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Study on the Impact of Digital Transformation on Regional Coordinated Development

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Abstract: The digital economy serves as a new engine for China's economic growth and plays a key role in addressing the principal contradiction of unbalanced and inadequate development. In-depth exploration of the impact of digital transformation on regional coordinated development is of great significance for resolving China's principal contradiction. This study is based on balanced panel data from 284 prefecture-level and above cities in China from 2011 to 2022. Using a double fixed-effects model, it empirically finds that digital transformation has overall exacerbated regional economic inequality during the sample period. Further mechanism analysis reveals the key forces behind this phenomenon: regional innovation capacity and the agglomeration of production factors play moderating roles in opposite directions. Specifically, a higher regional innovation capacity significantly amplifies the effect of digital transformation on widening regional gaps, while the agglomeration of production factors effectively mitigates this expansion. This inherent contradiction explains the complexity of the impact of digital transformation. The impact of digital transformation is not static but exhibits significant spatial and temporal heterogeneity. In the eastern and central regions, it actually promotes coordinated regional development. Moreover, its effectiveness shows distinct stage-specific dynamic characteristics with the advancement of major regional coordination policies (such as the series of deployments after the 19th National Congress of the Communist Party of China). After a series of robustness and endogeneity tests, the above core conclusions remain reliable. These research findings provide important theoretical basis and policy insights for understanding the new patterns of regional development in the digital economy era and formulating precise and effective regional coordination policies.

Keywords: Digital Transformation; Regional Coordinated Development; Regional Innovation Capacity.

1. Introduction

For a long time, regional development imbalance has been an important factor affecting China's economic development. Since the 18th National Congress of the Communist Party of China, the Party Central Committee has elevated the issue of alleviating regional economic development imbalance to a strategic level. The implementation of major regional strategies such as coordinated development of the Beijing-Tianjin-Hebei region, the development of the Yangtze River Economic Belt, the construction of the Guangdong-Hong Kong-Macao Greater Bay Area, integrated development of the Yangtze River Delta, and ecological protection and high-quality development of the Yellow River Basin has achieved remarkable results. The strategic deployment of the Third Plenary Session of the 20th Central Committee forms a comprehensive system for regional development. At its core is the overarching goal of building a regional economic layout and territorial space system with complementary advantages. To achieve this, the system and policy framework will be improved to drive the new western development pattern, breakthroughs in northeast revitalization, the rise of the central region, and the modernization of the eastern region. Furthermore, key powerhouses like Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area are positioned as high-quality development drivers, while mechanisms for the Yangtze River Economic Belt and Yellow River Basin will be optimized to balance development with ecological protection. This grand blueprint is solidified through the concrete advancement of two landmark projects: the high-standard construction of the Xiongan New Area and the in-depth development of the Chengdu-Chongqing Double-City Economic Circle. However, affected by economic transformation and changes in the international situation, China's regional development faces new problems, such as the gradual emergence of the north-south gap and the uncoordinated development between large, medium, and small cities. How to promote coordinated regional economic development remains an important issue for achieving high-quality development.

The Third Plenary Session of the 20th Central Committee of the Party proposed to "accelerate the construction of a system and mechanism for promoting digital transformation and development, and improve the policy system for promoting digital industrialization and industrial digitalization." Digital transformation is rapidly emerging and playing an important role in the national economic development. According to the "China Digital Transformation Development Research Report (2024)," in 2023, China's digital transformation accounted for 42.8% of GDP, with a nominal year-on-year growth rate of 7.39%, which is 2.76 percentage points higher than the nominal GDP growth rate during the same period. The contribution rate of digital transformation growth to GDP reached 66.45%. Regions with a better economic foundation and stronger scientific and technological innovation capabilities have effectively released the scale effect and scope economy of digital transformation development, achieving better, faster, and more resilient development in regional digital transformation. However, in terms of scale, among the provinces with a digital transformation scale exceeding 1

trillion yuan, the eastern region accounts for 45%, and the level of digital transformation development in the eastern region is still higher than that in the central and western regions. There is still a significant gap in the level of digital transformation development between regions. Therefore, digital transformation and development may become a key factor in reshaping the unbalanced regional economic development pattern.

Therefore, based on existing literature research, this paper uses the entropy method to construct a digital transformation and development index system and measures the level of digital transformation and development in 284 prefecture-level and above cities nationwide to explore the impact of digital transformation on coordinated regional development. Based on the neoclassical growth theory, the paper discusses the role of factor agglomeration and regional innovation capacity in the impact of digital transformation on coordinated regional development. From the perspectives of geographical location and time heterogeneity, the paper discusses the differential impact of digital transformation on coordinated regional development in different geographical regions and under different policy backgrounds at different times, in order to enrich the existing research on coordinated regional development.

