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# Digital Intelligence Empowering High-Quality Economic Development: An Empirical Study Based on Provincial Panel Data from China

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***Abstract.*** This study examines the impact of digital-intelligence transformation on high-quality economic development. Based on data from the China Statistical Yearbook and the National Bureau of Statistics for the period 2014–2023, this study constructs an evaluation system to measure both high-quality economic development and the level of digital-intelligence transformation. The coefficient of variation method is used to build a panel regression dataset, and a two-way fixed-effects model with regional and time effects is applied to analyse the effects and mechanisms of digital-intelligence transformation. The results show that digital-intelligence transformation significantly promotes high-quality economic development. In particular, digital infrastructure development and digital technological research and innovation have strong positive effects. However, the development of the digital industry presents a negative effect, reflecting adjustment pressures during the growth of the digital-intelligence economy. This finding suggests that traditional industries may face efficiency losses or transformation costs when adopting digital technologies, providing evidence for more targeted policy design.

***Keywords:*** digital-intelligence transformation, high-quality economic development, impact mechanism, empirical analysis

## 1. Introduction

Currently, digital-intelligence technologies have been widely applied across multiple sectors—including manufacturing, agriculture, and services—effectively driving industrial upgrading and efficiency improvement. China's digital-intelligence economy has also achieved remarkable progress: the digital economy now accounts for over 40% of GDP, and the density of industrial robots ranks among the highest in the world. However, the development process still faces challenges such as regional disparities, issues of technological ethics, and intensified international competition.

Therefore, systematically clarifying the internal mechanisms through which digital intelligence empowers high-quality economic development and empirically testing these mechanisms to propose targeted policy recommendations, has become the central focus of this study. Through theoretical analysis and empirical investigation, this paper aims to address the following questions: Does

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digital-intelligence transformation promote high-quality economic development, and if so, in what ways? What are its underlying mechanisms? Do different dimensions of digital-intelligence transformation exert heterogeneous effects?

## 2. Literature review

The current literature on digital-intelligence transformation and high-quality economic development has developed across several major strands, offering a solid theoretical and empirical foundation for this study.

The first strand of studies examines mechanisms from macro perspective through which digital intelligence affects economic performance. Theoretical research generally suggests that digital technologies enhance economic outcomes by reducing information gaps, improving the efficiency of resource allocation and industrial upgrading, and lowering coordination and transaction costs [1]. By reorganising production factors and reshaping firms' value creation processes, digital intelligence is considered to foster technological advancement and improve operational efficiency, thereby contributing to high-quality economic development [2]. These perspectives provide the theoretical basis for the analysis conducted in this study.

Another stream in the literature focuses on firm-level behaviour, with how digital-intelligence transformation is implemented and its outcomes. Recent works show the specific methods that enterprises use to improve digital transformation. For instance, research on Sunward Intelligent indicates that digital transformation typically follows a well-organised and integrated process. This process includes the digitalisation of product life cycles as well as the coordination of the entire value chain. These practices help firms build long-term competitive advantages and improve overall performance [3]. Overall, this literature provides micro-level evidence on the real-world impacts of adopting digital-intelligence technologies in detail.

In addition, several studies explore how external conditions affect digital-intelligence transformation. Previous studies suggest that environmental factors play an important role. A good business environment can strengthen the positive effects of digital transformation. The differences in digital infrastructure, economic development, and human capital across regions determine the degree to which digital intelligence creates value. This evidence indicates that regional and institutional differences in empirical analysis should be taken into consideration. These works also point to key areas for more targeted policy actions.

Existing studies have provided valuable insights into macro-level mechanisms, firm-level practices, and contextual factors related to digital-intelligence transformation. However, there is a clear gap remains in connecting theoretical arguments with rigorous macro-level empirical evidence. Based on these research, this study develops an integrated analytical framework. Provincial panel data are used to examine the effects and transmission mechanisms of digital-intelligence transformation.

