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Digitization, the Free Flow of Factors and the Coordinated Regional Development

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Abstract: In recent years, the digitization with the big data and information technologies as the core has effectively changed the flow mode of production factors, and increasingly shows the kinetic energy and potentials of affecting the coordinated development of regions. How does data and digitization affect the flow of factors, and what paths and mechanisms are used to promote the regional coordinated development? The answers to these two questions are increasingly becoming the underlying logic of relevant academic research and policy making. Based on this, relying on the spatial configuration model (SMM), this paper establishes the digital factor flow model, which proves the "inverted U-shaped" development trend of digitization - expanding the regional development gap in the short term and bridging the gap in the long term. Subsequently, in this paper, three empirical models are established to verify the "inverted U-type" conclusion, and to further discuss the relationship between digitization, free flow of factors and the coordinated regional development. Finally, this paper puts forward that local governments should scientifically understand the role of digital factors in promoting the free flow of factors, rationally perceive potentials of digitization in bridging regional development gaps, and give full play to the role of macroeconomic regulations and guidance to improve the underdeveloped digital infrastructure, promote the inclusive development of digital economy, better serve the underdeveloped western regions in China, and finally, to promote the coordinated regional development.

Keywords: Digitization; Free Flow of Factors; The Coordinated Regional Development.

1. Research Questions

With the profound evolution of information technology, the application of big data is gradually extensive. The role of digital globalization in reshaping the national competitive advantages is becoming more and more prominent, and it is increasingly becoming a competitive place for international competition. From 2012 to 2021, the scale of China's digital economy increased from 11 trillion yuan to more than 45 trillion yuan, with an average annual compound growth rate of over 17%, which became the second largest of the world in 2020. The proportion of digital economy in GDP increased from 21.6% to 39.8%. In 2022, the number of unicorns in China accounted for 38% of all worldwide, and the valuation accounted for 47.1%, second only to the United States. From the perspective of international competition, the digital economy has provided a key strategic opportunity and a time threshold for China to better cope with the profound changes unseen worldwide in a century.

At the same time, regional coordinated development has increasingly become an important starting point for China's sustainable economic and social development, and digitization has increasingly become an important engine for regional development. The continuous innovation of digital technology has not only changed the basic way of social production and life, but also reshaped the perspective and path of economic and social development. On the one hand, the spatial flow of production factors such as labor, capital, technology, and data is no longer completely dependent on regional geographical agglomeration and natural resource endowment, and the regulation function of market can be more fully stimulated. On the other hand, digitization has created a new strategic environment for urban and rural areas to cooperate and compete regionally, accelerated the "inverted U-shaped" evolution of regional economic gap in China, and optimized the quality and efficiency of regional coordinated development. In this context, digital services for regional economic development and accelerating the development gap have become an important path for regional high-quality development. Digital strategy with its policy design and implementation has increasingly become one of the key tasks of governments at all levels.

Based on this, this paper will take relationships between regional coordinated development and digitization as the research questions, the free flow of factors as the core clue. Consequently, this paper focuses on exploring the specific mechanism and transmission path of digitization in bridging the regional development gap as listed below to establish a theoretical model and carry out empirical analysis.

1. Is the free flow of factors a key factor affecting the coordinated regional development? After adding in the digitization variable, will the impact of the free flow of factors on the coordinated regional development change? What is the logical relationship between the three?

2. What role does digitization play in the coordinated regional development process? What are the existing possible mechanisms of impacts? What are the characteristics of it?

3. What is the status quo of regional coordinated development in China? How can digitization better serve the coordinated development of China?

On this basis, this paper tries to provide theoretical reference for the government and various regions to formulate and implement differentiated policies, so that digitization can better promote the coordinated development of regions in similar contexts.

2. Literature Reviews

2.1. Theoretical Foundations

2.1.1. Research on the Relationship between the Free Flow of Factors and the Coordinated Regional Development

After more than one hundred years of development, the theory of regional coordinated development has formed a relatively sound system. With the wide application of mathematics in economic analysis, the theory of regional coordinated development gradually embarked on the road of modeling, and then forms a series of new theories of regional coordinated development. The theory of regional coordinated development mainly includes the theory of balanced growth of regional economy, the theory of unbalanced growth of regional economy, the theory of regional division of labor and cooperation, the theory of regional spatial structure, the theory of sustainable development of resources and environment, and the theory of equalization of public services, among, More representative theory includes: Nelson's "low level equilibrium trap" theory, Rodin's "big advance" theory, the unbalanced growth theory, Williamson's inverted "U" shape theory, Myrdal's cycle cumulative causality theory, regional economic gradient theory, factor endowment theory, absolute cost advantage theory, comparative cost advantage theory, similar conditions of regional division of labor theory, network model theory, growth pole model theory, regional economic spatial integration theory (Fan, et al., 2012), spacecraft theory, agglomeration economic theory (Fujita et al., 2015), Environmental Kuznets curve theory, Rawls fairness theory, "new" new economic geography theory, Evolutionary economic geography theory (Martina and Sunley, 2014; Isaksen, 2015), Marx and Engels' social equity theory, etc. On this basis, many scholars began to discuss the path and mechanism of regional coordinated development, and the free flow of factors has been proved by many studies to be an important mechanism affecting regional coordinated development.