2. Literature Review

1. Spatial-Temporal Evolutionary Characteristics and Influencing Factors of Regional Coordinated Development

Since the reform and opening up, China's economic focus has shifted from high latitude to low latitude. The main contradiction in regional coordinated development is reflected in the north-south regions. Due to the speed of capital accumulation, unreasonable economic structure, and differences in innovation capabilities, a new development trend of "faster in the south, slower in the north, and increasing north-south divergence" has emerged[1]. From the perspective of provincial domains, due to the homogeneity within some regions and the heterogeneity outside regions, the regional economies of provinces tend to converge towards the steady state of their respective regions. Overall, China's regional economy does not have the characteristic of absolute convergence, but rather shows a pattern of kconvergence-divergence-convergence [33]. From a regional perspective, due to factors such as resource endowment, policy inclination, and industrial structure, economic development has shown obvious regional differentiation between the east, central, and west, as well as between inland and coastal areas[32].

There are many factors that influence regional coordinated development. First, in terms of geographical location, the economic gap between the eastern region and the central and western regions is key to the relative equilibrium of regional economies. Under the influence of new economic geography factors, the eastern coastal areas with locational advantages will attract a large number of production factors from the central and western regions to flow across regions, gradually widening the economic development gap in China [25]. Second, different national policy inclinations can lead to regional economic development differences. Some studies have found an inverse U-shaped relationship between urbanization and regional coordinated development, and that urbanization mainly affects the economic gap between regions when the economy reaches a certain level [16][17]. Third, industrial structure changes promote the optimization of resource allocation between sectors, which enhances total factor productivity. Differences in location, urbanization, and the degree of openness lead to human capital differences, which are the root of industrial structure and efficiency improvements. Compared with material capital investment, human capital, population growth, and technological differences, industrial structure changes have a greater impact on the economic differences between the eastern and central and western regions[17]. Fourth, the improvement of transportation infrastructure is conducive to regional economic growth and promotes convergence between the western and central-eastern regions. With the opening of the China-Europe train, trade facilitation has been accelerated, which is conducive to the flow of factors, technology transfer, and technological innovation. Inland regions, compared with coastal areas, can gain greater benefits, thus helping to narrow the gaps between regions [6].

2. Digital Transformation and Regional Coordinated Development

Digital transformation, with its high innovativeness, strong penetration, and wide coverage, has become an important driving force for economic development. At the macro level, the impact of digital transformation on economic growth is mainly reflected in promoting resource allocation, increasing entrepreneurial activity, boosting income and consumption, and enhancing total factor productivity and technological innovation levels. At the meso level, digital transformation is conducive to optimizing market structure and promoting the upgrading and rationalization of industries, thereby driving economic growth. At the micro level, the efficiency impact of digital transformation on the economy is mainly reflected in the resource allocation efficiency of enterprises and individuals [7][8][9].

However, differences in internet technology equipment access, usage skills, and impact results across regions lead to spatially unbalanced characteristics and a significant digital divide [28]. Therefore, there is a debate in academia about whether digital transformation can promote regional coordinated development. On the one hand, some scholars believe that digital transformation can eliminate market asymmetry, accelerate factor agglomeration, promote innovation and entrepreneurship, and optimize industrial structure, thereby promoting regional coordinated development. On the other hand, due to the digital divide, "polarization effects" and "suction effects" may occur, which can hinder regional coordinated development [26]. From the perspective of digital industrialization and industrial digitalization, differences in economic development levels across regions mean that the "two transformations" may be at different stages. The resulting polarization effects and economies of scope may put the central and western regions at a disadvantage, with the "two transformations" acting in opposite ways to hinder regional coordinated development [27].

A review of the existing literature reveals that regional coordinated development has always been a hot topic in academia. In the new development stage of China, where the main contradictions have changed, regional development imbalance has once again attracted the attention of many scholars. In the key period of China's economic new normal and the transition of old and new growth drivers, digital transformation has become an important engine for economic growth. Digital transformation provides a new perspective for our research on regional coordinated development. Existing literature mostly focuses on the impact of digital

transformation on economic growth and urban-rural income gaps, with few in-depth studies on the mechanism of digital transformation on regional coordinated development. Therefore, the possible innovations of this paper are as follows: (1) In terms of research perspective, most previous literature on the impact of digital transformation on regional coordinated development has focused on analyzing its effects on economic growth or urban-rural income gaps, lacking research on regional coordinated development. Thus, this paper aims to study the impact of digital transformation on regional coordinated development, enriching the existing research in this area. (2) In terms of research content, based on the neoclassical growth theory, this paper systematically selects factor agglomeration and regional innovation capacity as mechanism variables to empirically analyze the effects and heterogeneity of factor agglomeration and technological progress in the impact of digital transformation on regional coordinated development, providing a new perspective for interpretation. (3) In terms of heterogeneity analysis, this paper not only explores the impact of digital transformation on regional coordinated development between and within the eastern, central, and western regions, but also further examines the heterogeneity of policy impacts on the effect of digital transformation on regional coordinated development, analyzing the heterogeneity from geographical location and policy impact perspectives.