## 3. Theoretical hypotheses and empirical strategy

### 3.1. Development of hypotheses

Based on the existing literature, this study proposes the central hypothesis that digital-intelligence transformation plays a significant role in promoting high-quality economic development. This positive effect is expected to operate through three main mechanisms below:

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First, digital-intelligence transformation operates through an information-friction reduction mechanism. Digital-intelligence technologies significantly broaden information availability and enhance its transparency, timeliness and reliability. By reducing the costs of acquiring, processing, and transmitting information, these technologies enable more informed and efficient decisions in resource allocation, thereby supporting innovation activities and structural upgrading. Digital-intelligence systems also help overcome information segmentation across cities, facilitate real-time data exchange, and improve coordination in regional decision-making. Consequently, governance capacity and coordination efficiency within urban areas are obviously strengthened [4].

Second, the productivity enhancing channel. Aghion et al. highlight artificial intelligence as a key driver of future economic growth [5]. In this spirit, digital-intelligence transformation—through AI, industrial Internet platforms, and other smart technologies—reshapes production organisation by promoting automation, intelligent control, and flexible manufacturing [6]. These changes directly raise labor productivity and, via supply-chain optimisation and accelerated industrial upgrading, increase total factor productivity and strengthen the coupling between technological progress and economic development. Case evidence from FAW Group's Hongqi Prosperity Plant shows that industrial Internet and big data technologies enable equipment to self-diagnose failures, allow production processes to self-adjust, and support autonomous quality prediction and energy management. For instance, evidence from FAW Group shows that intelligent production systems and breakthroughs in key digital technologies can significantly improve sales performance, automation, and sustainability. The automation rate of the stamping line has reached 71.4%, and 739 robots in the welding line have achieved fully automated welding, while robots in the painting line have also recorded notable performance improvements [7]. These outcomes illustrate the sizable efficiency and quality gains associated with digital-intelligence adoption.

The third mechanism is cost-reducing channel. Digital-intelligence development can foster economic growth through innovation-based mechanisms [8]. By lowering traditional information-acquisition costs and factor-input costs, digital-intelligence technologies allow firms to reallocate resources toward R&D and innovation. At the same time, algorithm-assisted decision-making reduces trial-and-error and the opportunity costs of misjudgment, thereby promoting more efficient and greener resource use. For example, the construction of digital-intelligence supply-chain systems in Henan has improved cross-border e-commerce logistics efficiency, reduced supply-chain costs, and supported the upgrading and transformation of cross-border e-commerce firms [9].

Based on the above mechanisms, we expect a significant positive association between the degree of digital-intelligence transformation and the level of high-quality economic development. In our empirical specification, the coefficient on the core explanatory variable—digital-intelligence transformation—is therefore expected to be positive and statistically significant.

## 3.2. Empirical analysis

### 3.2.1. Data and construction of key variables

To measure high-quality economic development, an index comprising four dimensions is constructed—economic development, innovation, sustainability, and inclusiveness—which moves beyond the traditional GDP-centric framework and aligns with China's "innovation, coordination, green, openness, and shared development" principles. Digital-intelligence transformation is captured through three dimensions—digital infrastructure, digital industrial development, and digital technology innovation—reflecting its multi-layered structure from "foundation–application–innovation." All indices are aggregated using the coefficient-of-variation method to obtain a

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composite High-Quality Economic Development Index (HQEDI) and a Digital-Intelligence Transformation Index (DITI).

The dataset consists of a balanced panel for Chinese regions from 2014 to 2023, sourced from the China Statistical Yearbook and the National Bureau of Statistics.

#### 3.2.1.1. Dependent variable

High-Quality Economic Development Index (HQEDI). This index is constructed from four dimensions and ten indicators, as detailed below:

Economic development: This dimension reflects the foundation of high-quality development, emphasizing stable economic growth, rising household income, and the ability to participate in global markets. Indicators include GDP Index (previous year = 100), per capita disposable income, foreign trade dependence (total imports and exports / regional GDP).