Many experts and scholars at home and abroad have studied and analyzed the cross-regional flow of factors, among which the polarization-trickle-down effect theory proposed by Hirschmann (1958) and the core-edge theory proposed by Friedman (1969) have laid the theoretical foundation for the cross-regional flow of factors. These two theories believe that in the middle school of development, the production and innovation factors such as technology spontaneously converge to the primary area, namely "polarization", which weakens the economic development ability of the developing area; but with the improvement of the "pole" becoming stronger, the factors of production begin to spillover from the core area to the edge in the way of "trickle down", and the developing areas gradually obtain more development opportunities and progressive factors such as technology, information and values. Although the "polarization" effect will dominate for a certain period of time, in the long run, the "trickle-down" effect will eventually prevail. Lipton (1980) and others on the basis of this, further points out that in a certain stage of development, the agglomeration of factors to the developed region is determined by the law of the market. Therefore, in the case of regional development gap, factor flows will only reverse to flow from developed areas to less developed areas in the case of government intervention in industrial development such as the construction of satellite cities and other external force interventions. Similarly, domestic scholars such as Zhang (2012), Ye Chang (2015), Guo (2016), Fang (2017) and others agree that the coordinated regional development must be achieved by the reversed or two-way flows of factors. Zhu (2018) pointed out that free flows and reverse flows of the capitals, labors and lands are the keys to achieve the coordinated regional development.

2.1.2. Research on the Relationship between Digitization and the Regional Coordinated Development

With the advent of the big data era and the fourth scientific and technological revolution, the importance of data as a factor of production, is increasing, and the research on digitization affecting the coordinated development of regions is emerging. At present, these studies mainly focus on three aspects: the relationship between digital and regional coordinated development, the mechanism of digital influence on regional coordinated development, and the research on the regional coordinated development path of digital empowerment.

Digitization has significant and compound effects on the regional coordinated development. Wang et al. (2022), Yang (2021) and many other scholars believe that digital finance will divide regions in terms of the quality of the economic growth. Bell et al. (1993) and Liu et al. (2021) found through empirical research that digitization has a significant positive impact on regional economic growth. Dewan et al. (2000) found that digitization can promote the transfer of technological investment and application of digital economy to less developed areas, enabling less developed areas to obtain technological dividends, and realizing the two-way growth of regional economic fairness and efficiency. Zhang et al. (2023) analyzed the relationship between China's comprehensive pilot zone of cross-border e-commerce and regional coordinated development, and believed that the impact of the construction of cross-border e-commerce has significant heterogeneity on regional coordinated development. Wang and Yang (2023) studied the impact of digital finance development on the urban development gap and its mechanism, and believed that digital finance can help reduce the urban development gap, and play a more prominent role in helping the latecomer areas. He and Li (2022) believe that the improvement of the development level of digital economy has significantly narrowed the regional economic development gap. Si (2023) believes that China currently has good policy advantages and basic conditions for the development of digital economy, but the "digital divide" and other issues may become the key obstacles to bridge the regional economic development gaps.

The transformation and upgrading of digital enabling industries, technological innovation and the development of emerging industries are the main mechanisms to promote the coordinated regional development. Cao (2018), Zhan (2018), Chunfa Li (2020) and others studied the role and mechanism of digital economy in driving industrial transformation and upgrading, and further creating new forms of business, so as to promote the revitalization of the real economy. Ma et al. (2023) found that moderate development of digitization is conducive to promoting technological innovation and driving regional economic growth. Shen (2022), taking Jiangsu Province as an example, analyzed the enabling effect of digital technology on emerging industries such as cultural industries, and believed that digital technology will drive the development of emerging industries and provide new ways as well as new impetus for the coordinated development of

regions.

Digital infrastructure and digital regional economic system are the main tools to bridge the regional economic development gap. Shi (2023) proposed that digitization should be the lead to build an innovation-driven economy, starting from building a digital regional economic system in the new era and forming a new pattern of regional coordinated development with "digital characteristics". Based on the problems existing in the current digital development, Lijuan Si believes that the differentiated digital economy development strategy should be implemented with the focus of improving the construction of new digital infrastructure, so as to promote the coordinated development of regions.

To sum up, there have been a lot of studies on digitization, the free flow of factors, and the coordinated development of regions, which has laid a good theoretical foundation for this topic. However, there is still insufficiency on the mechanisms and paths of how digitization affecting the free flow of factors and promoting regional coordinated development. On the one hand, under the background of the new bid data era, the relationship between digital and regional coordinated development is becoming more and more heterogeneous and diversified, but related research either focuses on positive effects or on the negative impacts. Nor has a lot of studies discuss the application of the both-ends impacts of digitization under these findings. In addition, current empirical studies are more based on single data, lacking studies based on panel datasets. At the same time, most relevant studies discuss these questions from a more macro and abstract perspective, such as pointing out that digitization should not be blindly developed, but the systematic and complete influence path and coping strategies are insufficiently touched upon. This paper will take on and overcome the above deficiencies, start from the theoretical derivation and empirical research, clarify the relationship between digitization, free flow of factors and regional coordinated development, and try to find out the specific mechanism of digitization affecting regional coordinated development.

2.2. Concepts

2.2.1. Digitization

Based on Zhao (2020) and Cheng (2022), we will define regional digitization as applying informational technologies based on the digital infrastructure constructions and the Internet service, in order to improve regional productivity, efficiency, coordination, and to achieve economic structure optimization, which has the characteristic of time and space heterogeneity. Based on the definition above as well as the availability of data and other issues, we take the informational technology capability and informational technology application levels as the two core measures of digitization.

2.2.2. Free Flow of Factors

We define it as the cross-regional free flows and spontaneous adjustments of factors in space, including inputs and distributions of labors, capitals, technologies, natural resources and other factors. Due to the production factors with diversity, variability of space and time heterogeneity characteristics, is difficult to choose a long time, applicable across the region, and unified factor classification system for cross-regional research analysis. At the same time, considering the socialist market economic system has its particularity, we choose factors marketization configuration level as an alternative variable of free flow.