3. Theoretical Analysis and Research Hypotheses

1. The Direct Effect of Digital Transformation on Regional Coordinated Development

With the deepening application of technologies such as big data, cloud computing, and mobile internet, digital transformation has been deeply integrated with the real economy and has become an important driving force for China's economic transformation and high-quality development in the new era. At the micro level, digital transformation can promote economic growth through economies of scale, scope economies, and long-tail economies. At the macro level, digital transformation can bring new factor inputs, change the original resource allocation efficiency, and create new total factor productivity to promote regional economic growth[7][10]. Undoubtedly, digital transformation can promote regional economic growth, which is conducive to solving the problem of insufficiency in regional imbalance and the efficiency issue in regional coordinated development. However, in terms of fairness, due to the existence of the digital divide, whether digital transformation is conducive to solving the fairness issue in regional coordinated development is worth considering.

According to the theory of circular causality, regional economic coordinated development depends on the ratio of the feedback effect to the diffusion effect. The feedback effect refers to the fact that developed regions have a greater demand for factors and higher rates of return compared to underdeveloped regions. As a result, capital and labor from underdeveloped regions will flow to developed regions, leading to a shortage of factors in underdeveloped regions and slower development. In contrast, the diffusion effect refers to the fact that capital, labor, and technology from developed regions will promote the development of underdeveloped regions through spillover effects, thereby promoting regional coordinated development. Digital transformation is based on information and communication technology[11], and its development requires corresponding digital infrastructure as support. It also has a positive relationship with the level of economic development [12]. Digital transformation shows significant positive spatial dependence, spatial agglomeration, and relative stability. The higher the level of regional economic development, the better the digital transformation. Therefore, there is a significant "digital divide" between developed and underdeveloped regions, which leads to different effects of digital transformation on regional economic growth and gradually widens regional coordinated development. Therefore, this paper proposes Hypothesis 1.

Hypothesis 1: Digital transformation may lead to an expansion of regional coordinated development.

2. The Agglomeration Moderating Effect of Digital Transformation on Regional Coordinated Development

Factors of production are an important driving force for regional economic development and are also one of the causes of the expansion of regional coordinated development. Digital transformation is improving the agglomeration and diffusion of factors through platform economy, network effects, and optimized resource allocation. The agglomeration and diffusion of factors also affect the convergence role of regional coordinated development.

On the one hand, factor agglomeration has an inhibitory effect on the narrowing of regional coordinated development by digital transformation. Digital transformation can break geographical distance limitations and overcome administrative barriers and information asymmetry between regions through Internet technology [13], thereby accelerating regional information exchange and accessibility. Capital, labor, and other factors, following the principle of profit-seeking, will flow to regions with higher marginal returns [14], causing resource factors to flow from underdeveloped regions to better-developed regions, thereby creating a polarization effect. Regions with better economic development will receive more resources and drive their development.

On the other hand, factor agglomeration has a promoting effect on the narrowing of regional coordinated development by digital transformation. According to Hirschman's trickle-down effect, after a certain degree of factor agglomeration in the leading regions, it will produce a trickle-down spillover effect on surrounding areas, thereby driving the economic growth of lagging regions. Digital transformation can better diffuse the spatial spillover effect of leading regions to lagging regions through transmission and connection functions. At the same time, when leading regions absorb the inflow of factors from lagging regions, they will also increase the return rate of factors in lagging regions and stimulate the market potential of lagging regions, showing "coordinated agglomeration," thereby making the allocation and spatial distribution of factors more efficient. Moreover, excessive factor agglomeration in leading regions may also lead to diseconomies of scale, thereby inhibiting the economic growth of leading regions and possibly narrowing regional coordinated development [15]. Therefore, this paper proposes Hypothesis 2.

Hypothesis 2: Factor agglomeration has a moderating effect on the impact of digital transformation on regional coordinated development.