Innovation: Given innovation's role as the primary driver of development, this dimension captures a region's innovative capacity. Indicators include Number of patent applications, share of science and technology expenditure in general public budget spending, degree of industrial upgrading (ratio of value-added in the tertiary sector to that in the secondary sector).

Sustainability: This dimension incorporates resource and environmental considerations alongside economic performance. Indicators include $SO_2$ emissions per 10,000 yuan of GDP (negative indicator), electricity-use efficiency (electricity consumption / GDP; negative indicator). Lower values indicate more efficient resource use and stronger sustainability performance.

Inclusiveness and equity: Given China's population size and regional heterogeneity, inclusive development—particularly in income distribution and public services—is essential. Indicators include Urban–rural income ratio (urban per capita income / rural per capita income; negative indicator). A lower value (closer to 1) reflects narrower income gaps and greater inclusiveness. And number of hospital beds per 10,000 residents, capturing equitable access to healthcare resources.

Table 1. High-quality economic development index

| Primary Indicator | Secondary Indicator | Interpretation | Indicator Direction |
|---|---|---|---|
| Economic Development | Regional GDP Index (PY = 100) | Measures the speed and stability of economic growth | + |
| | Per Capita Disposable Income | Reflects household income level and living standards | + |
| | Foreign Trade Dependence (Total Imports & Exports / Regional GDP) | Measures openness and participation in international markets | + |
| Innovation | Number of Patent Applications | Technological innovation capacity and output | + |
| | Share of S&T Expenditure in General Public Budget | Intensity of innovation input | + |
| | Industrial-to-Service Upgrading Ratio (Value Added of Tertiary Sector / Secondary Sector) | Degree of economic structural modernization | + |
| Sustainability | $SO_2$ Emissions per 10,000 RMB of GDP | Degree of environmental pollution | - |
| | Electricity-Use Efficiency (Electricity Consumption / GDP) | Efficiency of energy utilization | - |
| Inclusiveness & Equity | Urban–Rural Income Ratio (Urban / Rural Per Capita Income) | Income inequality and shared development | - |
| | Hospital Beds per 10,000 People | Provision and accessibility of public services | + |

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#### 3.2.1.2. Core explanatory variable

Digital-Intelligence Transformation Index (DITI). The degree of digital-intelligence transformation is measured using a composite index constructed from three dimensions and six underlying indicators, aggregated using the coefficient-of-variation method. Each dimension is designed to capture a distinct facet of "foundation–application–innovation" within digital-intelligence development.

Digital Infrastructure Construction Index (DICI): Digital infrastructure and digital skills are core drivers of economic growth within the digital economy. Specific indicators include total telecommunications service volume and mobile phone penetration rate.

Digital Industry Development Index (DIDI): This dimension measures the application of digital and intelligent technologies at the industrial level and their economic output. Specific indicators include the number of urban employees in information transmission, software and information technology services, and e-commerce sales volume.

Digital Technology Innovation Index (DTII): Innovation serves as the core driver for the sustained development of the digital economy. Specific indicators include the volume of domestic patent applications granted and the R&D expenditure of industrial enterprises above designated size.

All six indicators are treated as positive indicators, meaning that higher values correspond to a higher level of digital-intelligence transformation within the respective dimension.

Table 2. Digital-intelligence transformation index

| Primary Indicator | Secondary Indicator | Interpretation | Indicator Direction |
|---|---|---|---|
| DICI | Total telecommunications service volume | Fundamental network and communications capabilities | + |
| | Mobile phone penetration rate | Level of information access and coverage | + |
| DIDI | Number of urban employees in information transmission, software and information technology services | Scale and development level of the digital industry | + |
| | E-commerce sales volume | Degree of industrialisation and commercialisation of digital technologies | + |
| DTII | Volume of domestic patent applications granted | Technological innovation outputs | + |
| | R&D expenditure of industrial enterprises above designated size | Innovation investment capacity | + |

Descriptive statistics reveal that the mean value of the High-Quality Development Index stands at 0.253, while the mean of the Digital and Intelligent Transformation Index is 0.175. Furthermore, substantial variations exist across provinces and years for each variable, providing a robust basis for empirical analysis.