2.2.3. Coordinated Regional Development

In China, the regional coordinated development can be divided into north and south regional coordination and east and west regional coordination, including economic, political, cultural, ecological aspects of coordination to narrow the regional economic and political development gap. In terms of measurements, because it is difficult to quantify the political, cultural, ecological and other dimensions, we choose the regional economic coordination as the core explained variable of this topic, and choose the regional income gap to quantify the regional economic development gap.

3. Theoretical Model

3.1. Theoretical Assumptions

Based on the space configuration model (SMM model), we argue that there exist functional relationships between digitization and the free flow of factors, and so it is between factor flows and regional economic development gap. Therefore, the digitization functions with the factor flow as an intermediary, through a functional relationship on the coordinated development of regional economy. Based on this, we propose the following assumptions:

Hypothesis 1: A country is a (2x2x2) economy, containing two regions: northern and southern regions, digital and non-digital sectors. Data factors exist. And other endowments such as technical conditions, trade costs, openness are symmetrical or identical. Among them, the north is the developed area, the south is the underdeveloped area.

Hypothesis 2: There is a D-S monopoly competition mode in the digital sector. The digital enterprise produces a single product in a differentiated way. The market is a completely competitive market. So there is no cooperative production, scope economy and excess profit. At the same time, the enterprise takes one unit of data factors as the fixed cost, and the other factors as the variable cost. Each input data factor is the output of a data product of one unit. The non-digital sector is also a fully competitive mode, which only uses non-data factors or other factors as costs, and each input of other factors is producing a unit of non-data product.

Hypothesis 3: Only data factors can flow across regions, while other factors cannot flow across regions. Moreover, due to the characteristics of data application across space, there is no time cost for the spatial flow of data factors. In other words, only the data factors can realize the market flow within the observable time, while the non-data factors are characterized by the characteristics of lagging liquidity and relative fixation.

Hypothesis 4: The liquidity of data factors is determined by the digital degree of factors such as research and development ability, technological progress and application ability. The liquidity of non-data factors is determined by the degree of market openness, and the degree of market openness is affected by the institutional mechanism, which is a given factor. Based on the overall stability of the policy, we believe that the degree of market openness is basically constant in the observable time.

3.2. Model Derivation

Based on the above assumptions, we set relevant indicators and further expand formula derivation: π and π^*refers to the northern and southern digital sector yields, b for digital production consumption constant, E for domestic GDP of the entire country, D for the overall data endowment, S_E for the northern GDP, $1 - S_E$for the southern GDP, $\emptyset$ for the degree

of marketization of data factors, and represent the data factors used in the northern and southern production respectively, S_n and $1 - S_n$ for the northern and southern data factors endowment.

According to the free capital model (FC model), we believe that there is a functional relationship between the regional income gap and the degree of factor marketization, and the yield of the digital sector in the developed northern region is:

$$\pi = bB\frac{E}{D}$$

Among them:

$$B = \frac{S_E}{\Delta} + \emptyset\frac{1 - S_E}{\Delta^*}, b = \frac{\mu}{\sigma}, \Delta = S_n + \emptyset(1 - S_n), \Delta^* = \emptyset S_n + (1 - S_n)$$

Similarly, the digital sector yield in the less developed areas of the south is:

$$\pi^* = bB^*\frac{E}{D}$$

Among them:

$$B^* = \emptyset\frac{S_E}{\Delta} + \frac{1 - S_E}{\Delta^*}$$

The gap in the market yield of available regional factors is as follows:

$$\pi - \pi^* = b(B - B^*)$$

In order to further investigate the relationship between digitization, flows of factors and the regional economic development gap, and based on hypothesis 2 and 4, the data factors marketization degrees should be determined by the market opening rate v and development time t. Based on the SMM model, we set $\emptyset_0$ as the initial value of data factor marketization degrees, $\emptyset'$ and $\emptyset_0'$ as other factors marketization degrees and their initial values respectively, λ for the degrees of digitization. So, we have:

$$\emptyset = \emptyset_0 + \lambda(\emptyset_0' + Tt) \quad (0 < t < 1/\lambda T)$$

Among them, the market opening rate v is mainly affected by policy orientation, so it is basically constant and of the smallestder of magnitude. Therefore, the degree of marketization of the factor is mainly determined by the initial value of the marketization degree and the digitization degrees within the observation time t, and we have:

$$0 < \emptyset' \le \emptyset < 1 \quad \text{and} \quad 1 \le \lambda < 1/\emptyset'$$

Next, according to the assumption 1, we try to quantify the developed and less developed regional GDP as functions. Starting from setting the digital sector yield being ω, S_O and S_O being the GDP for the digital sector, non-digital sector respectively. Due to the free flow of data factors, and the profit-oriented market flows, parts of the data factors within the underdeveloped area $(S_D^* - S_n^*)$ will spontaneously flow to the developed area.

