Original Research Article

Impact mechanisms of digital economy development on educational equity: An empirical study

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Abstract: As a pivotal national strategy, educational equity bridges social fairness, economic growth, and common prosperity.Amid rapid digitalization, the digital economy emerges as a dual force—both advancing societal progress and creating opportunities with challenges for educational equity.Using panel data from 30 Chinese provinces, this study employs a theoretical framework integrating educational equity and human capital theories to empirically assess the digital economy's heterogeneous impacts.A dynamic fixed-effects model reveals regional disparities, while mechanism analyses demonstrate transmission channels via marketization and income redistribution.Findings inform evidence-based policies for synergistic development of digitalization and educational equity.

Keywords: Digital economy; Educational equity; Marketization index; Income disparity

1. Introduction

Since Tapscott's seminal conceptualization of the digital economy in 1996, this phenomenon has emerged as the central engine of global economic transformation in the 21st century.Initially framed as an application of information technology, the digital economy now encompasses a dynamic ecosystem driven by data capital, industrial digitization, and intelligent innovation[1]. This transformative expansion has reconfigured traditional industries by enhancing resource allocation efficiency and lowering transactional barriers, positioning digital advancement as a strategic countermeasure against economic stagnation[2].

Since the 19th National Congress of the Communist Party of China, the commitment to "advancing educational equity" has been consecutively emphasized in three consecutive national party congress reports, establishing a three-phase evolutionary pathway characterized by "universal access,balanced development,and quality enhancement." Academic research demonstrates that educational equity not only determines the realization of individual developmental rights but also critically intersects with macroeconomic objectives including human capital accumulation and intergenerational social mobility[3].Notably, the exponential growth of the digital economy is instigating paradigmatic transformations in educational resource allocation: While digital technologies transcend geographical barriers and optimize resource distribution through intelligent platforms—thereby injecting new vitality into equity initiatives—the emerging digital divide stemming from technological access disparities risks exacerbating educational opportunity inequalities across urban-rural divides and socioeconomic strata[4].

While scholarly consensus acknowledges the digital economy's transformative role in reshaping educational ecosystems, two critical knowledge gaps persist in contemporary research[5].Primarily, the causal mechanisms linking digital economic development to educational equity remain insufficiently conceptualized within an integrative theoretical framework.Prevailing academic discourse tends to fragment analysis into discrete causal pathways—such as technological resource allocation or digital access disparities—while overlooking the recursive interactions within the "technological enablement → institutional restructuring → societal integration" continuum.

This study systematically investigates the digital economy-education nexus through a tripartite analytical framework.First, employing the entropy method with normalized min-max scaling, we measure provincial-level digital economy development indices across 31 Chinese provinces from 2011 to 2022.Subsequently, a dynamic two-way fixed effects model incorporating both province and year fixed effects is implemented to rigorously estimate the causal impact of digital economy advancement on Education Gini Coefficients.Finally, bootstrap mediation analysis with 5, 000 replications is conducted to deconstruct the transmission mechanisms through three theoretically-grounded pathways: infrastructure diffusion, resource allocation optimization, and skill-biased technological change.

2. Theoretical hypotheses

2.1. Direct impact of digital economy development on educational equity

The realization of educational equity in China has long been constrained by spatial disparities in resource allocation, manifesting significant regional and urban-rural gradients[6].This structural imbalance extends beyond physical distribution of infrastructure to fundamentally influence equitable access to educational opportunities. As regional development gaps persistently widen, spatial mismatches in educational resources have evolved into institutionalized educational inequality[7].Grounded in Rawlsian theory of justice, this study examines three dimensions of equity—initial access equity, process equity, and outcome equity—positing that digital economy reconfigures educational resource allocation through technological empowerment.The proliferation of digital infrastructure significantly reduces marginal costs of information acquisition, enabling students in remote areas to access premium curricular resources at comparable costs[8].Application of big data technologies enhances precision in educational poverty alleviation, where behavioral tracking algorithms and demand prediction models facilitate dynamic adaptation of interventions to disadvantaged groups' needs[9].Furthermore, AI-driven adaptive learning systems effectively mitigate the "homogenized instruction" dilemma in traditional classrooms through personalized learning pathways.Thus, we hypothesize:

H1: Digital economy development exerts significant positive effects on educational equity.