3. The Innovation Moderating Effect of Digital Transformation on Regional Coordinated Development

Innovation is the primary driving force for development

and a strategic support for building a modern economic system. Endogenous growth theory holds that technological progress is an endogenous driving force for economic growth. Regional innovation capacity is also a core driving force for the development process of digital transformation. The core manifestation of regional innovation capacity is the ability to break through in science and technology. Technological progress can promote the intersection and integration of different industries, establish cross-disciplinary, cross-departmental, and cross-industry cooperation mechanisms, and innovate new business models and technical application models, thereby leading to the innovation of digital business forms[18]. Digital production factors themselves are non-competitive and non-excludable, with rapid diffusion and low diffusion costs, which are conducive to reducing market asymmetry and improving information accessibility, thereby enhancing innovation quality and efficiency. Digital transformation can break through geographical distance and administrative boundaries to obtain a larger range of technological spillovers, thereby promoting regional innovation. However, due to differences in geographical location and city size, innovation may also have a "marginal increasing effect" based on city size as a threshold, and may cause "suction effects" and "Matthew effects" on neighboring regions, thereby affecting regional coordinated development [19][20]. Therefore, this paper proposes Hypothesis 3.

Hypothesis 3: Regional innovation capacity has a moderating effect on the impact of digital transformation on regional coordinated development.

4. Research Design

4.1. Model Specification

To examine the impact of digital transformation on regional coordinated development, this paper uses data from 284 prefecture-level and above cities in China from 2011 to 2021 and constructs a double fixed-effects model to assess the impact of digital transformation on regional coordinated development. The specific expression is shown in Equation (1):

$$Kakwani_{it} = \beta_0 + \beta_1 Digital_{it} + \gamma Controls_{it} + \lambda_i + \upsilon_i + \varepsilon_i \quad (1)$$

where i denotes the city, t denotes the time; gap_{it} represents regional coordinated development; $digital_{it}$ represents digital transformation; $controls_{it}$ represents a series of control variables; λ_i represents city fixed effects, υ_i represents time fixed effects, and ε_{it} represents the random disturbance term. If β_1 is significantly positive, then digital transformation has a promoting effect on regional coordinated development; if β_1 is significantly negative, then digital transformation has an inhibitory effect on regional coordinated development.

To test whether factor agglomeration and regional innovation capacity have an impact on the effect of digital transformation on regional coordinated development, we add factor agglomeration and technological progress, as well as their interaction terms with digital transformation, to Equation (1) and set up the moderation effect model as shown in Equation (2):

$$Kakwani_{it} = \beta_0 + \beta_2 Digital_{it} + \beta_3 M_{it} + \beta_4 Digital_{it} \square M_{it} + \gamma Controls_{it} + \lambda_i + \upsilon_i + \varepsilon_i \quad (2)$$

where M_{it} represents factor agglomeration and regional innovation capacity, and $Digital_{it} \square M_{it}$ represent the interaction terms between digital transformation and factor agglomeration and regional innovation capacity, respectively. The coefficients β_4 indicate the moderating effects of factor agglomeration and regional innovation capacity on the impact of digital transformation on regional economic development.

4.2. Indicator Selection and Data Sources

(1) Dependent Variable: Regional Coordinated Development. The dependent variable in this paper is regional coordinated development. Previous literature has mostly used variance and Theil indices to calculate the overall inequality between regions, but this approach overlooks the differences between regions. The Relative Deprivation Index (Kakwani) can effectively address this issue. The Kakwani index measures the economic gap between a region and the more economically developed regions within its reference group, and it can serve as an indicator of inequality between regions. A higher Kakwani index indicates a larger income gap between regions. Drawing on the methods of Zhou Wen (2017) and Li Heng (2023) for calculating regional coordinated development, the Kakwani index is calculated as shown in Equation (3):

$$Kakwani_i = \gamma_{y_i}^{+}[(\mu_{y_i}^{+} - y_i) / \mu_y] \quad (3)$$

where y_i represents the per capita gross domestic product (GDP) of city i, μ_y represents the average per capita GDP of all cities in the country, $\mu_{y_i}^{+}$ represents the average of the per capita gross domestic product among all cities in the country, $\gamma_{y_i}^{+}$ represents the percentage of the total sample that consists of cities whose per capita gross domestic product exceeds a certain threshold. According to Equation (3), the Kakwani index does not use the most developed city within a group as a reference to calculate regional coordinated development. Instead, it uses regions with higher economic development levels as references to calculate the imbalance index between regions. A higher Kakwani index indicates a larger gap in economic development levels between less developed regions and relatively developed regions.

(2) Independent Variable: To measure the core independent variable, digital transformation, this paper adopts the established methodologies of Zhao Tao (2020) and Huang Qunhui (2019), adapting them to the context of municipal-level data availability. A multifaceted index system is constructed, capturing the phenomenon through the critical lenses of digital infrastructure, digital industrialization, and industrial digitalization. The entropy weight method is then

applied to this system to calculate an integrated digital transformation development score for each city, with the complete structure of the indicator system presented in Table 1.