So, the per capita income of the developed regions is:

$$Y = \frac{\omega S_O + \pi S_D}{S_O + S_D}$$

Similarly, the per capita income of less developed areas is:

$$Y^* = \frac{\omega^* S_O^* + \pi^* S_D^* + \pi(S_D^* - S_n^*)}{S_O^* + S_D^*}$$

After all these, the relationship between the degree of digitization λ and the regional income gap can be obtained by substituting B and B^*:

$$f(t,\lambda) = Y - Y^* = (\frac{S_O}{S_O + S_D} - \frac{S_O^*}{S_O^* + S_D^*})\Omega + (\frac{S_E}{S_n + \lambda tv(1 - S_n)} + \frac{(1 - S_E)\lambda tv}{\lambda tv S_n + (1 - S_n)})(\frac{S_D}{S_O + S_D} - \frac{S_D^* - S_n^*}{S_O^* + S_D^*})b - \frac{S_n^* b}{S_O^* + S_D^*}(\frac{\lambda tv S_E}{S_n + \lambda tv(1 - S_n)} + \frac{(1 - S_E)}{\lambda tv S_n + (1 - S_n)})$$

3.3. Verification and Analysis

Based on the above assumptions, we simulated that the data factors of the north - the developed region are relatively rich, the south is relatively rich in other factors, and the developed region has a high GDP and the less developed region has a low GDP. Taking the appropriate unit and proportion relationship to make $\Omega, b,$ and v being the constant value of 1, we have:

$$S_O = 0.42, S_D = 0.53, S_O^* = 0.58, S_D^* = 0.47, S_n = 0.58, S_E = 0.64$$

Subsequently, we chose the degree of digitization λ as 0.1, 0.4, 0.7 and 1, representing the four regions with no, primary, intermediate and mature digitization levels, respectively, and draw the function images for $f(t,\lambda)$ in the table below. It can be clearly seen that the regional economic development gap evolves with time, in line with the "inverted U-shaped" trend. At the same time, with the deepening of digitization, the "inverted U-shaped" trend of regional economic development gap will be steeper.

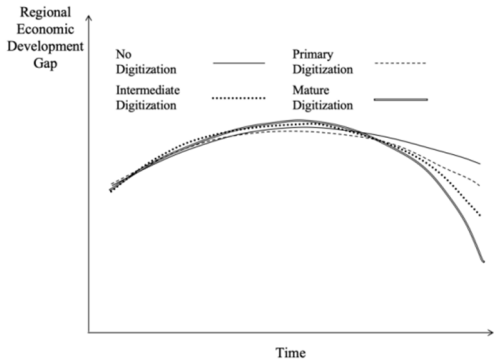

Figure 1. Numerical Simulation Diagram of Digitization Bridging the Regional Economic Development Gap

From the perspective of space economics, the chart above shows the significant spatial and temporal heterogeneity of the impact of digitization on the regional economic gap. In the short term, a deeper digitization may widen the regional economic development gap; however, in the long term, this gap will be significantly closed. Specifically, we believe that this effect is mainly achieved through the spillover mechanism.

First of all, digital development can effectively promote the optimization and upgrading of industrial structure and the high-quality improvement of technical capabilities. In the short term, due to the siphon effect, all kinds of factors of production through digital spontaneous to first areas, and be first areas based on the industry, technology, talent, capital integration, quickly realize frontier industry layout, and with automation, technology innovation and application way to

achieve productivity and production level. In the long run, the first region growth for developed areas, the industrial transformation and upgrading after the value chain of low-end manufacturing old industries, supporting industries and production factors, resources will also under the action of market regulation, policy spillover flow to less developed areas, objectively for backwardness or provide new development opportunities in less developed areas, implementation from "0" to "1" social production jumped.

Secondly, digitization reduces the flow cost of manpower, production means and other factors, and accelerates the spillover and market-oriented allocation of such factors. In the long run, in the long run, the developed areas social and economic development will inevitably lead to the cost of production, followed by the city "hollowing out" effect, labor factors of production will be under the support of digital technology, digital platform to move from the central city, with remote office, online management to reduce the cost of production and living, thus provide development opportunities for less developed cities.

Finally, digital information spillover, will provide new ways for regional coordination and cooperation, expand new channels, developed regions and less developed areas through digital technology, digital platform to realize information resource sharing and industrial development, in the long run can realize regional industrial mismatch and complementary advantages, drive equal basic public services between regions, so as to promote the coordinated development of productivity between regions, narrow the regional gap.

To sum up, the impact of digital development on the regional economic development gap is mainly realized through the spillover, flow and optimal allocation of factors, and this mechanism is consistent with the objective laws of macro-economy, urbanization and industrial development. Therefore, for China's participation in international competition and the coordination of competition and cooperation among domestic regions, the primary work is to objectively understand the objective laws of regional economic development, face up to and pay attention to the key opportunities and time passes brought by digitization, and strengthen the understanding of digitization and its opportunities and challenges. Secondly, we should actively use digitization, start the top-level planning and overall arrangement of digital development, constantly improve the digital infrastructure, industrial layout and main body construction, and promote the effective improvement of digitization level. Finally, it is necessary to strengthen the risk understanding of digital development and regional economy, strengthen the prediction of the necessary stages of siphon effect and urban hollowing, timely adjust and optimize the competition and cooperation relationship, improve the resilience and anti-risk ability of digital development, and realize the coordinated and healthy development of digital economy serving the national economy.

4. Empirical Analysis

Based on the above theoretical model, we will use the panel data of 31 provinces from 1997 to 2020 for empirical analysis, among which the degree of digital development, free flow of factors and regional economic development gap will be the core observation variables., First of all, we will through the least squares method (OLS) regression model, fixed effect model, two-step system GMM model to benchmark regression, among them, the OLS and fixed effect model will provide coefficient for system GMM main model range, to try comprehensive and objective observation of digital, free flow of the overall effect of regional economic development gap. Secondly, we will through the Bootstrap intermediary effect model quantitative factor free flow as a digital and regional economic coordination between intermediary variables, and the regional industrial structure level, technology innovation ability as a supplementary intermediary variable, try to analyze the influence of digital on the regional economic coordination of specific implementation path and mechanism of action. Finally, we will focus on the quantitative analysis of the development gap between east and west regions and the development gap between north and south regions, in order to explore the heterogeneous impact of digital development degree on different regions.