Table 3. Descriptive statistics (2014-2023)

| Variable | Observations | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| HQEDI | 310 | 0.2532 | 0.1495 | 0.0098 | 0.7704 |
| DITI | 310 | 0.1746 | 0.1890 | 0.0000 | 0.9094 |
| DICI | 310 | 0.2485 | 0.1836 | 0.0000 | 0.9061 |
| DIDI | 310 | 0.1716 | 0.2112 | 0.0000 | 0.8930 |
| DTII | 310 | 0.1817 | 0.2329 | 0.0000 | 1.0000 |

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### 3.2.2. Model construction and regression results

To test the theoretical hypotheses, the following basic econometric model was first established:

$$\mathrm{HQEDI}_{it} = \alpha_0 + \alpha_1 \mathrm{Infra\_index}_{it} + \alpha_2 \mathrm{Industry\_index}_{it} + \alpha_3 \mathrm{Innovation\_index}_{it} + \lambda_i + \theta_t + \epsilon_{it}$$

In the specification, $i$ and $t$ denote region and year, respectively. $\mathrm{HQEDI}_{it}$ represents the High-Quality Economic Development Index for region $i$ in year $t$. $\lambda_i$ and $\theta_t$ denote region fixed effects and year fixed effects, respectively, controlling for time-invariant regional characteristics and nationwide macroeconomic trends that are common across regions. $\epsilon_{it}$ is the random error term.

A pooled ordinary least squares (OLS) model is estimated. The estimation results presented in Table 4 indicate that the coefficient of the DITI is 0.7354 and is statistically significant at the 1% level. This finding offers preliminary empirical evidence in support of the core hypothesis, suggesting that higher levels of digital-intelligence transformation are closely associated with improvements in high-quality economic development.

Table 4. Pooled OLS results

| Dependent Variable: High-Quality Economic Development | |
|---|---|
| DITI | 0.7354***(0.0229) |
| Constant | 0.1248***(0.0043) |
| Observations | 310 |
| $R^2$ | 0.8637 |

To further explore differences across various dimensions of digital-intelligence transformation and to control for unobserved heterogeneity, a two-way fixed effects model (TFEM) is estimated. The composite index is decomposed into three sub-dimension indicators, and the corresponding estimation results are reported in Table 5. The estimated coefficients for DICI and DTII are both positive and statistically significant at the 1% level, with technological innovation showing the largest effect, at 0.364. These results indicate that research and development as well as digital-technology innovation serve as the primary driving forces of high-quality economic development, while advances in digital infrastructure provide the essential basis for the application of digital-intelligence technologies.

In contrast, the coefficient on the DIDI is negative (–0.103) and significant at the 10% level. This may indicate that, during the period under observation, the integration between emerging digital industries and traditional sectors remained incomplete, or that digital industrial expansion may exert short-term adjustment pressures on the existing economic structure. The positive effects of industrial digitalisation may therefore materialise with a lag or require complementary conditions to be fully realised.

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Table 5. TFEM results

| Dependent Variable: High-Quality Economic Development | |
|---|---|
| DICI | 0.173*** (0.041) |
| DIDI | -0.103*(0.054) |
| DTII | 0.364***(0.049) |
| Time-fixed | Yes |
| Region-fixed | Yes |
| Observations | 310 |
| $R^2$ | 0.385 |
| Adjusted $R^2$ | 0.288 |
| F Statistic | 13.921*** |

Empirical findings broadly support the theoretical hypotheses presented above. Overall, digital-intelligence transformation has demonstrated a significant enabling effect on China's high-quality economic development, with regression coefficients being positive and highly significant. This aligns with theoretical expectations and the trends observed in representative case studies such as FAW Group and Sunward Intelligent Machinery.