Table 1. Evaluation Index System for the Development Level of Digital Transformation

Primary Indicator	Secondary Indicator	Indicator Description	Indicator Attribute
Digital Infrastructure	Mobile Internet Foundation	Number of mobile phone users / Total population	Positive
	Internet Penetration Rate	Number of internet users / Total population	Positive
Digital Industrialization	Telecommunications Output	Per capita total volume of telecommunications services	Positive
	Number of Internet Professionals	Proportion of personnel in computer services and software industries	Positive
Industrial Digitalization	Development of Digital Financial Inclusion	Digital financial inclusion index	Positive
	Volume of Postal Services	Per capita total volume of postal services	Positive

(3) Control Variables. There are many factors that influence regional economic growth. Based on existing literature, economic growth, the degree of government intervention, technological level, education level, and urbanization rate are all major factors affecting regional coordinated development. This paper controls for critical regional characteristics to isolate the effect of digital transformation. The baseline economic condition is captured by the logarithm of per capita GDP. The role of the state is incorporated through two key aspects: first, the overall scale of government intervention, measured by its fiscal expenditure as a share of GDP; and second, its strategic allocation of resources, reflected in the shares of spending dedicated to science/technology and education. The urbanization level, represented by the share of the urban population, is included as a pivotal structural factor.

(4) Moderating Variables. This paper mainly examines factor agglomeration in terms of labor and capital. For labor agglomeration (M-labor), we refer to Lei Xin et al. (2014) and select the ratio of non-agricultural employees to urban construction land area. For capital agglomeration (M-capital), we refer to Li Zheng et al. (2019) and select the ratio of total fixed asset investment to urban construction land area as the measure. The total fixed asset investment for each city is calculated using the perpetual inventory method. Regional innovation capacity is measured by the number of patents granted per capita.

(5) Data Sources. Since the Digital Inclusive Finance Index was first published in 2011, and data for the Tibet Autonomous Region and some cities are severely missing, to ensure the uniformity of the sample and the integrity of the data, this paper does not include them in the study. To construct a robust dataset, this paper integrates data from multiple authoritative sources, namely the China City Statistical Yearbook, the China Statistical Yearbook, official statistical bulletins, and municipal bureaus. The integrity of this dataset is ensured by applying interpolation methods to address any missing values. The resulting comprehensive panel data defines the final research sample, encompassing 284 prefecture-level and above cities for the period 2011-2021.

Table 2. Descriptive and Statistical Analysis Results of the Variables

Variable Name	Variable Symbol	Sample Size	Mean	Standard Deviation	Minimum Value	Maximum Value
Regional Coordinated Development	Kakwani	3408	0.280	0.177	0	0.811
Digital Transformation	Digt	3408	0.163	0.067	0.184	0.688
Economic Development Level	Gdp	3408	10.752	0.571	8.773	13.056
Degree of Government Intervention	Gov	3408	0.203	0.102	0.0439	0.916
Education Level	Edu	3408	0.176	0.039	0.010	0.356
Science and Technology Level	Tech	3408	0.017	0.017	0.000	0.207
Urbanization Level	Urban	3408	0.563	0.151	0.181	1

Source of data: Compiled by the author.

5. Empirical Results Analysis

5.1. Benchmark Regression

Benchmark regression results, as presented in Table 3, reveal that digital transformation exerts a significant expanding effect on regional economic disparities. This primary finding, derived from the two-way fixed effects model (Model 3), indicates that digital transformation amplifies imbalances in regional coordinated development. The robustness of this conclusion is confirmed, as the result holds consistently across alternative specifications, including the pooled OLS (Model 1) and random effects models (Model 2). Furthermore, the analysis identifies several significant inhibitory factors: regional economic development level, urbanization rate, and technological development level all contribute to narrowing regional economic disparities. Specifically, a negative correlation is observed between the level of regional economic development and regional coordinated development. According to the inverse "U" hypothesis proposed by Willianson (1965), China's economy may have already passed the inverse "U" turning point. The

new urbanization policy, as a regional coordinated development policy in China, has an inhibitory effect on regional coordinated development. This suggests that China's in-depth implementation of a people-oriented new urbanization policy is conducive to building a regional economic layout with complementary advantages and high-quality development, and to promoting regional coordinated development. Science and technology, as important drivers of economic growth, are beneficial to regional economic growth. The more local governments invest in science and technology, the greater the potential impact on economic growth. Government intervention and education level show a positive correlation with economic growth. The increase in the proportion of government fiscal expenditure has exacerbated the unbalanced development of China's regional economy. This may be due to target bias and structural imbalance in the implementation of the transfer payment system.