4.1. Index Selection and Data Processing

Regional Economic Development Gap (GDP): This paper draws on the practice of Ni et al. (2014), and measures the per capita GDP data of 31 provinces in the National Bureau of Statistics. Log deviations are often used to quantify the magnitude differences in regions with different means. So i is the province code, t is the year code, and the per capita income log is Y, so the specific algorithm of the per capita income log difference is $YD_{it} = |Y_{it} - \overline{Y}_t|$. The larger the value, the higher the degree of dispersion, that is, the greater the regional development gap. Because this algorithm can get rid of the influence of dimension, it has small requirements for data grouping, development level and growth rate. It can comprehensively investigate the annual regional per capita GDP development gap and obtain empirical results with high efficiency, so it will be added to the model as the core explained variable.

Degrees of digital Development (Digi and $Digi^2$): This paper uses the Digital Financial Inclusion Index of Peking University as an alternative variable to the degree of regional digitization. The index is constructed from three dimensions: coverage breadth of digital finance, use depth of digital finance and digitization degree of inclusive finance, and contains 33 specific indicators. Compared with broadband installation rate, the number of Internet users, Internet penetration and other commonly used digital variables, Peking University inclusive digital financial index better combines the regional digital infrastructure, digital technology acceptance effect, inclusive digital development degrees, and has a long data acquisition period, less missing data, can provide empirical model, reliable data support, so will serve as a core explanatory variables to join the model. In addition, in view of the above analysis, digital has the characteristics of short-term amplification of regional development gap and long-term bridging of development gap, that is, the development trend of "inverted U-shaped". Therefore, we added the secondary item of digital financial inclusion index to the model to conduct visual analysis of the trend characteristics of digital development.

factor flows (Mvmt): This paper uses the factor marketization index system proposed by Fan et al. (2011) as the alternative variable of factor flows. The index combines the four dimensions of economic freedom, financial marketization, administrative intervention and social security level, and adds the numerical expansion results of Ma et al. (2015), and combining the factor marketization data results of 31 provinces in China from 1997 to 2020. The larger the value, the higher the marketization level of factors, which can

comprehensively reflect the development degree of factor flows under the socialist market economy system, so it will be added to the model as the main explanatory variable.

Internet penetration (Internet): we refer to the 1997-2020 China Internet network information center (CNNIC) released the China Internet network development statistical report, which includes 30 provinces' Internet penetration statistics, statistical method for the province Internet users (Internet broadband users) accounted for the proportion of the total population. In order to supplement the missing values in Xinjiang and some years, we searched through the National Bureau of Statistics and local Bureau of Statistics, and auxiliary adopted the ARIMA model interpolation method to fill in the missing values of time series data in the same region. Therefore, we included it to the model as the primary control variable.

Education level (Edu): based on Wan (2005), this paper will education level as an important control variable of empirical model, because the education level is difficult to measure accurately, we learn the Ni (2014), through the National Bureau of Statistics screening 1997-202031 provinces per ten thousand fiscal education spending (one hundred million yuan) as a measure of regional education level and education development speed, the missing data is more, temporarily through the assignment method to complement, so only as a control variable to join the model.

Science and technology level (Tech): Wan et al. (2005) also conducted an in-depth study on the gap of science and technology level and its role. For the same consideration, we chose the financial expenditure of science and technology per 10,000 people (100 million yuan) as the index to measure the regional science and technology level and the speed of science and technology development. The NBS data also had more missing values, so they were only added to the model as control variables.

Degree of opening to the outside world (Opu): According to the practice of Wan (2005) and others, the total import and export volume of foreign-invested enterprises in 31 provinces from 1997 to 2020 was selected to measure the openness of regional market. The greater the value, the greater the degree of openness. This data also had more missing values, and therefore was only added to the model as a control variable.

Industrial structure level (Ind): based on Wang (2022) and others, we through the National Bureau of Statistics screening the national 31 provinces between 1997-2020 added value of the third industry and GDP, by calculating the proportion of the third industry briefly measure the upgrading of industrial structure, the third industry accounted for the higher the growth, the faster the upgrading of industrial structure.

Technology innovation ability (Innov): in order to ensure the data integrity, we through the National Bureau of Statistics and screening the national 31 provinces in 1997-2020 technology market turnover (one hundred million yuan) and domestic patent application acceptance (item), through the weighted average around this observation time technology innovation ability index, the greater the value, the stronger the regional technology innovation ability. Due to the large correlation between this index and the level of science and technology, the endogeneity problem is strong, so it is not added to the main model as a control variable, and is mainly used for the analysis of the mediation model test.

