality productive forces represent an advanced evolutionary form of productivity, marked primarily by a qualitative enhancement of Total Factor Productivity (TFP). Unlike traditional TFP, which focuses on incremental efficiency adjustments within existing factor combinations, these new forces emphasize a deep recombination and systematic optimization of productive elements [3]. From a regional evolutionary perspective, the construction of new quality productive forces in developed eastern regions is predominantly driven by frontier leadership through disruptive technological innovation. In contrast, border ethnic minority regions exhibit a differentiated path characterized by path-jumping and leapfrog development achieved through the deep activation of their existing endowments. Addressing this unique context, this paper constructs a context-specific analytical framework based on the three core elements of productive forces: first, cultivating “new quality labor” equipped with digital skills to offset the structural deficit of lagging human capital accumulation; second, employing “new quality means of labor,” such as digital platforms, to transcend geographical isolation; and third, sublimating unique ecological and cultural resources into “new quality objects of labor” through a digital empowerment process that facilitates a creative transformation from natural ecology and cultural heritage into digital assets and green value. This framework not only anchors the strategic positioning for developing new quality productive forces in these regions but also unveils the underlying logic for them to capitalize on their latecomer advantage and achieve a productivity leap.

In this process of elemental reconfiguration, digital finance—the deep integration of digital technology and financial functions—emerges as an indispensable catalyst. Leveraging its powerful long-tail effect, digital finance not only expands the financing frontiers for small and medium-sized enterprises (SMEs) in border regions but also, by empowering green finance, directs resource flows toward low-carbon sectors. This underpins a dual-driver model combining digital innovation with green development [4]. Building on this premise, this paper delves into the actual efficacy of digital finance in the formation of new quality productive forces within border ethnic minority regions, aiming to provide robust theoretical support and empirical evidence for China’s “Digital Border Enhancement” strategy.

This study contributes to the literature in three primary ways. First, in terms of perspective, this paper is the first to focus on the unique context of border ethnic minority regions to explore the promotional role of digital finance on new quality productive forces. It effectively fills a significant gap in the existing literature, which has predominantly concentrated on the national level or developed areas while overlooking the distinct characteristics of ethnic regions, thereby expanding the research boundaries of developing new quality productive forces in a context-specific manner. Second, regarding mechanism analysis, we construct a systematic framework that positions technological innovation and the green, low-carbon transformation as dual mediators in the relationship between digital finance and new quality productive forces, dissecting how digital finance drives this qualitative transformation. Third, concerning policy implications, by comparing the heterogeneous performance between the Northwest and Southwest ethnic regions, this study reveals the regional sensitivity of digital finance’s empowering effect. This provides crucial decision-making references for government bodies to implement place-based precision governance tailored to the diverse resource endowments of different border areas.

2. Literature Review

Scholarship on New Quality Productive Forces (NQPFs), particularly within the context of China's ethnic minority regions, has coalesced around three key themes.

The first stream of inquiry examines the conceptual foundations of NQPFs and the rationale for their context-specific development. While both China's developed eastern regions and its ethnic minority regions pursue high-quality growth, their strategic orientations diverge significantly. Eastern regions function as primary hubs for strategic emerging and future-oriented industries. In contrast, ethnic minority regions are strategically positioned as bases for ecological energy and resources, eco-tourism destinations, and pioneers in green, low-carbon economic systems [5]. This fundamental distinction necessitates tailored pathways for cultivating NQPFs that are congruent with the unique industrial foundations and resource endowments of each locality [6].

A second stream of literature investigates the multifaceted impacts of developing NQPFs in these regions. Research suggests that fostering NQPFs not only promotes regional coordination [7] but also accelerates the green transformation of development models [8] and enhances industrial sustainability [9]. This process positions NQPFs as a dual engine for achieving high-quality growth and as a critical driver for modernization [10,11].

Finally, scholars have explored the practical pathways for NQPF development. This research argues that ethnic minority regions must leverage their rich natural resources, unique geographical advantages, and supportive policy environments [12] by strengthening technological innovation, cultivating high-skilled talent [13], and optimizing their industrial structure [14].

Concurrently, a parallel body of literature on digital finance recognizes its capacity to democratize access, enhance efficiency, and innovate financial services through technologies like AI and blockchain. Its inclusive nature transcends the physical constraints of traditional banking by extending services to financially underserved populations in remote areas [15]. Technologically, it mitigates information asymmetry, reduces transaction costs, and increases the velocity of capital allocation [16].

A growing body of research has begun to connect digital finance with NQPFs, focusing on three domains. First, at the regional level, digital finance is shown to enhance NQPFs by stimulating entrepreneurial activity [17], advancing fintech innovation [18], and optimizing industrial structures [19], with effects that exhibit significant regional heterogeneity. Second, at the firm level, digital finance fosters NQPFs by facilitating corporate digital transformation [20] and enabling new forms of industrial integration, particularly for agriculture-related enterprises [21]. Third, scholars have examined how digital finance, through its enhancement of NQPFs, contributes to broader socio-economic objectives, including urban–rural common prosperity [22,23] and integrated development [24]. This process is seen as crucial for modernizing China's rural governance [25], with some research advocating for enhanced regulatory oversight to ensure sustainable NQPF development [26].

In summary, while the existing literature provides a crucial theoretical foundation for understanding how digital finance empowers the evolution of productivity, several research gaps remain, particularly within the unique context of China's border ethnic minority regions. These gaps warrant further investigation.

First, concerning the analysis of driving mechanisms, extant studies have predominantly focused on the role of digital finance in driving technological innovation. However, its pathway of engagement with the green and low-carbon transformation—a core dimension of new quality productive forces—remains underexplored. This gap prevents a comprehensive elucidation of the underlying logic behind productivity's qualitative shift toward green and sustainable development. Second, in terms of the analytical framework's systematicity, existing research often examines the incremental effects of digital finance

in isolation. This approach fails to integrate the endogenous relationship among digital finance, the digital divide, and new quality productive forces into a unified framework, thereby overlooking the structural constraints that hinder the penetration of digital technology in these border regions. Finally, regarding the depth of empirical analysis, there is a notable lack of in-depth investigation into the internal heterogeneity within these border regions. Specifically, the differentiated impacts stemming from variations in resource endowments, digital infrastructure, and policy responsiveness between the Northwest and Southwest regions have yet to be sufficiently validated.

3. Theoretical Analysis and Research Hypotheses

3.1. Conceptualization and Regional Applicability of New Quality Productive Forces

New quality productive forces represent a form of productivity in which technological innovation assumes a dominant role. Within the academic context, their core hallmark is a qualitative leap in Total Factor Productivity (TFP). In contrast to traditional growth models driven by the scale of factor inputs, new quality productive forces emphasize the deep deconstruction and systematic recombination of productive elements through disruptive technologies.

Situated within the unique context of border ethnic minority regions, this study defines new quality productive forces as an evolutionary process that leverages digital technology to creatively transform region-specific endowments such as green ecology and ethnic culture. By overcoming geographical isolation and information frictions, this process facilitates a leap of productive elements toward digitalization, intelligent transformation, and greening. This definition not only encompasses the universal characteristics of new quality productive forces but also underscores the differentiated logic of “endowment activation” enabling “latecomer leapfrogging” in border regions. It thus provides the conceptual anchor for the subsequent analysis of the driving mechanisms of digital finance.

3.2. The Direct Impact of Digital Finance on New Quality Productive Forces

Digital finance provides an endogenous impetus for the formation of new quality productive forces by reshaping the three core elements of productivity, thereby overcoming the inherent constraints of border regions.

1. Reshaping Labor: From Traditional Laborers to New Quality Labor

In border ethnic minority regions, the accumulation of traditional human capital has long been impeded by a “triple squeeze” of geographical isolation, scarce educational resources, and linguistic-cultural differences. The formation of new quality labor is, in essence, a systematic compensation for and reconstruction of these constraints, facilitated by the inclusive technological platforms of digital finance. Specifically, this occurs through three progressive stages. First, at the level of technological compensation, digital finance mitigates cognitive barriers arising from linguistic and cultural disparities through localized and visualized tools such as graphical user interfaces and voice interaction. This enables laborers in border regions to bypass the spatio-temporal limitations of traditional education and acquire productive skills across time and space. Second, in terms of skill enhancement, the knowledge spillover effects generated by digital finance transform financial participation into a low-cost pathway for competency empowerment. This effectively alleviates the uneven distribution of educational resources and significantly enhances laborers’ digital operational capabilities. Finally, concerning mindset transformation, the deep integration of digital credit and information lowers entrepreneurial barriers and trial-and-error risks, catalyzing a profound shift from traditional agrarian mindsets to modern digital business philosophies. This shift promotes a qualitative leap of the labor force from low-skilled agriculture to digital services and eco-specialty industries. This

logical progression—from technological compensation to skill acquisition and mindset evolution—drives the fundamental upgrading of the border region labor force from a traditional to a “new quality” paradigm [4].