A detailed analysis across dimensions indicates that digital technological innovation represents the most important driver of digital-intelligence empowerment for high-quality economic development and exerts the strongest promoting effect. This finding highlights the central role of independent research and development as well as breakthroughs in key technologies in building long-term competitive advantages. At the same time, the strengthening of digital infrastructure also shows a significant positive impact, as it provides the essential foundation for the broad application of digital-intelligence technologies.

By contrast, the negative association observed for the digital industry development dimension is a notable result. This outcome may reflect transitional adjustment pressures within the digital-intelligence economy. The rapid growth of digital industries may temporarily draw resources such as capital and skilled labor away from traditional sectors. Besides, the process of industrial digitalisation requires time, and the complementary benefits between traditional industries and digital technologies tend to emerge only after deeper integration is achieved. These findings point to the need for a systematic policy approach. Such policies should support both the growth of digital industries and their deep integration with traditional sectors.

## 4. Key findings & policy recommendations

### 4.1. Key findings

Based on the theoretical framework and empirical results discussed above, this study derives several key conclusions.

First of all, digital-intelligence transformation significantly promotes high-quality economic development through three main pathways: reducing information frictions, improving production efficiency, and lowering development and coordination costs. The regional panel regression results confirm a strong and statistically significant positive relationship between the level of digital-intelligence transformation and the quality of economic development.

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Secondly, the enabling effects of digital intelligence display clear structural differences across dimensions. Among the three components, digital technological innovation functions as the most influential driving force, while digital infrastructure plays a critical supporting role by enabling the wide diffusion and application of digital-intelligence technologies.

Finally, the effects of digital industry development are relatively weak in the early stages and may involve certain adjustment pressures. This indicates that the integration of digital industries with traditional sectors remains incomplete, and that the full benefits of industrial digitalisation are likely to emerge gradually or under appropriate complementary conditions.

### 4.2. Policy recommendation

Building on these findings, this study offers several policy recommendations.

First, reinforce the central role of technological innovation and accelerate breakthroughs in key digital technologies. Continued investment is needed in frontier domains such as artificial intelligence, big data, and integrated circuits. Policies should encourage collaborative research among firms, universities, and research institutes to achieve breakthroughs in core technologies and strengthen the technological foundation for digital-intelligence transformation.

Second, promote deep integration between the digital and real economies and optimize the pathways through which digital industries generate spillovers. Policy efforts should move beyond merely supporting the expansion of digital industries and instead focus on fostering their substantive integration with the real economy and traditional sectors. Targeted initiatives—such as digital-intelligence empowerment programs for traditional industries—should be advanced, and successful cases (e.g., FAW Group, Sunward Intelligent) should be disseminated to address practical bottlenecks, shorten the adjustment period, and accelerate the diffusion of digitalisation gains across the broader economy.

Third, greater priority should be given to digital infrastructure development in order to narrow regional gaps in digital access. Sustained investment in 5G networks, computing capacity facilities—including initiatives such as the “East Data, West Computing” program—and the industrial Internet remains essential. Policy efforts should place particular emphasis on extending infrastructure coverage in central and western regions as well as in rural areas. More balanced access to digital infrastructure will help ensure that digital-intelligence technologies are adopted in a more inclusive and widespread manner.

Fourth, complementary institutional arrangements should be strengthened to improve the overall environment for digital-intelligence development. This involves optimising the business environment, promoting the development of data-related markets, strengthening intellectual property protection, and increasing investment in talent cultivation and attraction. At the same time, governance frameworks related to digital ethics and technology regulation should be further improved. Together, these institutional measures are critical for maintaining the long-term enabling role of digital-intelligence transformation in supporting high-quality economic development.

## 5. Conclusion

Overall, this study connects theoretical mechanisms with macro-level empirical evidence. The findings show that digital-intelligence transformation significantly promotes high-quality economic development. Digital technological innovation and digital infrastructure plays the central roles, while digital industry development involves short-term adjustment pressures. Future research could

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examine dynamic effects, firm-level responses, and cross-country comparisons to further advance understanding of digital-intelligence-driven development.

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