Table 1. Description of the sample variables

variable		symbol	definition
explained variable	per capita GDP	GDP	The ratio of the annual standard deviation of per capita GDP to the annual average
explanatory variable	Digital financial inclusion	Digi, $Digi^2$	Peking University's inclusive digital financial Index system
	factor flows	Mvmt	Fan Gang (2011), Ma (2015), etc
controlled variable	Internet penetration rate	Internet	The ratio of the number of Internet users to the total population of the region (%)
	educational level	Edu	Annual financial expenditure on education per 10,000 people (100 million yuan)
	scientific and technological level	Tech	Annual fiscal expenditure on science and technology per 10,000 people (100 million yuan)
	Open to the outside world	Opu	Annual total import and export volume of foreign-invested enterprises (one thousand US dollars)
metavariable	Industrial structure level	Ind	The annual ratio of the added value of the tertiary industry to the regional GDP
	Technology innovation ability	Innov	The weighted average of the annual technology market turnover (100 million yuan) and the acceptance amount of regional patent applications

4.2. Benchmark Regression Analysis

In order to comprehensively compare the advantages and disadvantages and applicability of various models, we conducted the stationarity, collinearity, heteroscedasticity and cross section correlation tests after cleaning the panel data. The results showed that each variable passed the stationarity test, but the data had multiple collinearity, heteroscedasticity between groups, and cross-sectional correlation. Therefore, we chose the two-step system GMM method as the core model of regression analysis, and provided the conclusions of ordinary least squares (OLS) and fixed effect model for a comprehensive comparative analysis. In the following two tables, model 2, Model 4 and Model 10 are the regression results of adding all control variables, model 1, Model 3 and Model 5 are the regression results of retaining only core explanatory variables, and model 6 to Model 9 are the regression results of controlling Internet penetration, education level, technology level, and openness to the outside world.

4.2.1. Levels of Digital Development

As you can see, in the OLS and fixed effect model, and Digi

as the two-core explanatory variable are mostly statistically insignificant, but the symbol and magnitude is very stable, both presenting a sign trend consistent with the signs in GMM regression, confirmed that the digital "inverted U" influence on regional economic development gap. In addition, the first-item coefficient is positive, indicating that during the observation period (1997-2020), China is still dominated by the "polarization" of the first region, that is, the regional economic development gap is large. The "trickle-down" effect of digital bridging gap has just appeared, but the impact is still limited.

4.2.2. Factor Flows

The regression results of the core explanatory variable of factor flows are quite different from the other models, showing the completely opposite situation in the sign. Because there is heteroscedasticity between groups in the panel data, the fixed effect model is limited here, we will mainly compare the regression results of OLS and GMM, and take OLS results as the auxiliary, and GMM regression as the main reference.

Table 2. Results of OLS and the Fixed Effects Model

Results	OLS		fixed effect model	
variable	model 1	model 2	model 3	model 4
$Digi^2$	-0.0422 (0.0472)	-0.0662 (0.0458)	-0.0427 (0.0469)	-0.0609 (0.0430)
Digi	38.6371 (32.6726)	56.6893** (32.5109)	45.3370 (32.4776)	45.3192 (29.9621)
Mvmt	873.1988*** (209.2541)	456.5106*** (145.2297)	-819.4877*** (444.2540)	-1020.387*** (460.7682)
Internet		160.2388*** (36.0344)		57.8038 (43.7850)
Edu		-1.2708 (0.7839)		-1.3471 (2.3785)
Tech		5.3281 (3.4268)		12.1854*** (5.6010)
Opu		4.14e-06 (4.67e-06)		0.00002 (0.00001)
constant term	-16468.33** (7018.08)	-26570.16*** (7399.154)	-3424.4490 (8830.0680)	-4734.454 (7720.898)
N	279	278	279	278
$AdjustedR^2$	0.9718	0.9793	0.9253	0.9514
			Sargan	0.245 NA
			$AdjustedR^2$	0.9952 0.9943

Table 3. Results of the Regression of the Two-step Systematic GMM Model

Results	Two-step system by the GMM method					
variable	model 5	model 6	model 7	model 8	model 9	model 10
$Digi^2$	-0.8431*** (0.3471)	-1.0874*** (0.4002)	-0.8575*** (0.3527)	-0.8371*** (0.3467)	-0.7485*** (0.3333)	-1.0569*** (0.3533)
Digi	547.4986*** (237.1660)	726.8575*** (278.5612)	556.0754*** (240.3196)	540.2528*** (236.0579)	480.8392*** (226.6269)	701.2828*** (246.9943)
Mvmt	1280.895*** (331.0237)	1093.187*** (250.7581)	1252.222*** (365.4296)	1123.864*** (340.7196)	1005.573*** (320.2986)	1100.732*** (212.529)
Internet		184.0664*** (45.6556)				195.7179*** (54.6381)
Edu			0.1569 (0.7966)			0.7716 (1.1637)
Tech				3.2790 (2.3426)		-3.9799 (5.4517)
Opu					6.05e-06*** (2.37e-06)	2.84e-07 (9.15e-06)
constant term	-98706.11*** (41564.77)	-138291.3*** (48918.02)	-99779.72*** (42149.36)	-95718.46*** (41422.99)	-85154.95*** (39760.62)	-134061.2*** (43854.96)
N	278	278	278	278	278	278
AR (2)	0.316	0.676	0.320	0.264	0.168	0.642
Hansen	0.155	0.226	0.127	0.143	0.223	0.160

In both models, the regression results of factor mobility are very significant, and the symbol and magnitude are very stable, which helps us to answer the aforementioned core question of "whether the free flow of factors is the key driving force for the coordinated development of regional economy". It can be seen that the stronger the liquidity of factors is, the greater the gap in regional economic development is, that is, the worse the coordinated development of regional economy is. This conclusion can be understood as follows: During the observation period (1997-2020), the observation subjects (31 provinces in China) are still in the stage of rapid development, that is, the first areas are still in the stage of regional

polarization development, and various production factors spontaneously flow to the first areas with the polarization effect, and the "trickle-down" effect has not been fully stimulated. This conclusion also provides a basis for the temporal heterogeneity of digital development in promoting the optimal allocation of factors and the coordinated development of regional economy, which intensifies the Matthew effect of regional competition in this stage.