Table 3. Benchmark Regression Results

Variable Name	Variable Symbol	(1) 0ls	(2) re	(3) fe
Digital Transformation	Digt	0.706*** (32.13)	0.333*** (10.46)	0.382*** (11.59)
Economic Development Level	Gdp	-0.283*** (-73.02)	-0.244*** (-53.41)	-0.216*** (-42.63)
Degree of Government Intervention	Gov	0.213*** (13.90)	0.242*** (11.50)	0.226*** (9.34)
Education Level	Edu	0.189*** (6.41)	0.194*** (5.45)	0.136*** (3.51)
Science and Technology Level	Tech	-0.612*** (-9.06)	-0.331*** (-4.69)	-0.228*** (-3.10)
Urbanization Rate	Urban	-0.086*** (-8.21)	-0.059*** (-4.43)	-0.047*** (2.78)
Constant Term	constant	3.188*** (76.10)	2.784*** (55.51)	2.454*** (43.14)
City Fixed Effects	City	NO	NO	YES
Time Fixed Effects	Year	NO	YES	YES
Sample Size	N	3408	3408	3408
R^2	R^2	0.907	0.948	0.940

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are z-statistics

5.2. Robustness Test

To test the robustness of the benchmark regression results, based on the two-way fixed effects model, this paper conducts the following tests on the empirical results.

(1) Replace the core independent variable. Drawing on the approach of Zhao Tao (2020), we use principal component analysis to re-measure the level of digital transformation development.

(2) Replace the dependent variable. Considering that the Kakwani index focuses on dynamically measuring the gaps between regions, to measure the overall economic disparities between regions, we follow the practice of Bian Yuanchao (2018) and use the deviation of per capita GDP to redefine digital transformation.

(3) Winsorize the data. To exclude the impact of outliers on the experimental results, we perform a two-sided 1% winsorization on all variables.

(4) Lag the independent variables by one period. Considering the existence of a digital divide, regions with larger regional coordinated development may have higher or lower levels of digital transformation development. To avoid endogeneity issues caused by "reverse causality" between control variables, we lag all independent variables by one period and conduct regression tests again.

(5) Instrumental variable. Since there may be a bidirectional causal relationship between the core independent variable, digital transformation, and the dependent variable, regional coordinated development, which could lead to endogeneity problems, we refer to the approach of Liu Na (2023) and select the distance from the city to Hangzhou as an instrumental variable. However, since this indicator lacks time variation, to avoid difficulties in measuring it in the fixed effects model, we follow the research of Nunn & Qian (2014) and select a time variable multiplied by a historically invariant variable as the time variation of the instrumental variable. We choose the interaction term between regional Internet penetration rate and the distance from the region to Hangzhou as the instrumental variable for model estimation.

The robustness test regression results are shown in Table (3). The robustness of the benchmark finding—that digital transformation significantly amplifies regional economic disparities—is confirmed through a series of stringent tests. As summarized in Table 3, the estimated coefficient for digital transformation remains consistently positive and significant across multiple alternative specifications. These include replacing the core independent and dependent variables, applying winsorization to outliers, excluding special administrative samples, and narrowing the study period. Furthermore, to address potential endogeneity from reverse causality, all independent variables were lagged by one period. The result, shown in Column (6), indicates that the lagged

digital transformation coefficient is still significantly positive at the 1% level, thereby reinforcing the robustness and causal credibility of the main conclusion. Column (6) shows that after lagging all independent variables by one period, the parameter estimate for digital transformation is significantly positive at the 1% level, thus excluding endogeneity issues caused by reverse causality. Column (6) results indicate that the p-value of the $K-\Pr k\ LM$ -statistic is 0.0000, and the $K-\Pr k\quad Wald\quad F$ -statistic is greater than the critical value of the weak identification test at the 10% level, which is 16.38. It passes the "unidentifiability test" and the "weak instrumental variable test," indicating that the choice of instrumental variable is reasonable. Moreover, the parameter estimate for digital transformation in the model is significantly positive, suggesting that digital transformation has a significant expanding effect on regional coordinated development.

Table 4. Robustness Tests

Variable Name	(1) Replace the Explanatory Variable	(2) Replace the Explained Variable	(3) Winsorizing	(4) Lagged Variable	(5) Instrumental Variable
Digital Transformation	0.229*** (12.49)	2.087*** (20.26)	0.329*** (8.92)	0.357*** (9.47)	0.277** (2.10)
Control Variables	YES	YES	YES	YES	YES
K-P rk LM Statistic					21.526 [0.00]
K-P rk LM F Statistic					605.782 {16.38}
Control Variables	YES	YES	YES	YES	YES
City Fixed Effects	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES
Sample Size	3408	3408	3408	3124	3408
R2	0.9420	0.253	0.946	0.2633	0.581

Note: [ ] is the p-value, and { } is the critical value of the Stock-Yogo weak identification test at the 10% level