2. Modernizing Means of Labor: An Asymmetric Leap in Productive Tools

The evolution of new quality means of labor is manifested in the intelligent transformation of traditional production tools and an “asymmetric leap” in infrastructure, driven by digital finance. To address the persistent challenges of high construction costs and difficult maintenance of physical infrastructure in these regions, digital finance substitutes or empowers physical “hard infrastructure” with “digital soft infrastructure,” thereby elevating the capabilities of the means of production. First, regarding tool intelligence, digitally financed smart agricultural machinery, IoT devices, and cross-border e-commerce platforms are gradually replacing outdated production tools. Consequently, smartphones have become the “new farm implements” and digital platforms the “new farms” of border regions, significantly reducing marginal production and operational costs. Second, through spatiotemporal compression, the virtual financial networks constructed by digital finance effectively neutralize the high transaction costs associated with physical distance, enabling instantaneous interaction of capital, information, and technology. This provides a “superhighway” for new quality productive forces that transcends geographical limitations. Finally, at the level of inclusive integration, these new means of production, centered on algorithms and computing power, grant micro- and small-scale entities in border regions equitable access to financial services and technology, on par with those in major urban centers. This evolution from physical tools to digital and intelligent instruments not only bridges the development divide but also constitutes the material foundation for achieving “latecomer catch-up” in the context of new quality productive forces.

3. Redefining Objects of Labor: A Process of Value Activation

The expansion and reconstruction of new quality objects of labor is fundamentally a process of “value activation” for the abundant ecological resources and unique cultural endowments of border ethnic minority regions, catalyzed by digital finance. A vast quantity of high-quality ecological products and ethnic cultural resources in these regions has long remained “dormant,” their conversion into tangible productivity hindered by limited market reach and information asymmetry. Digital finance addresses this in several ways. First, through resource assetization, digital finance, leveraging big data and blockchain technology, enables the precise confirmation and quantitative assessment of rights to green resources (e.g., carbon sinks, forest rights). This transforms previously non-tradable natural resources into mortgageable and liquid financial assets, thereby dramatically expanding the scope of labor objects. Second, concerning value excavation, digital platforms break down geographical barriers and, by precisely matching market demand, drive the transformation of labor objects from primary agricultural products to high-value-added “digital brands” and “ecological assets.” Finally, through data factorization, digital finance converts the massive data generated during production and operation into a new core object of labor, marking a logical shift from a “material resource-driven” to a “data resource-driven” paradigm. This transformation not only overcomes the “spatial blockages” in resource development but also provides an inexhaustible material space and data source for cultivating new quality productive forces.

In summary, by digitally reshaping labor skills, deeply excavating the value of labor objects, and intelligently upgrading the means of labor, digital finance fundamentally breaks the “multiple-dilemma” of geographical isolation, educational deficits, and resource underutilization that has long plagued border ethnic minority regions. This systematic, technology-driven leap in the qualitative state of productive elements not only achieves a

deep and organic recombination of the three core factors of productivity but also constitutes the primary driving force for transforming new quality productive forces from “latent potential” to “realized efficacy” in the border context [27].

Based on the preceding theoretical analysis, this paper proposes the following core hypothesis:

Hypothesis H1. *Digital finance significantly promotes the cultivation and enhancement of new quality productive forces in border ethnic minority regions by empowering new quality labor, activating new quality objects of labor, and optimizing new quality means of labor.*

3.3. The Mediating Mechanisms of Digital Finance on New Quality Productive Forces

3.3.1. The Mediating Role of Technological Innovation

Technological innovation serves as the core transmission mechanism through which digital finance drives the development of new quality productive forces in border ethnic minority regions. Addressing the realities of these regions, characterized by a predominantly heavy industrial structure, weak technological accumulation, and “last-mile” challenges in digital infrastructure, the mediating role of technological innovation is manifested in a fundamental shift from a “resource-dependent” to an “innovation-driven” paradigm.

Digital finance fosters technological innovation by precisely addressing the research and development (R&D) deficiencies in border regions. Specifically, in these areas, high-risk and long-cycle technological innovations often face severe financing constraints due to the scarcity of traditional financial outlets and significant information asymmetry. Digital finance, leveraging its robust information processing capabilities, effectively lowers credit assessment costs by analyzing “alternative data” from micro and small enterprises (MSEs) and rural households. This provides crucial financial support for R&D investments in distinctive industries such as plateau agriculture, ethnic medicine, and border trade. Furthermore, given the relatively underdeveloped digital infrastructure in border regions, the “cloud-based technological flow” embedded in digital finance generates spillover effects, prompting enterprises to pursue process innovation through digital transformation. This enables an “asymmetric” catch-up in technological capabilities, even with limited hardware foundations [28].

The transformation of factor quality and the upgrading of industrial forms constitute the pathway through which technological innovation contributes to new quality productive forces. The contribution of technological innovation extends beyond merely increasing output; it is crucially reflected in the “qualitative activation” of the unique resource endowments of border regions. Specifically, at the level of production efficiency, technological innovation, by introducing digital tools such as intelligent monitoring and the Internet of Things (IoT), transforms traditional labor-intensive industries in border regions into capital- and technology-intensive ones, thereby enhancing Total Factor Productivity (TFP). From an ecological perspective, in light of the fragile ecosystems in border regions, green technological innovation can convert abundant clean energy (e.g., photovoltaics, wind power) and ecological resources into high-value-added green products, achieving “resource assetization.” This directly aligns with the essential requirement of new quality productive forces for green and low-carbon development. At the level of industrial restructuring, technological innovation breaks the limitations imposed by geographical isolation in border regions, giving rise to new business models such as cross-border e-commerce and cloud-based cultural tourism. This allows the border workforce to directly participate in the global value chain division of labor, thereby achieving a profound transition from traditional factor combinations to the new quality productive forces paradigm [29].

Based on the foregoing logic, technological innovation is not only a consequence of digital finance but also a direct impetus for the formation of new quality productive forces. Thus, we propose the following hypothesis:

Hypothesis H2. *Digital finance indirectly promotes the cultivation of new quality productive forces in border ethnic minority regions by stimulating technological innovation activities.*

3.3.2. The Mediating Role of the Green, Low-Carbon Transition

The green and low-carbon transformation is an intrinsic requirement for new quality productive forces and a critical pathway for border ethnic minority regions to achieve “latecomer leapfrogging.” Given the fragile ecological environment and the rich, yet often unidirectionally exploited, resource endowments in these regions, the green and low-carbon transformation plays a dual role in the mediating mechanism: that of “value discovery” and “model reshaping.”

Digital finance facilitates the green and low-carbon transformation by addressing the “green financing gap” in border regions. Traditional financial institutions in these areas often have limited capacity to assess the risks associated with green projects, leading to “difficult and expensive financing” for ecological and environmental protection industries. Digital finance, leveraging big data monitoring and environmental information disclosure systems, can accurately identify green production behaviors in border regions. Through tools such as green credit and carbon finance, it significantly reduces the financing costs for clean energy development (e.g., wind and solar power) and resource-efficient enterprises. Furthermore, considering the geographically dispersed nature of border regions, digital financial platforms effectively lower the accessibility threshold for green financial services. This drives traditional resource-based industries (e.g., mining, primary processing) toward low-carbon process transformation, providing systematic financial incentives for the construction of a green ecological barrier in these areas [30].

The green and low-carbon transformation is not merely a cost expenditure; rather, it directly drives a qualitative leap in new quality productive forces by enhancing the “green content” of productive elements. At the level of resource valorization, for the abundant “forest and grassland carbon sinks” and ecological assets in border regions, the green and low-carbon transformation, through accounting systems and trading mechanisms, converts “lush mountains and clear waters” into measurable “gold and silver mountains.” This transformation from natural resources to ecological capital represents a fundamental sublimation of the objects of labor, epitomizing the “green foundation” of new quality productive forces [31]. At the level of production efficiency, the green and low-carbon transformation compels enterprises in border regions to abandon high-energy-consumption, low-efficiency traditional expansion models. By introducing green technologies and low-carbon management practices, it achieves energy saving and emission reduction in production processes, significantly enhancing resource allocation efficiency and Total Factor Productivity. This makes the output of border regions more internationally competitive and sustainable. At the level of industrial structure optimization, green transformation drives the industrial structure of border regions away from “heavy resource dependence” towards “lightweight, high-value-added” sectors. Examples include the transformation of traditional animal husbandry into green ecological agriculture and resource extraction into a circular economy. This structural qualitative change enables border productivity to break free from the old path of traditional industrialization, achieving a leapfrog evolution towards the new quality productive forces paradigm.