4.3. Mediator Regression Analysis

Next, in order to further verify the digital development, liquidity and the relationship between the coordinated development of regional economy, at the same time the digital development to promote the realization of regional economic coordination path analysis, we selected the factor flows, industrial structure level and technological innovation ability three intermediary variables, the Bootstrap test, the results are shown in the table below.

It can be seen that the three intermediary regressions all get the results of the concealment effect (that is, the direct effect is opposite to the indirect effect sign, some of which cancel each other), the indirect effect and its a and b coefficients are positive, and the direct effect - the c' coefficient is negative. This can be explained as follows: On the one hand, A is positive, and the influence of digital development on the three intermediary variables is all uni-linear, and it is positive, that is, factor flows, industrial structure level and technological innovation ability improve with the improvement of digital level. On the other hand, b is positive, and the benchmark regression results are twice verified that the factor flows and the regional economic development gap change in the same direction, the higher the factor flows, the greater the regional economic development gap (in the same way, the level of industrial institutions and technological innovation ability). In addition, the direct effect c' is not significant, which means that under the control of the three intermediary variables, the direct impact of digital development on the regional economic development gap cannot be analyzed by simple linear regression, which also confirms the temporal heterogeneity of digital development from the side. In the future, under appropriate conditions, we will further carry out empirical research to find, test and clarify the intermediary mechanism that can offset the liquidity of factors, industrial structure level and technological innovation ability through chain action, so as to effectively bridge the regional economic development gap.

Table 4. Results of Bootstrap mediation effect regression

explained variable	mediator	explanatory variable	effect Analysis*	coefficient	standard error	95% confidence interval	
GDP	Mvmt	Digi	direct effect	-4.0303	9.0582	-31.3813	3.9855
			indigo effect	7.7961***	2.9442	1.8684	11.6490
			gross effect	3.7658	9.0085	-26.4930	12.8855
	Ind		direct effect	-34.9319***	7.7565	-58.7182	-26.6671
			indigo effect	38.6977***	6.4156	24.6872	46.0655
			gross effect	3.7658	8.9938	-18.8461	14.1527
	Innov		direct effect	-14.5872***	7.4317	-31.8969	-7.6461
			indigo effect	18.3530***	4.6403	4.6921	23.5216
			gross effect	3.7658	8.4250	-20.2369	13.7393

*Mediation regression analysis fixed the years and individuals. In the results, the direct effect is c ', the indirect effect is a * b, and the total effect is c = a * b + c'. In the 3-mediation regression, the a and b coefficients were always positive.

4.4. Heterogeneity Regression Analysis

Finally, in order to quantify the spatial heterogeneity of the impact of digitization on the economic development of different types of regions, we divided 31 provinces into east, south, west and north according to their locations (the dividing line is roughly "X" on the map), and conducted regression analysis on each region. The results are shown in the following table. [Eastern region: Zhejiang, Shanghai, Shandong, Jiangxi, Jiangsu, Hubei, Henan, Anhui; Western region: Xinjiang, Tibet, Sichuan, Qinghai, Guizhou, Gansu; South: Chongqing, Yunnan, Hunan, Hainan, Guangxi, Guangdong, Fujian; Northern: Beijing, Tianjin, Hebei, Shaanxi, Shanxi, Ningxia, Inner Mongolia, Liaoning, Jilin, Heilongjiang.]

The coefficient of digital development of constant terms and core explanatory variables is significant and shows a reasonable magnitude distribution. First, the constant item quantifies the degree of coordination of economic development in the region. The smaller the value (i. e. the larger the absolute value), the smaller the economic development gap in the region and the more harmonious. Therefore, the order of economic development coordination in the four regions from high to low is the south, north, east and west. This is in line with the common perceptual cognition --The development level of the north and south regions is relatively good, while the west is the most backward.

Secondly, from the perspective of the secondary term ($Digi^2$) coefficient of digital development, the regional economic development gap of the four districts shows a trend of "inverted U-shaped" under the influence of digital, and the greater the absolute value, the steeper the "inverted U-shaped" curve, that is, the more severe the impact of digital development in the short term. This is also in line with our perceptual cognition. --The pioneer areas tend to have better digital technology and industrial base, and can rapidly improve the degree of digital development in the short term, thus obtaining the strongest "polarization" effect; while the latecomer regions are due to their weak foundation, the "trickle-down" effect usually takes longer time to appear.

At the same time, from the coefficient of each control variable, the regional heterogeneity was more significant, and only some regions of each control variable obtained significant coefficient results after regression. It can be briefly understood as follows: factor flows has a significant positive impact on the economic development gap in the southern

region, Probably the best business environment and the best market environment, Therefore, the phenomenon of "polarization" of the first provinces in the region is significant; Internet penetration rate has a significant positive impact on the economic development gap in the east, west and south provinces, Perhaps because the changes in the construction and adoption of Internet infrastructure in the three regions were most significant between 1997 and 2020, The northern region is little or relatively balanced; Education level has a significant positive impact on the economic development gap in the eastern and northern regions, Probably to the existence of a few provinces with dense quality higher education resources in these two regions, Such as Beijing in the north, Eastern Shanghai, Jiangsu and Hubei, Thus the distribution of educational resources in the east and north is more uneven than in the west and south, The impact on the economic development gap in the region is more significant; The level of science and technology only has a significant positive impact on the economic development gap in eastern China, It may be related to the outstanding investment and level of scientific and technological research and development in Shanghai and Jiangsu in eastern China; The degree of opening to the outside world has a significant positive impact on the economic development gap in western China, This is consistent with the development opportunities brought by the inland area opening strategy such as Belt and Road " and its short-term impact. In addition, it should be pointed out that in addition to the Internet penetration rate, the data of the remaining three control variables have many missing years. For example, the data of education level and technology level from 1997 to 2006 cannot be obtained, which can only be supplemented by statistical methods, which affects the regression results and accuracy to a large extent.