5.3. Heterogeneity Analysis

1. Location Heterogeneity

Digital transformation exerts a divergent impact on regional economic disparities across China, a finding that underscores the critical role of regional heterogeneity. Regression analyses conducted on 284 prefecture-level cities—stratified into eastern, central, and western regions—reveal that digital transformation narrows regional gaps in the more digitally advanced eastern and central areas, whereas it amplifies disparities in the western region (Table 5, Columns 1–3). This pattern can be attributed to the spatial congruence between digital transformation and economic development levels. The existing digital divide, coupled with the profit-driven flow of production factors from west to east and central regions, intensifies interregional inequality. At the intraregional level, digital transformation contributes to convergence within the eastern and central regions, facilitated by positive spatial spillovers that foster growth in less developed areas. By contrast, internal disparities continue to widen in the western region, likely due to its weaker digital foundation and limited capacity to absorb transformative benefits (Table 5, Columns 4–6).

Table 5. Location Heterogeneity Analysis

Variable Name	(1) Eastern China	(2) Central China	(3) Western China	(4) Eastern China	(5) Central China	(6) Western China
Digital Transformation	-0.019*** (-2.74)	-0.071*** (-5.72)	0.183*** (3.40)	-0.083*** (-11.72)	-0.124*** (-9.13)	0.018 (0.56)
Constant Term	0.007*** (0.28)	0.285*** (9.65)	1.977*** (20.84)	0.048*** (1.98)	0.181*** (5.58)	2.865*** (49.99)
Control Variables	YES	YES	YES	YES	YES	YES
City Fixed Effects	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES
R2	0.2322	0.7821	0.9479	0.6673	0.8351	0.9628

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are z-statistics.

2. Time Heterogeneity

The strategic emphasis on digital transformation since the 18th National Congress of the Communist Party of China has introduced a distinct temporal dimension to its impact on regional coordinated development. This period heterogeneity stems from the evolution of national policy priorities. A pivotal shift occurred with the 19th Party Congress, which redefined the principal societal contradiction to highlight "imbalances and inadequacies in development" and explicitly called for "establishing a more effective new mechanism for regional coordinated development." This institutional prioritization fundamentally altered the context in which digital transformation influences regional development pathways. In 2018, the "Opinions of the Central Committee of the Communist Party of China and the State Council on Establishing a More Effective New Mechanism for Regional Coordinated Development" were issued, calling for the accelerated formation of a new mechanism for regional coordinated development that is well-coordinated, orderly competitive, green and coordinated, and shared and win-win, to promote regional coordinated development. Therefore, this paper divides the policy period into two stages, 2011–2017 and 2018–2022, using the 19th National Congress in 2017 as the dividing line, and conducts separate tests. Columns (1) and (2) in Table 6 represent inter-regional differences, while columns (3) and (4) represent intra-regional differences. The estimation results in Table 6 show that the impact of digital transformation on regional coordinated development has significantly decreased after 2017, both inter-regionally and intra-regionally. This indicates that the impact of digital transformation on regional coordinated development is influenced by the implementation of regional coordinated development policies.

Table 6. Time Heterogeneity Analysis

Variable Name	(1) 2011-2017	(2) 2018-2021	(3) 2011-2017	(4) 2018-2022
Digital Transformation	0.496*** (11.09)	0.128*** (2.78)	0.300*** (8.63)	0.153*** (4.15)
Constant Term	2.351*** (29.46)	1.869*** (17.01)	2.610*** (42.08)	3.791*** (43.06)
Control Variable	YES	YES	YES	YES
City Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Observation	1988	1136	1988	1420
R2	0.9190	0.957	0.850	0.845

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are z-statistics.

5.4. Mechanism Test

To examine the impact of factor agglomeration and innovation capacity on regional coordinated development, we combine the theoretical analysis from the previous sections and the moderation model set in Equation (2) to verify whether factor agglomeration and regional innovation capacity affect the impact of digital transformation on regional coordinated development.

(1) Moderating Role of Factor Agglomeration

As shown in Table 7, the core independent variable of digital transformation remains significantly positive, further corroborating the previous finding that digital transformation exacerbates regional coordinated development. The interaction terms between digital transformation and talent agglomeration and capital agglomeration have significantly negative coefficients, indicating that factor agglomeration plays an inhibitory role in the expansion of regional coordinated development driven by digital transformation. This may be because the development of digital transformation can eliminate market asymmetry, thereby accelerating the flow of factors between regions, improving the efficiency of factor resource allocation, and enhancing the benign interaction between regions. Moreover, the implementation of urban agglomeration development plans also facilitates the flow and efficient agglomeration of regional factors. While factor flow increases labor productivity in the factor-inflow regions, it also significantly improves the return rate of factors in the factor-outflow regions and stimulates market potential on the demand side. Factor flow exhibits a trend of "coordinated agglomeration" as factor allocation efficiency continuously improves, which is conducive to narrowing regional coordinated development [4].