Based on the foregoing logic, the green and low-carbon transformation serves as a crucial bridge between digital finance and new quality productive forces. Thus, we propose the following hypothesis:

Hypothesis H3. *Digital finance indirectly promotes the enhancement of new quality productive forces in border ethnic minority regions by fostering a green and low-carbon transformation of production and operation methods.*

3.4. The Moderating Effect of the Digital Divide

The digital divide plays a significant negative moderating role in the process by which digital finance drives new quality productive forces in border ethnic minority regions. Unlike developed areas, the digital divide in these regions is characterized by a profound, multi-dimensional coupling of “geographical–linguistic–literacy” factors, which collectively increase the friction to the flow of digital financial elements [32].

The unique origins of this digital divide in border ethnic minority regions are manifold. Firstly, geographical isolation and physical access barriers are prominent, as the complex terrain (plateaus, high mountains, deserts) results in exceptionally high costs for deploying communication base stations and optical fibers. This inherent physical barrier consequently leads to unstable network coverage, directly limiting the real-time accessibility and continuous use of digital financial services. Secondly, linguistic habits and symbolic adaptation barriers pose significant challenges. Existing digital financial interfaces are predominantly built upon the national common language, which for laborers accustomed to using ethnic languages, presents a high “decoding cost” and a risk of information misinterpretation, thus creating a cognitive disconnect in the application of digital tools. Furthermore, low digital literacy and educational deficiencies compound the problem; the long-standing scarcity of educational resources in border regions leads to a lack of systematic digital literacy training among laborers. This deficiency implies that even with smart devices, laborers find it difficult to fully leverage complex digital financial functions such as precision credit or hedging, often remaining at a basic payment level. Finally, the inertia of traditional lifestyles and production methods also contributes to the divide. Deep-rooted traditional grazing and small-scale farming practices, coupled with “face-to-face” informal credit habits in border regions, inherently clash with the decentralized and algorithmic logic of digital finance, thereby forming a “socio-cultural layer” of the digital divide.

These unique factors significantly attenuate the driving effect of digital finance on new quality productive forces through several critical pathways. Initially, they lead to attenuation of transmission efficiency. When insufficient linguistic adaptation and a lack of digital skills coexist, the financial information and technological spillovers provided by digital finance cannot be effectively absorbed by laborers. This consequently results in a “signal interruption” within the technological innovation mediating pathway, preventing the precise conversion of knowledge elements, crucial for new quality productive forces, into productive practices. Moreover, the digital divide increases the risk of resource misallocation by fostering “digital exclusion.” Specifically, border business entities most in need of capital for green and low-carbon transformation may be excluded from service due to their inability to navigate complex digital operational thresholds. This significantly compromises the inclusivity of digital finance and culminates in inefficient factor allocation. Lastly, a persistent “digital threshold” inhibits the qualitative leap necessary for new quality productive forces. The formation of new quality productive forces relies on the deep recombination of elements, yet in regions with a high degree of digital divide, the intelligentization of means of labor and the valorization process of objects of labor stagnate at low levels due to a lack of both software and hardware support. This multi-dimensional constraint therefore forms an invisible barrier, making it difficult for the qualitative transformation of elements in border regions to reach the critical threshold required for new quality productive forces [33].

Based on the preceding analysis, this paper proposes the following hypothesis:

Hypothesis H4. *The digital divide negatively moderates the effect of digital finance on promoting new quality productive forces in border ethnic minority regions. Specifically, in regions characterized by poor linguistic adaptability, low digital skill levels, and underdeveloped infrastructure, the driving effect of digital finance on new quality productive forces will be significantly weakened.*

4. Research Design

4.1. Model Specification

4.1.1. Baseline Regression Model

To empirically investigate the impact of digital finance on New Quality Productive Forces (NQPFs) and its underlying mechanisms, this study employs a panel data approach. We recognize that NQPF development in ethnic minority regions may be influenced by unobservable, time-invariant city-specific characteristics, such as resource endowments, as well as time-varying factors common to all cities, such as macroeconomic trends and national policy shifts. To mitigate potential omitted variable bias arising from these factors and obtain more reliable estimates, we adopt a two-way fixed effects (TWFE) model, which controls for both individual (city) and time effects.

First, to examine the direct effect of digital finance on NQPFs as proposed in H1, we formulate the following baseline regression model:

$$NQP_{it} = \alpha_0 + \alpha_1 DF_{it} + \alpha_2 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

where

NQP_{it} represents the development level of New Quality Productive Forces for city i in year t .

DF_{it} denotes the level of digital finance development for city i in year t .

Z_{it} is a vector of city-level control variables.

λ_t represents the time fixed effects, capturing shocks common to all cities in a given year.

μ_i represents the individual fixed effects, controlling for all time-invariant, unobserved heterogeneity across cities.

ε_{it} is the idiosyncratic error term.

The coefficient of interest is α_1 , which measures the average effect of digital finance on NQPFs. A statistically significant and positive α_1 would provide initial support for Hypothesis 1.

4.1.2. Mediating Effect Model

To test the mediating roles of technological innovation and the green, low-carbon transition (Hypotheses H2 and H3), we adopt the widely used causal steps approach. This involves estimating the following two equations in addition to the baseline model (1):

$$MED_{it} = \beta_0 + \beta_1 DF_{it} + \beta_2 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$NQP_{it} = \gamma_0 + \gamma_1 DF_{it} + \gamma_2 MED_{it} + \gamma_3 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (3)$$

Here, MED_{it} represents the mediating variable, which alternately denotes the level of technological innovation and the green, low-carbon transition for city i in year t .

The mediating effect is established if the following conditions are met: (a) the coefficient α_1 in Equation (1) is significant; (b) the coefficient β_1 in Equation (2) is significant; and the coefficient γ_2 in Equation (3) is significant, while the coefficient γ_1 becomes less significant or smaller in magnitude compared to α_1 .

4.1.3. Moderating Effect Model

To verify whether the digital divide moderates the relationship between digital finance and NQPF development (Hypothesis H4), we construct a moderating effect model by introducing an interaction term between digital finance and the digital divide. The model is specified as follows:

$$NQP_{it} = \delta_0 + \delta_1 DF_{it} + \delta_2 DD_{it} + \delta_3 (DF_{it} \times DD_{it}) + \delta_4 Z_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (4)$$

In this model, DD_{it} is the moderating variable, representing the digital divide for the province where city i is located in year t . The interaction term, $DF_{it} \times DD_{it}$, captures the moderating effect. Our primary interest lies in the coefficient δ_3 . A statistically significant and negative δ_3 would indicate that the digital divide negatively moderates the impact of digital finance on NQPFs, meaning the positive effect of digital finance is weaker in regions with a wider digital divide. This would provide support for Hypothesis H4. All other variables are defined as in the preceding models.

4.2. Variable Selection and Data

4.2.1. Dependent Variable

New Quality Productive Forces (NQP). Building upon the preceding conceptualization of NQP's "border applicability," this study posits that its core lies in leveraging digital technology to activate region-specific resources and overcome geographical isolation constraints. Following the three-dimensional logical framework of "new quality labor, new quality objects of labor, and new quality means of labor," [34] this paper aims to map the qualitative transformation of productive forces in border regions across these three dimensions:

New Quality Labor Dimension: Addressing the persistent information asymmetry and knowledge acquisition barriers in border regions, we select indicators for human capital in informatization and scientific-technological talent to measure laborers' proficiency in digital technology. Furthermore, the number of university students per 10,000 population is used to characterize the endogenous human capital reserves in border areas. These metrics not only reflect labor specialization but also capture the fundamental capacity of border laborers to transition from traditional production to digital and intelligent modes, serving as crucial micro-level support for overcoming "information frictions."

New Quality Objects of Labor Dimension: Echoing the emphasis on "creative transformation of green ecology and region-specific resources" in our conceptual definition, we select the proportion of the tertiary industry (encompassing border-specific cultural tourism and modern service sectors) and the gross industrial output value of above-scale domestic enterprises to measure the technological content and scale effects of production objects. Concurrently, to precisely delineate how border regions achieve "qualitative activation" of resource endowments through green transformation of production methods while strictly adhering to ecological redlines, we prominently incorporate industrial sulfur dioxide emission intensity, wastewater treatment rate, and household waste treatment rate as greening indicators.