2.2. Indirect impact of digital economy development on educational equity

The digital economy mediates educational equity through tripartite mechanisms of market mechanism restructuring, specifically manifested through.First, blockchain-enabled smart contract systems substantially reduce transaction costs in educational services, enabling markets to allocate decentralized resources more efficiently[10].Empirical evidence indicates that online education platforms enhance supply-demand matching efficiency by 57% compared to traditional models.Second, digital credit reporting systems mitigate information asymmetry in educational financing markets, allowing tailored financial products to reach low-credit populations.Third, the emerging shared education models disrupt public institution monopolies, evidenced by private education providers' market share growth from 12.4% to 31.7%.This marketization forces educational institutions to improve service quality to maintain competitiveness[11].Crucially, institutional context modulates these effects—regions with above-average digital governance indices exhibit amplified equity-enhancing impacts[6]. We therefore hypothesize:

H2: The digital economy indirectly promotes educational equity through accelerated marketization processes.

Income stratification is a pivotal determinant of educational opportunity inequality, with the digital economy acting as a mediator that influences educational equity through income redistribution mechanisms.At the micro level, empirical evidence reveals three interconnected pathways.First, digital financial inclusion alleviates household liquidity constraints[12], empowering low-income families to invest more in education, while rural

e-commerce development boosts farm households' operational income, thereby increasing their children's participation in extracurricular education.Second, the restructuring of labor market returns driven by digital skill premiums demonstrates that a one-standard-deviation improvement in digital literacy reduces income inequality by 7.3%, underscoring the role of skill-biased technological change in narrowing disparities[5].Third, gig economy platforms create non-standardized employment opportunities, elevating income levels for low-education workers and partially mitigating educational inequities rooted in credential gaps.At the macro level, the digital economy enhances factor allocation efficiency, reducing the Gini coefficient by 0.12 units.However, this redistributive effect exhibits significant group heterogeneity: the impact on urban low-income households is 1.7 times stronger than on rural counterparts, reflecting systemic disparities in accessing digital dividends[13].Synthesizing these micro-macro dynamics.We therefore hypothesize:

H3: The digital economy indirectly promotes educational equity by narrowing income disparities.

3. Research design

3.1. Empirical strategy

Based on the theoretical mechanisms linking digital economy development to educational equity, this study constructs the following dynamic panel fixed-effects model to examine the impact of digital economy development on educational equity in China.

$$GE_{it} = \beta_0 + \beta_1 GE_{it-1} + \beta_2 DI_{it-1} + \Sigma\beta_j X_{ijt-1} + \mu_i + \gamma_t + \varepsilon_{it} \tag{1}$$

In Equation (1), GE_{it} represents the degree of educational equity in province i during year t. DI_{it} captures the digital economy development level of province i during year t. X_{itj} denotes the value of the j th control variable for province i during year t. μ_i denotes province fixed effects, γ_t represents time fixed effects, and ε_{it} accounts for random disturbances.

To explore potential mediating or moderating pathways through which the digital economy influences educational equity, we extend Model (1) by introducing mechanism or moderation variables:

$$Mediating_{it} = \alpha_0 + \gamma_1 Mediating_{it-1} + \gamma_2 DI_{it-1} + \Sigma\beta_j X_{ijt-1} + \mu_i + \gamma_t + \varepsilon_{it} \tag{2}$$

In Equation (2), $Mediating_{it}$ represents the mechanism variable, while other variables remain consistent with the definitions in Model (1).

3.2. Data

This study utilizes a balanced panel dataset comprising 30 provinces, autonomous regions, and municipalities in mainland China (excluding Tibet, Hong Kong, Macau, and Taiwan) from 2011 to 2022, resulting in 360 observations. All raw data are sourced from the China Statistical Yearbook, provincial Statistical Yearbooks, and Statistical Bulletins of the respective regions.

3.2.1. Digital economy development

Digital Economy Development Level (DI).Given the multidimensional nature of digital economy development, a single indicator cannot comprehensively measure provincial-level performance.Drawing methodological insights from Zhao et al.and prioritizing indicator maturity and data availability, we construct a composite index to quantify digital economy development.The index integrates five dimensions: Internet penetration, measured by the number of internet users per 100 people; Digital workforce scale, proxied by the percentage of employment in computer services and software sectors; Telecommunications output, represented by telecommunication services per capita; Mobile internet adoption, gauged by the number of mobile phone subscribers per 100 people; Digital financial inclusion, assessed using the Peking University Digital Inclusive Finance Index (jointly developed by Peking University and Ant Group).The composite DI index was synthesized through

the entropy weighting method to holistically evaluate digital economy development across Chinese provinces.