(2) Moderating Role of Regional Innovation Capacity

The significantly positive interaction term between digital transformation and regional innovation capacity in Table 7, Column (3) reveals an important mechanism: regional innovation capacity amplifies the disparity-widening effect of digital transformation. This occurs because the benefits of digital transformation are unevenly distributed, following a distinct Matthew effect. Regions with stronger pre-existing innovation capabilities—shaped by advantages in economic development, infrastructure, and factor agglomeration—leverage digital tools more effectively, accelerating their growth. Conversely, less innovative regions struggle to capture these benefits, leading to a further divergence in regional economic outcomes.

6. Research Conclusion and Policy Implications

This study employs data from prefecture-level cities from 2011 to 2022, utilizing the entropy method to measure the level of digital transformation development, and analyzes its impact on regional economic disparities in China. The results indicate that the "digital divide" between regions leads to an exacerbation of regional coordinated development due to digital transformation. Digital transformation primarily amplifies regional coordinated development by fostering technological progress. However, the agglomeration of factors of production can mitigate this expansionary effect. Geographically, digital transformation mainly widens the gap between the western region and the eastern and central regions. Within regions, the economic disparities within the eastern and central regions show a trend of narrowing, while

those within the western region continue to expand. Lastly, digital transformation is subject to phased policy impacts. After the 19th National Congress of the Communist Party of China, the continuous improvement of regional coordinated development policies has led to a decline in the expansionary effect of digital transformation on regional coordinated development. Based on the theoretical and empirical analysis of the impact of digital transformation on regional coordinated development, the following policy recommendations are proposed:

Table 7. Moderation Effect Analysis

Variable Name	(1) Capital Agglomeration	(2) Talent Agglomeration	(3) Scientific and Technological Innovation
Digt	0.348*** (10.26)	0.375*** (11.26)	0.347*** (9.84)
M-capi	-0.012*** (-4.27)		
Digt×M-capi	-0.056*** (-3.18)		
M-tale		-0.005*** (-2.40)	
Digt×M-tale		-0.056** (-2.65)	
inv			-0.005*** (-3.03)
Digt×inv			0.014** (2.32)
Constant Term	2.507*** (42.90)	2.505*** (42.91)	2.452*** (40.80)
City Fixed Effects	YES	YES	YES
Time Fixed Effects	YES	YES	YES
Sample Size	3408	3408	3408
R^2	0.9395	0.9391	0.9371

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses are z-statistics.

Firstly, it is essential to accurately assess existing gaps and enhance the level of digital transformation. The study finds that while digital transformation promotes economic growth, the current imbalanced development of digital transformation across regions in China, characterized by a digital divide, places less developed regions at a disadvantage in the digital transformation value chain. This results in a gradual widening of economic disparities between regions. However, for less developed regions, the technological innovation and progress spurred by digital transformation are permeative and can alter the efficiency of resource allocation. These regions should recognize the significance of digital transformation and strive to seize its opportunities. They should improve their digital infrastructure, accelerate the implementation of the "East Data, West Calculation" project, expedite the transformation of local enterprises through digital technology, cultivate new development advantages, and promptly shift their economic development structure.

Secondly, accelerating the flow of factors of production can enhance the internal development momentum of less developed regions. The study finds that digital transformation promotes the agglomeration of factors of production, which in turn aids lagging regions in catching up with leading regions, particularly in areas with higher levels of digital transformation development. Therefore, it is necessary to expedite the construction of digital infrastructure and the establishment of a unified national market to further facilitate the cross-regional circulation and trade of digital, capital, and labor factors. Eliminating market segmentation and breaking down regional market barriers can optimize the allocation of resources in less developed regions and activate their unused factors of production.

Lastly, enhancing interregional cooperation in digital transformation can boost technological progress in less developed areas. Our research indicates that technological advancement is pivotal in how digital transformation affects coordinated regional development. Digital transformation, characterized by its innovativeness, integrativeness, efficiency, and openness, facilitates the rapid dissemination of information, knowledge, and technology. Through technological and knowledge spillovers, less developed regions can quickly elevate their technological standards at low risk and cost. However, this rapid improvement may lead to dependency in these regions, diminishing their indigenous R&D capabilities. Over-reliance on rapid technological gains from spillovers can impede less developed regions from acquiring core technologies, making it difficult for them to take the initiative in innovation and economic development and to transition from being "followers." Therefore, while actively absorbing technological spillovers from other regions, less developed areas should strengthen their talent pool and enhance their indigenous innovation capabilities to take control of technological progress.

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