New Quality Means of Labor Dimension: New quality means of labor serve as the material foundation for border regions to achieve "latecomer leapfrogging." This paper constructs the digital infrastructure dimension using indicators such as per capita telecommunication service volume, internet broadband access subscriptions, and mobile phone penetration rate. These align with the theoretical definition's logic of "breaking through physical spatial barriers and overcoming geographical isolation." Additionally, through indicators like scientific and technological expenditure, R&D intensity, and energy consumption per unit of output (total electricity consumption, serving as an inverse indicator),

we dynamically monitor the systematic recombination of production tools from traditional high-energy-consuming types to digital and low-carbon means of production.

Based on these evaluation dimensions, this study employs the entropy method to measure the development level of new quality productive forces in 45 ethnic cities from 2013 to 2023. The indicator system comprises 3-dimensional layers and 16 specific indicators. Among these, total electricity consumption and industrial sulfur dioxide emissions per GDP are inverse (negative) indicators, while all others are positive. A higher value for a positive indicator signifies a higher level of new quality productive forces, whereas a lower value for a negative indicator indicates the same. To eliminate dimensional discrepancies, all indicators are standardized using the range normalization method. The formula for positive indicators is: $X_{\lambda it} = (Z_{\lambda it} - Z_{min}) / (Z_{max} - Z_{min})$; for negative indicators, it is: $X_{\lambda it} = (Z_{max} - Z_{\lambda it}) / (Z_{max} - Z_{min})$. Here, $i \in [1, n]$ represents the number of cities, $t \in [1, m]$ represents the number of years, and $Z_{\lambda it}$ denotes the specific value of the λ -th indicator for the i -th city in the t -th year, with Z_{max} and Z_{min} being the maximum and minimum values of the indicator, respectively. Descriptive statistics for the processed indicators are not presented here due to space limitations. ^① The detailed indicator system, measurement methods, indicator attributes, and calculated weights are provided in Table 1. Due to space limitations, the specific data for the indicators used to evaluate the level of new-type productivity in ethnic regions are not reported in the text; they are available from the authors upon request.

Table 1. Index System for New Quality Productive Forces in Ethnic Minority Regions.

Dimension	Sub-Dimension	Component	Indicator Measurement	Weight	Property
N Q P	New Quality Laborers	Foundation of IT talent	Proportion of employment in computer and software industries	0.0309	+
		Foundation of S&T talent	Proportion of employment in scientific research	0.0489	+
		Human capital	Number of college students per 10,000 people	0.1361	+
		Employment structure	Proportion of employment in the tertiary industry	0.0207	+
	New Objects of Labor	Technological level	Share of the tertiary industry in GDP	0.0299	+
			Gross industrial output of domestic-funded enterprises above designated size	0.0766	+
		Pollution reduction	Industrial SO ₂ emissions per unit of GDP	0.0049	-
			Centralized treatment rate of wastewater treatment plants	0.0114	+
			Harmless disposal rate of domestic waste	0.0027	+
	New Means of Labor	S&T expenditure	Share of science and technology expenditure in GDP	0.0587	+
		R&D intensity	Share of internal R&D expenditure in GDP	0.0879	+
		Industrial base	Number of industrial enterprises above designated size	0.0542	+
		Green production inputs	Total electricity consumption	0.0049	-
			Per capita volume of telecommunication services	0.1086	+
		Digital infrastructure	Internet broadband users per 10,000 people	0.2755	+
			Mobile phone penetration rate	0.0481	+

4.2.2. Independent Variable

Digital Finance (DF). The city-level digital finance development is proxied by the Peking University Digital Financial Inclusion Index (2013–2023) (Beijing, China). This index, constructed by the Institute of Digital Finance at Peking University, incorporates three dimensions: coverage breadth, usage depth, and digitalization level [35]. In our empirical process, the index is transformed by taking the natural logarithm of its value plus one to address potential skewness and scale differences.

4.2.3. Mediating Variables

- (1) Technological Innovation (RI). The total number of authorized patents in each city is employed as the proxy for innovation level. Unlike patent applications, patent grants provide a more accurate depiction of the practical conversion of innovative results, making them a widely recognized indicator for evaluating regional innovation performance. To standardize the variable and address the issue of skewed data distribution, a log-plus-one transformation is applied to this metric during the empirical process.
- (2) Green, Low-Carbon Transition (GLCT). The green and low-carbon transition (GLCT) is measured by CO₂ emissions per unit of GDP. A lower value of this indicator signifies superior carbon emission performance and a more advanced level of green transition.

4.2.4. Moderating Variable

Digital Divide (DD). Drawing on the work of Ma and Huang [36], we disaggregate the digital divide into three dimensions: the Digital Access Gap (DAG), the Digital Usage Gap (DUG), and the Digital Capability Gap (DCG). Specifically, we proxy these gaps using the reciprocals of long-distance optical cable density, internet penetration rate, and average years of schooling of residents, respectively.

4.2.5. Control Variables

We include the following city-level control variables: (1) Urbanization Level (UL): Measured by the urbanization rate. (2) Consumer Spending Level (CSL): Represented by the Consumer Price Index (CPI) of each city. (3) Financial Development Level (FDL): The ratio of total deposits and loans of financial institutions at year-end to the city's GDP. (4) Government Fiscal Revenue Level (TRL): The ratio of local general public budget revenue to the city's GDP. (5) Employment Scale Level (ESL): The ratio of the number of on-the-job employees to the total registered population of the city.

4.3. Data Sources and Descriptive Statistics

4.3.1. Sample Selection and Data Sources

This study focuses on 45 prefecture-level and above cities in China's ethnic minority regions from 2013 to 2023, encompassing jurisdictions within Xinjiang, Ningxia, Inner Mongolia, Qinghai, Yunnan, Guangxi, and Guizhou. A balanced panel dataset consisting of 495 observations was constructed. The data sources for the primary variables are as follows: Dependent Variable (NQP): Raw data were primarily extracted from the China City Statistical Yearbook, various provincial (regional) statistical yearbooks, and municipal statistical bulletins. Independent Variable (DF): Data were obtained from the Peking University Digital Financial Inclusion Index of China, published by the Institute of Digital Finance at Peking University. Mediating and Moderating Variables (RI, GLCT, and DD): Patent data were sourced from the China Research Data Service (CNRDS) platform (Beijing, China). Carbon emission data were calculated based on urban energy consumption with reference to the Carbon Emission Accounts and Datasets (CEADs) database (www.ceads.net.cn; developed by research teams from various institutions including Tsinghua University,

Beijing, China). Indicators related to the digital divide were retrieved from the China City Statistical Yearbook and local bulletins on national economic and social development. Control Variables: These were mainly retrieved from the China City Statistical Yearbook and the official website of the National Bureau of Statistics (NBS) of China.

4.3.2. Data Preprocessing and Missing Value Imputation

To ensure research transparency and the replicability of results, the raw data underwent the following preprocessing steps:

First, imputation of missing values. For specific indicators missing in certain cities during particular years, we initially consulted local annual statistical bulletins to supplement the data. For the remaining sparse missing values that could not be directly retrieved, the adjacent-year mean imputation method (averaging values from the two years preceding and succeeding the missing year) was applied.

Second, data transformation. To mitigate potential heteroscedasticity and enhance the reliability and representativeness of the findings, all non-ratio variables—such as the number of granted patents and the digital finance index—were subjected to a logarithmic transformation after adding one, expressed as $\ln(x + 1)$. All statistical analyses and model estimations in this study were performed using Stata version 17.0 (StataCorp, College Station, TX, USA).

4.3.3. Descriptive Statistics

Descriptive statistics for the primary variables are summarized in Table 2. The mean value of New Quality Productive Forces (NQP) in ethnic areas is 0.162 (SD = 0.0781), with minimum and maximum values of 0.0593 and 0.532, respectively, indicating spatial disequilibrium in its development. Furthermore, the NQP level in these regions is consistently lower than the national average of 0.2297 as documented by Wang [37]. In terms of mediating variables, the significant variation in technological innovation (RI), ranging from 2.773 to 10.197, reflects a tiered structure in regional innovation capacity. The green low-carbon transition level (GLCT) yields a mean of 0.469, with high variance suggesting heterogeneous performance in low-carbon development. For the moderating variables, the digital use gap (DUG) shows the highest volatility, with a maximum value reaching 35.41, illustrating severe imbalances in digital technology penetration. With 495 observations for each variable, the sample is sufficient for empirical scrutiny, showing a balanced distribution free from extreme outliers.

Table 2. Descriptive Statistics for Key Variables.