Table 5. Results of the Heterogeneity Regression for the Fixed Year and the Individuals

variable	region			
	east	west	south	north
$Digi^2$	-0.6178*** (0.1974)	-0.4223* (0.2007)	-0.8080*** (0.3660)	-0.8079*** (0.3946)
Digi	359.4835*** (124.2208)	238.3436* (145.7706)	550.2667*** (242.0862)	570.1882*** (274.5783)
Mvmt	-273.5327 (492.3690)	-86.7434 (260.1162)	681.8092*** (237.0953)	-867.2631 (1146.625)
Internet	335.1945*** (63.5785)	261.2143*** (57.144)	235.2332*** (47.7196)	96.4268 (106.3605)
Edu	3.8397*** (1.8199)	-0.0901 (2.6834)	-1.4278 (2.1565)	2.6160*** (1.2447)
Tech	27.0340*** (6.2635)	20.5356 (19.6289)	-2.1911 (3.9211)	8.7613 (21.2160)
Opu	-0.00000831 0.00000911	0.0000391*** (0.00000779)	0.00000233 (0.00000658)	0.0001127 (0.0000803)
constant term	-77783.06*** (20635.17)	-39462.19*** (17239.7)	-109610.7*** (40178.88)	-99206.73*** (43809.52)
N	72	53	63	90
AR (2)	0.112	0.24	0.185	0.187
Hansen	0.22	0.18	0.1	0.17

5. Conclusion and Policy Recommendations

After the above theoretical model derivation and empirical model test, we answer the three research questions raised at the beginning of this paper one by one.

First, through existing research in the retrospective community, we find that the concept of factor mobility plays an important role in the coordinated development of regions. Classical economic theories such as polarization, trickle down, core and edge all emphasize the importance of the free flow of progress and innovative factors such as technology, information and values. neoclassical economics believes that a fully competitive market environment will ensure the free flow of production factors, so as to realize the "Pareto optimal" of various resource allocation. At the same time, many studies have proved that digitization can significantly promote the free flow of factors or marketization. Based on these basic research, we through the system GMM model and intermediary effect model, preliminary quantified in the observation time (1997-2020) factors free flow of regional economic development gap, hinder the coordinated development of regional economic linear relationship, and found the digital promotion factors free liquidity, and expand the regional economic development gap chain influence.

Second, through the introduction of new intermediary variables, we found that the regional industrial structure upgrading, technology innovation ability has similar to the factors of free flow path, although the three negative effect on coordinated development of regional economy, but the negative effects are in different degrees by we failed to verify, digital other mechanisms of action, and make the regional economic coordinated development overall presents the evolution trend of "inverted U", and the trend with the deepening of digital degree and highlight. Based on the symbolic relationship between the primary term and the second term coefficient, we are able to verify the temporal heterogeneity of digital development, and make the judgment that China is still in the process of regional "polarization".

Furthermore, by dividing the 31 provinces into four regions and performing heterogeneity regression, we verified the spatial heterogeneity of digital development. Specifically, digital development has the most obvious role in bridging the development gap in the southern and northern regions with the good foundation of the Internet and other digital information technologies, and the most limited role in bridging the gap in the western regions with the weakest foundation. Each control variable is mainly restricted by the local development basis and situation, and there is also spatial

heterogeneity.

Although the above findings are affected by multidimensional uncertainties in variable selection, data integrity, and model reliability, these findings still have strong realistic significance.

On the one hand, the "Pareto optimality" brought about by the fully marketable and fully free-flowing factors of production has its limitations. The concentration of production factors in the first areas will bring development achievements such as optimization and upgrading of industrial structure and upgrading of technological innovation capacity, and promote the continuous improvement of development efficiency in the whole region. But in this process, the equity of development is bound to be challenged. Therefore, how to coordinate the relationship between the government and the market in the socialist market economy, use policies and other means to scientifically regulate the flow of factors, and ensure the fairness of development on the basis of fully stimulating the market vitality should always be the core issue of China's social and economic development, and also the core task of the work of local governments.

On the other hand, during the period of 1997-2020, the regional development gap is prominent, which proves that the "polarization" effect of China's first-mover areas is still strengthening and the "trickle-down" effect of the late-mover areas has not yet dominated, which highlights the fact that the problem of unbalanced and inadequate development as a developing country is still not solved. Therefore, how to give full play to the function of digital bridge regional development gap, accelerate and shorten the "polarization" or in advance, enlarge "trickle-down" effect, make the digital economy inclusive development, better service, backwardness regional economic and social, so as to achieve balanced development with strong development force, may be a new stage of development around the new direction of government work.

Finally, the spatial heterogeneity of various variables such as digitization, free flow of factors, Internet penetration rate and education level also provides a reference for the government in terms of specific paths. The basic construction of digital infrastructure such as the Internet and a unified national market, as well as the sinking and popularization of supporting systems and mechanisms such as education, innovation and opening up and their implementation, should become the key focus for realizing coordinated regional development.

To sum up, we hope that this paper can provide theoretical basis for the government's future digital work, promote the government to better understand the unbalanced development of our country, inadequate reality, scientific understanding the role of digital free flow of factors and may appear in the process of siphon effect and risk, rational potential of digital bridge regional development gap, as a whole the government and market, efficiency and fairness, focus, in a planned way, cultivate and play a regional comparative advantage, strengthen regional complementary advantages, shape the new pattern of regional coordinated development in our country.

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