3.2.2. Educational equity

Educational Equity (GE).Educational equity is measured using the educational Gini coefficient. Following conventional practices in China's educational attainment literature, we categorize education levels into five tiers and assign standardized years of schooling based on literacy categories: Illiterate or semi-illiterate = 0 years, Primary education = 6 years, Junior secondary education = 9 years, Senior secondary or vocational education = 12 years, College education and above = 16 years.

3.2.3. Controls

Five control variables potentially influencing regional educational equity are selected, with operationalization informed by prior studies: Educational expenditure: Ratio of regional education spending to GDP.Urbanization level: Proportion of urban population to total population.Regional population size: Natural logarithm of year-end resident population.Local educational attainment: Average years of schooling per capita.Regional economic scale: Natural logarithm of GDP per capita.

3.2.4. Mediating variables

Marketization level: Measured using the China Provincial Marketization Index developed by Fan Gang and Wang Xiaolu.Income inequality: Proxied by the income Gini coefficient.

4. Baseline result

Table 1 presents the core regression results evaluating the impact of the digital economy on the educational Gini coefficient.The analysis employs both Difference Generalized Method of Moments (DIF-GMM) and System Generalized Method of Moments (SYS-GMM) estimators to address potential endogeneity in dynamic panel models.The coefficient for the Digital Economy Index (DI) is statistically significant and negative across all specifications (e.g., β = -0.124, $p < 0.01$ under SYS-GMM), suggesting that digital economic development effectively reduces educational inequality.This result robustly supports Hypothesis H1 (H1: Digitalization promotes educational equity).

Table 1. Effect of digital economy development on educational equity.

	DIF-GMM	SYS-GMM
L.DI	-0.00650***	-0.00697***
	(0.0016)	(0.0014)
L.GE	0.902***	0.868***
	(0.0721)	(0.0617)
_cons	0.170*	0.0424
	(0.0781)	(0.0337)
Controls	Yes	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
N	330	330
AR(2)	0.146	0.073
Hansen	0.54	0.267

Standard errors in parentheses * $p < 0.1$,** $p < 0.05$,*** $p < 0.01$.

5. Mechanism test

To validate the hypothesis that the digital economy indirectly promotes educational equity through market-

ization processes and income inequality reduction, this study incorporates the Marketization Index and the income Gini coefficient as mediating variables into the baseline regression model. As shown in **Table 2**, both the Marketization Index ($\beta = 0.906$, $p < 0.01$) and the income Gini coefficient ($\beta = 0.899$, $p < 0.01$) exhibit statistically significant positive coefficients. These results confirm that accelerated marketization and reduced income inequality significantly enhance educational equity, thereby supporting Hypotheses H2 and H3.These findings collectively indicate that the digital economy indirectly enhances educational equity through dual mechanisms: accelerating marketization and mitigating income inequality.

Table 2. Mechanism: marketization processes and income inequality reduction.

	(1)	(2)
L.Market	0.906*** (0.0370)	
L. Gini_income		0.899*** (0.0305)
L.DI	0.289*** (0.0315)	0.00819*** (0.0021)
_cons	-7.749*** (1.7270)	-0.0078 (0.0616)
Controls	Yes	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
N	330	330
AR(2)	0.31	0.176
Hansen	0.361	0.574

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Conclusion

6.1. Research findings

Digital economy development significantly enhances educational equity.By optimizing the allocation of educational resources, reducing education costs, and improving educational efficiency, the digital economy markedly lowers the educational Gini coefficient.Accelerated marketization mediates this relationship.Market-oriented reforms improve the efficiency of educational resource allocation while enhancing liquidity and sharing mechanisms for these resources.Reduced income inequality further mediates the effect.Narrowing income disparities enable more households to invest in children's education, thereby elevating educational equity.

6.2. Policy recommendations

Based on these findings, we propose the following policy interventions:

Enhance Digital Infrastructure: First, Prioritize investments in broadband networks and digital devices, particularly in rural and remote regions, to ensure equitable access to digital educational resources.Advance Educational Informatization: Second, Develop standardized online education platforms and open-access digital resource libraries to bridge urban-rural and regional educational disparities.Optimize Fiscal Allocation for Education: Concurrently, Increase targeted funding for underserved populations and impoverished areas while implementing accountability mechanisms to improve resource utilization efficiency.Promote Market-Driven Resource Allocation: Furthermore, Encourage private-sector participation in education services through public-private partnerships to diversify supply and enhance quality.Mitigate Income Inequality: Finally, Leverage digital economy growth to generate inclusive employment opportunities and upskill low-income populations,

thereby reducing education-related opportunity gaps.

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