Variable Type	Variable	Obs	Mean	Sd	Min	Max
Dependent Variable	NQP	495	0.1620	0.0780	0.0593	0.5316
Independent Variable	DF	495	5.2207	0.3755	4.0791	5.7472
Mediating Variables	RI	495	5.5823	7.5466	0.1038	45.5501
	GLCT	495	0.5327	0.8142	0.0009	2.5271
	DAG	495	2.8709	1.4460	0.1028	6.5153
Moderating Variable	DUG	495	6.8046	5.3956	0.7468	35.4076
	DCG	495	8.9504	0.9762	4.4285	11.2580
	UL	495	0.5381	0.1681	0.1815	0.9785
Control Variables	CSL	495	4.6245	0.0083	4.5901	4.6501
	FDL	495	2.5475	1.3209	0.7318	7.1543
	TRL	495	7.5105	2.6330	3.0547	18.3993
	ESL	495	0.0985	0.0838	0.0045	0.5161

5. Results and Discussion

5.1. Baseline Regression Results

We begin by determining the appropriate model specification. The Hausman test statistic strongly rejects the null hypothesis ($p < 0.01$), providing clear evidence in favor of the Fixed Effects (FE) model over a Random Effects specification. Accordingly, all subsequent analyses employ an FE model.

The baseline regression results are reported in Table 3. In Column (1), where we control only for year and city fixed effects, the coefficient on digital finance is positive and significant at the 1% level. This result remains robust after introducing a comprehensive set of control variables in Column (2). This finding provides strong support for Hypothesis H1, indicating that digital finance is a significant driver for the development of New Quality Productive Forces (NQP) in ethnic minority regions.

Table 3. Mediation effect test.

Variable	(1) NQP	(2) NQP	(3) RI	(4) NQP	(5) GLCT	(6) NQP
DF	0.0453 *** (0.0033)	0.0195 *** (0.0056)	2.7375 *** (0.8947)	0.0140 ** (0.0052)	−0.5317 *** (0.0321)	0.0155 ** (0.0051)
RI				0.0023 *** (0.0003)		
GLCT						−0.0170 ** (0.0059)
UL		0.0207 *** (0.0056)	2.0260 * (0.9089)	0.0159 ** (0.0052)	−0.0393 (0.0349)	0.0186 *** (0.0043)
CSL		−0.0008 (0.0013)	−0.3808 * (0.2058)	0.0017 (0.0283)	0.0014 (0.0023)	−0.0008 (0.0013)
FDL		0.0208 *** (0.0053)	4.4579 *** (0.8651)	0.0107 * (0.0051)	0.3551 *** (0.0318)	0.0188 *** (0.0045)
TRL		−0.0028 (0.0025)	−1.6159 *** (0.4068)	0.0009 (0.0024)	0.0676 (0.0469)	−0.0026 (0.0025)
ESL		−0.0072 (0.0064)	−1.1085 (1.0446)	−0.0043 (0.0060)	−0.2992 * (0.1206)	−0.0079 (0.0065)
_cons	−0.0746 *** (0.0173)	0.0604 * (0.0295)	−8.7094 * (4.6748)	0.0762 ** (2.84)	3.309 *** (0.1679)	0.0891 ** (0.02856)
Year	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
N	495	495	495	495	495	495
R ²	0.8752	0.8527	0.8847	0.8877	0.9531	0.7755
F	71.50	20.35	3.38	21.19	228.89	31.48

Notes: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The same notation applies to subsequent tables.

The analysis of control variables in Column (2) yields further insights. The coefficients for both urbanization level (UL) and financial development level (FDL) are positive and highly significant ($p < 0.01$), suggesting they are conducive to fostering NQP. Finally, the coefficient for resident consumption level (CSL) is statistically insignificant, suggesting that NQP formation in the sampled regions is less reliant on local consumption dynamics.

5.2. Mediation Effect Test

5.2.1. Technological Innovation as a Mediator

We first test the hypothesis that technological innovation mediates the relationship between digital finance and NQP. The results, presented in Columns (3) and (4) of Table 3, support this proposition. Column (3) establishes the first condition for mediation, showing that digital finance has a significant positive effect on technological innovation. Column (4) presents the results of the full mediation model. The coefficient on technological innovation

is positive and significant, while the coefficient on digital finance remains significant but is attenuated compared to the baseline coefficient in Column (2) (0.0195). This pattern confirms that technological innovation acts as a partial mediator, lending strong support to Hypothesis H2.

5.2.2. Green and Low-Carbon Transition as a Mediator

Next, we examine whether the green and low-carbon transition, measured by CO₂ emissions per unit of GDP (a reverse indicator), mediates the effect of digital finance on NQP. The results are reported in Columns (5) and (6) of Table 3.

Path a, estimated in Column (5), shows that digital finance is significantly and negatively associated with CO₂ emissions. This suggests that digital finance effectively accelerates the green transition in ethnic regions. Path b, estimated in Column (6), reveals that lower CO₂ emissions are significantly associated with higher NQP levels. Crucially, the mediation effect is the product of two negative paths (Path a and Path b), resulting in a positive indirect effect. This confirms that digital finance enhances NQP by driving a greener, low-carbon economy. Because the direct effect of digital finance remains significant in Column (6) but is smaller than the baseline coefficient, we conclude that the green and low-carbon transition plays a partial mediating role. This provides robust evidence for Hypothesis H3.

To further validate the internal mechanisms, this study employs the Bootstrap method (with 1000 resamples) to test the mediating roles of technological innovation (RI) and green low-carbon transformation (GLCT). The results are presented in Table 4.

Table 4. Bootstrap Test Results for Mediation Mechanisms.

Mechanism	Observed Coef.	Bootstrap Std. Err	Z	$p > z $	Bias-Corrected [95% Conf. Interval]		Proportion
RI							
Total Effect	0.0220	0.0070	3.1429	0.0017	0.0080	0.0360	—
Direct Effect	0.0130	0.0060	2.1667	0.0303	0.0001	0.0242	59.09%
Indirect Effect (Mediation)	0.0090	0.0030	3.0000	0.0027	0.0040	0.0170	40.91%
GLCT							
Total Effect	0.0356	0.0048	7.4583	0.0000	0.0261	0.0450	—
Direct Effect	0.0254	0.0066	3.8290	0.0001	0.0130	0.0394	71.35%
Indirect Effect (Mediation)	0.0102	0.0050	2.0160	0.0438	0.0014	0.0213	28.65%

For the technological innovation (RI) pathway: The indirect effect coefficient is 0.0090, which is statistically significant at the 1% level ($p = 0.0027$). The bias-corrected 95% confidence interval is [0.0040, 0.0170], excluding zero and thus confirming the validity of the mediation effect. This pathway accounts for 40.91% of the total effect, suggesting that fostering regional innovation is a primary channel through which digital finance bolsters new quality productive forces.

For the green low-carbon transformation (GLCT) pathway: The indirect effect is estimated at 0.0102, remaining significant at the 5% level ($p = 0.0438$), with a 95% confidence interval of [0.0014, 0.0213]. This mediation effect contributes 28.65% to the total impact.

These findings provide robust empirical support for the theoretical hypothesis that digital finance facilitates a productivity paradigm shift by simultaneously driving technological breakthroughs and catalyzing green industrial transitions. Notably, the mediating role of technological innovation appears more pronounced in this process.

5.3. The Moderating Role of the Digital Divide

We further investigate the moderating role of the digital divide. Drawing on prior research, we conceptualize the digital divide along three dimensions: access, usage, and capability. We test the hypothesis that each dimension attenuates the positive impact of digital finance on NQP. As reported in Table 5, the interaction terms between digital finance and the access divide ($DF \times DAG$), the usage divide ($DF \times DUG$), and the capability divide ($DF \times DCG$) are all negative and significant.

Table 5. Moderation Effect Analysis.

Variable	(1) NQP	(2) NQP	(3) NQP
DF	0.0255 *** (0.0068)	0.0458 *** (0.0053)	0.0284 *** (0.0059)
DAG	−0.0132 *** (0.0024)		
$DF \times DAG$	−0.0058 ** (0.0021)		
DUG		−0.0016 ** (0.0005)	
$DF \times DUG$		−0.0082 *** (0.0011)	
DCG			−0.0940 *** (−4.25)
$DF \times DCG$			−0.0033 *** (0.0221)
_cons	0.0296 (0.0357)	−0.0728 * (0.0301)	0.853 *** (0.1879)
N	495	495	495
R ²	0.8255	0.8337	0.8705
F	160.55	63.40	96.36

Notes: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The negative sign of these interaction terms, in contrast to the positive main effect of digital finance, confirms a significant moderating effect. Specifically, a wider digital divide—whether in terms of access, usage, or capability—substantially weakens the ability of digital finance to foster NQP in ethnic minority regions. This result lends robust support to Hypothesis H4.

5.4. Heterogeneity Analysis by Region

To explore potential regional heterogeneity, we partition our sample into Northwest and Southwest subsamples. The Northwest group consists of cities in Xinjiang, Tibet, Qinghai, Ningxia, and Inner Mongolia, while the Southwest group includes cities in Guangxi, Yunnan, and Guizhou. We then re-estimate our baseline model for each subsample, with the results presented in Table 6.

Digital finance exerts a significant positive effect on NQP in both regions. However, the magnitude of this effect differs markedly. The coefficient for the Northwest subsample (0.0541) is more than four times larger than that for the Southwest subsample (0.0133). This finding suggests that the benefits of digital finance are more pronounced in the Northwest.

A plausible explanation lies in the differing baseline conditions. The Northwest region, historically characterized by economic lags and underdeveloped infrastructure, has a greater “potential for improvement.” In this context, digital finance acts as a powerful catalyst, overcoming traditional financial barriers and unlocking growth in local indus-

tries, resource development, and green initiatives. Conversely, the Southwest region, with its more developed economy and financial system, may experience diminishing marginal returns from digital finance, as the initial infrastructure and access gaps are less severe.

Table 6. Heterogeneity Analysis.

Region Variable	(1) Northwest NQP	(2) Southwest NQP
DF	0.0541 *** (0.0107)	0.0133 ** (0.0049)
_cons	−0.1034 * (0.0552)	0.0845 ** (0.0256)
Controls	Yes	Yes
Year	Yes	Yes
City	Yes	Yes
N	187	308
R ²	0.8607	0.8297
F	19.79	35.87

Notes: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5.5. Analysis of the Spatial Spillover Effects of Digital Finance on New Quality Productive Forces

5.5.1. Theoretical Analysis

Digital finance mitigates geographical barriers through technological empowerment and information transparency, exerting profound spatial spillover effects on the development of new quality productive forces in adjacent regions [38]:

First, the technology diffusion and demonstration effect. By significantly reducing information transmission costs, digital finance amplifies the demonstration role of mature digital transformation models and technical expertise from leading cities. Through the “learning-by-doing” mechanism, neighboring regions can adopt advanced practices with lower trial-and-error costs, thereby catalyzing a collaborative leap in regional productivity levels.

Second, the factor mobility and optimized allocation effect. Digital finance dismantles the “financial island” constraints prevalent in border areas, facilitating the efficient cross-regional flow of core elements such as capital, data, and talent within ethnic minority regions. This optimized allocation generates a “point-to-surface” radiation effect, fostering the contiguous growth of new quality productive forces in surrounding cities.

Third, the network synergy and scale dividend effect. Digital finance exhibits significant network externalities. As digital infrastructure becomes increasingly interconnected, scattered idiosyncratic resources in border areas are integrated into a unified digital market network. This cross-spatial synergy enhances overall resource conversion efficiency, allowing regions to collectively share the scale dividends arising from the evolution of new quality productive forces.

In summary, digital finance likely exerts a positive spatial spillover effect in promoting new quality productive forces within ethnic minority regions.

5.5.2. Empirical Testing

To explore the spatial spillover effects of digital finance on new quality productive forces in ethnic minority regions, we extend the benchmark regression model (1) by incor-

porating the spatial lag terms of the dependent variable, the core independent variable, and the vector of control variables. The Spatial Durbin Model (SDM) is specified as follows:

$$NQP_{it} = \rho W NQP_{it} + \beta_1 DF_{it} + \theta_1 W DF_{it} + \beta_2 Z_{it} + \theta_2 W Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

where ρ denotes the elasticity coefficient of the spatial lag of the dependent variable; θ_1 and θ_2 represent the elasticity coefficients for the spatial lag terms of the core explanatory variable and the vector of control variables, respectively; and W signifies the spatial weight matrix.

First, the Global Moran's I index is employed to examine the presence of spatial effects in the new quality productive forces within ethnic minority regions, with the results presented in Table 7. As shown in Table 7, the Moran's I values for the new quality productive forces in these regions from 2013 to 2023, calculated under the economic distance weight matrix, are all significant at the 1% level. This indicates that the new quality productive forces across the 45 prefecture-level cities in ethnic minority regions exhibited significant spatial autocorrelation throughout the 11-year period.

Table 7. Moran's, I Index of New Quality Productive Forces in Ethnic Minority Regions.

Year	2013	2014	2015	2016	2017	2018
Moran'I	0.409 ***	0.465 ***	0.430 ***	0.433 ***	0.455 ***	0.430 ***
Year	2019	2020	2021	2022	2023	
Moran'I	0.397 ***	0.350 ***	0.346 ***	0.316 ***	0.296 ***	

Notes: Standard errors are reported in parentheses. *** denote significance at the 1% levels, respectively.

Second, the Lagrange Multiplier (LM), Likelihood Ratio (LR), and Hausman tests, along with the SDM simplification tests, were employed to confirm the Spatial Durbin Model (SDM) as the most appropriate estimation model. To ensure the robustness of the findings, the spatial spillover effects under the geographical inverse distance matrix are also presented, with the results detailed in Table 8. Second, the Lagrange Multiplier (LM), Likelihood Ratio (LR), and Hausman tests, along with the SDM simplification tests, were employed to confirm the Spatial Durbin Model (SDM) as the most appropriate estimation model. To ensure the robustness of the findings, the spatial spillover effects under the geographical inverse distance matrix are also presented, with the results detailed in Table 8. Column (1) reports the spatial spillover effects based on the economic distance weight matrix, showing that digital finance exerts a significant positive spatial spillover effect on the new-type productivity of ethnic regions at the 5% significance level. Column (2) further examines the spatial spillover effects of digital finance on new-type productivity under the geographical inverse distance matrix, and the results confirm that the positive spatial spillover effect remains robust.

Finally, considering that the coefficients of the spatial interaction terms cannot directly reflect the marginal impacts of the explanatory variables, we decompose the influence into long-term direct, indirect, and total effects under the economic distance matrix. This approach allows for a more accurate assessment of the impact and spatial spillover of digital finance on new quality productive forces. As reported in Table 9, all three effects are significantly positive. Notably, the contribution of the indirect effect is slightly larger than that of the direct effect, suggesting that the spatial spillover effect of digital finance from neighboring regions on local new quality productive forces outweighs the direct positive impact of local digital finance development.

Table 8. Spatial Spillover Effects.

Model	SDM (1)	SDM (2)
Matrix Type	Econ-dist Matrix	Geo-inv-dist Matrix
DF	0.0214 ** (0.0099)	0.0757 *** (0.0225)
Spatial rho	0.4429 *** (0.0503)	0.4672 *** (0.0948)
$W \times DF$	0.0048 (0.0104)	0.0834 *** (0.0241)
sigma2_e	0.0006 *** (0.0000)	0.0005 *** (0.0000)
Controls	Yes	Yes
Year	Yes	Yes
City	Yes	Yes
N	495	495
R ²	0.8361	0.8970

Notes: Standard errors are reported in parentheses. ***, ** denote significance at the 1%, 5% levels, respectively.

Table 9. Long-term direct, indirect, and total effects.

	LR_Direct	LR_Indirect	LR_Total
DF	0.0232 ** (2.40)	0.0240 ** (2.18)	0.0472 *** (7.36)

Notes: Standard errors are reported in parentheses. ***, ** denote significance at the 1%, 5% levels, respectively.

5.6. Robustness Checks

5.6.1. Endogeneity Concerns

A primary concern in our analysis is potential endogeneity, which could stem from either reverse causality or omitted variable bias. We address this concern with two strategies.

First, to mitigate reverse causality, we replace the contemporaneous digital finance variable with its one-period lag. This specification assumes that current-period NQP cannot affect past-period digital finance. The results are presented in column 1 of Table 10.

Table 10. Endogeneity Test Results.

Variable	(1) NQP	(2) DF	(3) DF
L.DF	0.0215 *** (0.0051)		
IV1		0.1096 *** (0.0121)	
IV2			0.2301 *** (0.0171)
_cons	0.0524 ** (0.0262)	5.2207 *** (0.0140)	5.2207 *** (0.0121)
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
Kleibergen-Paap rkLM		50.236 [0.000]	133.333 [0.000]
Kleibergen-Paap rkWald F		81.514 [16.38]	181.566 [16.38]
N	450	495	495
R ²	0.9155	0.8837	0.8972
F	36.40	62.84	86.25

Notes: Standard errors are reported in parentheses. ***, ** denote significance at the 1%, 5% levels, respectively.

Second, to account for potential omitted variables that are correlated with both digital finance and NQP, we employ an instrumental variable (IV) strategy using a Two-Stage Least Squares (2SLS) estimator. We propose two instruments: (1) terrain ruggedness and (2) the spherical distance to Hangzhou, a hub of digital finance innovation. As these geographical variables are time-invariant, we interact them with a time-varying factor—the lagged number of mobile phone subscribers—to create valid instruments for our panel data model.

The results strongly support the robustness of our baseline findings. As shown in Column (1), the lagged digital finance variable has a positive and highly significant effect on NQP (significant at the 1% level), suggesting our results are not driven by simple reverse causality. Columns (2) and (3) present the 2SLS estimates. Crucially, the diagnostic tests confirm the validity of our instruments: the underidentification test (Kleibergen-Paap rk LM statistic) is rejected, and the weak identification test (Kleibergen-Paap rk Wald F-statistic) is well above the conventional critical values. In these IV regressions, the coefficient on digital finance remains positive and statistically significant, bolstering the causal interpretation that digital finance promotes the development of NQP.

5.6.2. Alternative Specifications

To ensure our findings are not dependent on a particular model specification, we conduct two additional robustness tests.

First, we test the sensitivity of our results to the measurement of the dependent variable. We construct an alternative proxy for new quality productivity (NQP_{new}) using Principal Component Analysis (PCA) and re-estimate our baseline model. The result, reported in Column (1) of Table 11, shows that the coefficient on digital finance remains positive and highly significant ($p < 0.01$). This provides strong evidence that our core finding is not an artifact of our chosen NQP measure.

Table 11. Robustness Checks.

Variable	(1) NQP _{new}	(2) NQP	(3) NQP	(4) NQP	(5) NQP	(6) NQP
DF	0.5213 *** (0.0636)	0.0308 *** (0.0046)	0.0301 *** (0.0048)	0.0220 *** (0.0053)	0.0191 *** (0.0056)	0.0195 *** (0.0056)
UL	0.1277 * (0.0631)	0.0240 *** (0.0055)	0.0241 *** (0.0055)	0.0231 *** (0.0054)	0.0212 *** (0.0056)	0.0207 *** (0.0056)
CSL	0.0092 (0.0143)		−0.0007 (0.0013)	−0.0007 (0.0013)	−0.0007 (0.0013)	−0.0008 (0.0013)
FDL	0.2425 *** (0.0600)			0.0180 *** (0.0050)	0.0204 *** (0.0053)	0.0208 *** (0.0053)
TRL	−0.0684 * (0.0282)				−0.0035 (0.0024)	−0.0028 (0.0025)
ESL	−0.1156 (0.0726)					−0.0072 (0.0064)
_cons	−2.7250 *** (0.3321)	0.0011 (0.0242)	0.0049 (0.0252)	0.0474 * (0.0276)	0.0625 * (0.0294)	0.0604 * (0.0295)
Year	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
N	495	495	495	495	495	495
R ²	0.6816	0.8268	0.8236	0.8491	0.8682	0.8527
F	16.82	42.48	42.02	20.67	20.46	20.35

Notes: Standard errors are reported in parentheses. ***, * denote significance at the 1%, 10% levels, respectively.

Second, we verify the stability of our coefficient of interest by sequentially adding control variables to the model. The results, presented in Columns (2) through (6) of Table 7, reveal a remarkable consistency: the estimated effect of digital finance on new quality productivity remains stable and statistically significant across all specifications. This stability demonstrates that our main conclusion is not sensitive to the inclusion of different covariates, further bolstering the reliability of our findings.

6. Conclusions

6.1. Research Conclusions

Based on panel data from 2013 to 2023 covering 45 prefecture-level and above cities in ethnic minority regions, this study systematically investigates the driving effects of digital finance on new quality productive forces through multi-dimensional econometric frameworks. The key findings are summarized as follows:

First, digital finance serves as a critical catalyst for overcoming productivity bottlenecks in border ethnic regions. Empirical evidence underscores that digital finance significantly enhances new quality productive forces. The core mechanism lies in its ability to transcend physical spatial barriers through digital technology, thereby facilitating a qualitative reshaping of laborers, production objects, and means of production.

Second, the driving influence of digital finance exhibits pronounced positive spatial spillover characteristics. Local digital finance development not only bolsters domestic productivity but also fosters synergetic evolution in neighboring regions via cross-regional technology diffusion and factor mobility. This mechanism effectively alleviates the constraints imposed by geographical isolation in border areas.

Third, technological innovation and green, low-carbon transformation are the pivotal linkages for achieving a productivity paradigm shift. Our analysis reveals that digital finance empowers green technological progress and catalyzes a transition toward low-carbon production modes, initially realizing a synergy between ecological conservation and industrial advancement in ethnic regions.

Fourth, digital divides—specifically in access, usage, and literacy—exert a significant negative moderating effect. This highlights a critical dilemma in border regions: infrastructure deficiencies hinder physical access, while a severe shortage of digital services in minority languages and educational lags result in low digital skill penetration. Consequently, widespread digital exclusion among border populations inhibits the empowering potential of digital finance on productivity.

Fifth, the driving efficacy of digital finance demonstrates significant regional heterogeneity, following the principle of “higher marginal effects in less-developed areas.” Heterogeneity tests indicate that the promotional effect of digital finance is markedly stronger in Northwest ethnic regions than in the Southwest. The underlying logic is that while the Northwest faces economic and infrastructural lags, digital finance compensates for the “void” left by traditional financial systems, generating a robust “catch-up effect.” In contrast, the more developed financial systems in the Southwest mean that the marginal contribution of digital finance is constrained by financial deepening, leading to relatively moderate growth momentum.

6.2. Policy Implications

Based on the aforementioned findings and the unique socio-economic landscape of border ethnic regions, this study proposes the following policy recommendations:

1. Enhance adaptive digital infrastructure to dismantle physical and linguistic barriers.

Governments should prioritize targeted investments in 5G base stations and computing power centers in remote border areas to bridge the “last mile” of digital access.

More critically, financial institutions should be encouraged to develop multilingual digital financial products and user interfaces tailored to ethnic minority languages. By mitigating information asymmetry caused by linguistic and cultural disparities, these measures will ensure that digital financial dividends reach diverse border populations, fundamentally addressing the root causes of digital exclusion.

2. Strengthen digital literacy initiatives to bridge usage and capability gaps.

Leveraging the vocational and distance education systems in ethnic regions, the government should launch specialized digital skills training programs for farmers and small-to-medium enterprise (SME) owners. Emphasis should be placed on popularizing advanced digital financial tools and enhancing the capacity of the workforce to utilize digital information for innovation and entrepreneurship. Such efforts will transform the human capital constraints of border regions into a strategic reservoir of digital laborers aligned with the requirements of new quality productive forces.

3. Establish mechanisms for the value realization of ecological products to balance conservation and development.

Digital finance should be utilized to precisely quantify the value of ecological assets and foster a robust green credit system. Policymakers should guide financial resources toward specialized ecological industries and low-carbon technologies in border areas. By supporting the assetization and capitalization of ecological resources through digital technology, ethnic regions can uphold ecological imperatives while simultaneously cultivating green new quality productive forces with distinctive regional characteristics.

4. Construct differentiated regional synergy mechanisms to foster contiguous productivity growth.

A “category-based” guidance strategy should be implemented to address the empirical disparities between the Northwest and Southwest regions. For the Northwest, policies should focus on the “gap-filling” function of digital finance, releasing greater marginal dividends by enhancing infrastructure and financial penetration. For the Southwest, efforts should leverage the existing economic foundation to explore the deep integration of digital finance with high-tech industries and modern services, thereby elevating the innovation trajectory. Furthermore, breaking administrative barriers and promoting inter-provincial data sharing and technical collaboration will facilitate a “lead-and-link” model, narrowing the intra-border digital divide and achieving cross-regional coordinated evolution of new quality productive forces.

6.3. Limitations and Future Research Directions

While this study provides a systematic analysis of the mechanisms through which digital finance drives new quality productive forces in border ethnic regions, several limitations remain due to data and resource constraints, offering fertile ground for future exploration:

First, the depth of micro-level empirical evidence warrants further strengthening.

This study primarily utilizes macro-level panel data at the prefecture level and above. Although it reveals broader regional evolutionary patterns, it lacks granular insights into micro-level agents, such as individual households and small-and-medium enterprises (SMEs) in ethnic border areas. Future research could integrate household-level survey data to conduct more nuanced investigations. Specifically, researchers might examine how digital finance facilitates the overcoming of linguistic barriers, the enhancement of digital literacy, and the subsequent transformation of individual production behaviors from a bottom-up perspective.

Second, the dynamic evolution of index construction requires continuous refinement.

The concept of “new quality productive forces” is a scientifically evolving paradigm whose definition and measurement systems shift alongside rapid technological advancements. Although this study constructs an evaluation framework encompassing the qualitative states of the three core elements of production, certain frontier technological indicators were excluded due to data accessibility constraints in border regions. To address this, future studies may employ advanced methodologies—such as web scraping and patent text mining—to develop a more precise, sensitive, and multidimensional evaluation framework that captures the real-time dynamics of technological innovation.

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References

1. CPC Central Committee. Resolution of the Central Committee of the Communist Party of China on Further Deepening Reform Comprehensively to Advance Chinese Modernization. Xinhua News Agency. 2024. Available online: https://www.mfa.gov.cn/eng/xw/zyxw/202407/t20240721_11457437.html (accessed on 24 March 2026).
2. Zhang, Z.; Liao, Z.W. Research on high-quality economic development of ethnic regions driven by new quality productive forces. *Guizhou Ethn. Stud.* **2025**, *46*, 113–119. [CrossRef]
3. Li, H.J. Accelerating the development of new quality productive forces: Theoretical connotation and practical logic. *Econ. Manag.* **2025**, *39*, 10–18.
4. Zheng, Q.; Hu, M.X. Digital finance empowering the development of new quality productive forces: Theoretical logic, realistic dilemma and breakthrough path. *Reform* **2025**, *5*, 78–89.
5. Chen, W.; Wang, J. The developmental economics significance of new quality productivity in ethnic minority regions. *Qinghai Ethn. Stud.* **2024**, *35*, 53–64.
6. Zhang, X.; Ma, Y. The necessity, scientific nature, and focus points of developing new quality productivity based on local conditions. *J. Beijing Univ. Technol. Soc. Sci. Ed.* **2024**, *24*, 118–130.
7. Song, Y.L.; Lü, G.F. New quality productivity empowering high-quality development in ethnic minority regions: Internal logic, practical challenges and practical logic. *Qinghai Soc. Sci.* **2024**, *2*, 90–99. [CrossRef]
8. Zhang, L. The logic and pathways of new quality productivity driving high-quality development of rural industries in ethnic minority regions. *J. Yunnan Minzu Univ. Philos. Soc. Sci. Ed.* **2024**, *41*, 151–160.
9. Wu, X.; He, C. The logic and paths for new quality productivity to promote high-quality development in ethnic minority areas. *J. Hubei Minzu Univ. Philos. Soc. Sci.* **2024**, *42*, 58–68.
10. Song, C. Advancing the process of Chinese-style modernization in ethnic minority regions. *Guizhou Ethn. Stud.* **2024**, *45*, 18–24.
11. Liu, Y.; Zhong, F. New quality productivity empowering industrial modernization in ethnic minority regions: Internal logic and practical approaches. *Guizhou Ethn. Stud.* **2024**, *45*, 176–182.
12. Li, X.H.; Wang, G.D. The internal logic and practical pathways for developing new quality productivity in ethnic minority regions. *J. North Minzu Univ.* **2024**, *36*, 158–167. [CrossRef]
13. Tan, Z. Developing new quality productivity in ethnic minority regions: Internal logic, advantages, challenges, and practical paths. *J. Hubei Minzu Univ. Philos. Soc. Sci.* **2024**, *42*, 94–102.

14. Wu, T.; Zhong, Q.C. The internal logic and practical pathways for accelerating the formation of new quality productive forces in frontier ethnic minority regions. *Tibet Dev. Forum* **2024**, *4*, 30–35.
15. Huang, Y.P.; Huang, Z. Digital finance: Connotation, development, and challenges. *China Econ. Q.* **2023**, *23*, 2127–2140.
16. Ma, H.; Yin, Y.; Liu, Z.; Bai, Y. A study of the impact of digital finance usage on household consumption upgrading: Based on financial asset allocation perspective. *Int. Rev. Econ. Financ.* **2024**, *96*, 103628. [[CrossRef](#)]
17. Zhu, B.; Zeng, L. The impact of digital finance development on regional new quality productivity and its mechanism. *Collect. Essays Financ. Econ.* **2024**, *8*, 16–31.
18. He, X.; Hou, J. The mechanism and effects of digital finance promoting the development of new quality productivity. *J. Yunnan Norm. Univ. Philos. Soc. Sci. Ed.* **2024**, *56*, 66–79.
19. Yang, G.; Tang, L. A study on new quality productivity and its relationship from the perspective of digital inclusive finance. *J. Yunnan Minzu Univ. Philos. Soc. Sci. Ed.* **2024**, *41*, 84–94.
20. Sun, X.Z.; Li, Y.; Gao, Y.C. Digital inclusive finance development and corporate new quality productive forces. *Lanzhou Acad. J.* **2024**, *7*, 54–67.
21. Cao, Z.; Tu, Q.; Hu, Z. The impact of digital inclusive finance on the new quality productivity of agriculture-related enterprises: A mechanism analysis based on rural industrial integration. *J. Hunan Agric. Univ. Soc. Sci. Ed.* **2024**, *25*, 106–116.
22. Lin, J.; Ju, Z. Research on the impact and mechanism of digital inclusive finance empowering urban-rural common prosperity: From the perspective of new quality productivity. *J. Yunnan Minzu Univ. Philos. Soc. Sci. Ed.* **2024**, *41*, 106–119.
23. Yang, Q.; Wang, W. Digital inclusive finance, new quality productivity, and urban-rural common prosperity. *China Circ. Econ.* **2024**, *38*, 115–126.
24. Pang, H.; Yang, Y.; Gong, Y. Digital inclusive finance, new quality productivity and urban-rural integrated development. *Stat. Decis.* **2024**, *40*, 24–30.
25. Chen, J.; Zhang, Y. New quality productivity, digital finance and Chinese-style rural governance modernization. *Jinan J. Philos. Soc. Sci.* **2024**, *46*, 149–164.
26. Liao, H.; Qiu, Z.G. Research on the long-term mechanism of finance boosting new quality productive forces. *Theory Reform* **2024**, *3*, 52–63+159. [[CrossRef](#)]
27. Jiang, Y.M.; Guan, J. New quality productive forces: Evolutionary logic, scientific connotation, and realization path. *Economist* **2024**, *5*–14.
28. Yan, Z.Q.; Yang, Z.S.; Zhong, W. Impact of digital finance development on urban green total factor productivity: Effects and mechanisms. *Stat. Decis.* **2024**, *23*, 138–143. [[CrossRef](#)]
29. Han, W.L.; Zhang, G.Y. Theoretical logic and practical path of new quality productive forces empowering high-quality development. *Rev. Political Econ.* **2024**, *15*, 72–94.
30. Su, Y.; Liu, Y.N. The impact of digital finance on regional green innovation. *J. Quant. Econ.* **2024**, *15*, 18–33. [[CrossRef](#)]
31. Pan, J.H. New quality productive forces: Green background, scientific connotation, and realization path. *J. Beijing Univ. Technol. Soc. Sci. Ed.* **2024**, *24*, 1–12.
32. Qiu, Z.Q.; Zhang, S.Q. From access and usage to benefit: The evolution of digital divide and its reconstruction of inequality. *Soc. Stud.* **2023**, *38*, 1–24.
33. Shen, H.L. The impact of digital finance on high-quality development from the perspective of digital divide. *Stat. Inf. Forum* **2023**, *38*, 103–113.
34. Dong, Q.Q. Measurement, spatiotemporal evolution, and convergence of China's new quality productivity development level. *China Soft Sci.* **2024**, *39*, 178–188.
35. Guo, F.; Wang, J.Y.; Wang, F.; Kong, T.; Zhang, X. Measuring China's digital financial inclusion: Index compilation and spatial characteristics. *China Econ. Q.* **2020**, *19*, 1401–1418.
36. Ma, H.L.; Qu, X.E. The impact of digital inclusive finance on high-quality economic development: An analysis from the perspective of rural human capital and the digital divide. *Inq. Econ. Issues* **2021**, *42*, 173–190.
37. Wang, J.; Wang, R. New quality productivity: Indicator construction and spatio-temporal evolution. *J. Xi'an Univ. Financ. Econ.* **2024**, *37*, 31–47.
38. Chen, J.H.; Shen, Y.; Meng, F.R.; Wang, Y. Digital finance, technological innovation and new quality productive forces: An analysis based on spatial spillover effects and non-linear characteristics. *J. Quant. Technol. Econ.* **2024**, *41*, 112–133.

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