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A study on the development of China's digital economy based on provincial panel data

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Abstract: *In recent years, China's economic development has entered a "new normal". Instead of pursuing GDP growth, maximizing economic scale, and pursuing aggregate economic growth, we have shifted to pursuing stable growth of economic structure, sustainable development under symmetric economic structure, and high-quality economic development. In view of this, this paper selects panel data of 30 provinces in China from 2010 to 2019, and finds the connection between the two indicators through coupled coordination degree model and panel vector autoregressive model (PVAR), and analyzes each province accordingly. The results show that: there are obvious synergistic effects between digital economy and high-quality economic development; China's overall digital economy has continued to develop in this decade, but the development in the east and west remains unbalanced; digital economy and high-quality economic development are integrated with each other and promote each other. Therefore, the digital economy is one of the new driving forces for China's high-quality economic development and economic structure transformation.*

Keywords: *Total Factor Productivity; SFA; Coupling; PVAR*

1. Introduction

Over the past 40 years of reform and opening up, China's economy has experienced rapid development, and the total national economy has leaped to the second in the world. However, behind this rapid growth, there are a series of problems such as environmental degradation, waste of resources, unreasonable industrial structure and low share of information technology-based industries. According to the data released by the National Bureau of Statistics: Since 2007, China's GDP growth rate has slowed down significantly, which is actually a necessary path for a country's economic development. Therefore, the Party took the lead in the 19th National Congress to propose that "China's economy has shifted from the stage of high-speed growth to the stage of high-quality development", officially unveiling the prologue of China's economic transformation. How to accelerate the economic transformation? This has also become an important issue of general concern to the Party Central Committee and all sectors of society.

At present, the new crown epidemic remains, protectionism and unilateralism are on the rise, and the world economy is in the doldrums. At the same time, the widespread development of online services such as telemedicine, online education and cross-border e-commerce has not only promoted international cooperation against the epidemic, but also facilitated the development of digital economy in various countries. This paper analyzes the status of digital economy and high-quality economic development of each province by using the coupled coordination degree model through the provincial panel2 data of China from 2010 to 2019, and chooses the PVAR model to analyze the inner connection between digital economy and high-quality development, so as to provide some theoretical reference for digital economy and high-quality development.

2. Model Construction

2.1. Coupling coordination degree model

The concept of coupling, which first arose in physics, is a measure of the interdependence5 between two or more entities. The degree of coordination can measure the degree of harmony and coherence between systems. The coupling coordination degree model unifies the coupling and coordination degree to further reveal the interaction relationship between two and more systems. In this paper, the coupling coordination degree model of two systems is developed for the relationship between digital economy and high-quality economic development [1,2], and the model is constructed as follows.

$$C = \frac{2\sqrt{UV}}{(U+V)} \tag{1}$$

$$D = \sqrt{CT} \tag{2}$$

$$T = \alpha U + \beta V \tag{3}$$

In the above model, U and V represent the comprehensive indicators of digital economy and high quality economic development, respectively, and C represents the system coupling degree of digital economy and economic development, which can be used to judge the degree of coupling between the two and the magnitude of their influencing effects on each other. However, in some cases, it is difficult to judge the coordination role between systems by simply relying on the coupling degree, and there may be a situation where the coupling degree is high due to the low level of comprehensive development of both systems. To avoid this problem, the coupling coordination degree D is introduced. in this paper, D represents the coupling coordination degree of digital economy and high quality economic development, and T represents the comprehensive index of digital economy and high quality economic development, which responds to the overall coordination effect and contribution between the two. α and β are parameters to be determined, which are the corresponding weights of the two systems, respectively. In this paper, the digital economy and high-quality economic development are regarded as two equivalent systems, so α and β are assigned as α=β=0.5. For the evaluation indexes of the coupling coordination degree model, the coupling coordination degree is divided into 10 evaluation criteria by referring to the division criteria of Liao Chongbin (1999) [3], as shown in Table 1

Table 1: Criteria for judging the degree of coupling and coordination between the digital economy and high-quality economic development

Coupling coordination D range	Coordination level	Coordination Type
(0,0.1]	extreme disorder	
(0.1,0.2]	Severe disorders	Dysfunctional decline class
(0.2,0.3]	Moderate disorder	
(0.3,0.4]	Mild disorders	
(0.4,0.5]	On the verge of disorder	Transition Class
(0.5,0.6]	Barely coordinated	
(0.6,0.7]	Primary Coordination	Coordinated development category
(0.7,0.8]	Intermediate Coordination	
(0.8,0.9]	Good coordination	
(0.9,1.0]	Quality Coordination	

2.2. PVAR model

The PVAR model (panel vector autoregressive model) [4] is developed on the basis of the VAR (vector autoregressive model), which not only combines the advantages of the VAR model (i.e., no prior determination of causal relationships between variables, treating each variable as endogenous, and analyzing the effects of each variable and its lagged variables on other variables in the model), but also incorporates the large cross-section and short time series of panel data It also incorporates the advantages of large cross-section and short time series of panel data, takes into account the effects of endogeneity of variables, and also controls for estimation bias caused by individual heterogeneity. The digital economy studied in this paper has a two-way influence interaction with the high quality economic development, which can lead to the problem of endogeneity. Therefore, the PVAR model is selected for customer service, and based on the coupling coordination degree, the dynamic coupling relationship between the digital economy and economic high-quality development is further explored. The model is set as follows.

$$y_{it} = \alpha_0 + \sum_{r=1}^{k} \alpha_j y_{i,t-j} + u_i + v_t + \varepsilon_{it} \tag{4}$$

In this paper, the PVAR model is constructed and the analysis process is [5].

(1). Smoothness test and cointegration test

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In order to avoid the problem of pseudo-regression due to the original series containing a trend, a smoothness test is required before the model is built. In this paper, the unit root test is used to determine whether the series is smooth or not, and the unit root test for panel data usually includes six methods. In this paper, we choose the LLC test for testing homogeneous series, the HT test for testing short time series panel data, and the IPS test for testing heterogeneous series. In case of non-stationarity, smoothing is performed by differencing.

For non-stationary data, if the time-series data of different variables are stationary of the same order, cointegration tests are also required. The cointegration test is used to test whether a set of series has a stable equilibrium relationship. In the PVAR model, the variables need to have cointegration relationship with each other for the established autoregressive model to be meaningful and for further Granger causality testing.

(2). Optimal lag order selection

The optimal lag order should be selected by considering AIC, BIC, HQIC and other criteria, and the corresponding PVAR model should be established according to the optimal lag order.

(3). PVAR model GMM estimation and result analysis

For the estimation of the model, we choose generalized moment estimation (GMM), which does not require the random error term to obey a certain deterministic distribution and allows serial correlation compared with the traditional estimation method, and thus is more effective for the estimation of panel data.

(4). Granger causality test

The Granger causality test can investigate whether there is a causal relationship between the variables. This paper establishes PVAR and further investigates the dependence between digital economy and economic quality development through Granger causality test.

(5). Impulse response analysis

Impulse response analysis can describe the response of an endogenous variable to shocks brought about by changes in the error term, specifically, the effect on the endogenous variable at different lags after a shock of the size of the standard deviation of any other variable is applied to the random error term. For a stable PVAR model, the impulse response function should converge to zero over time.

(6). Variance decomposition and analysis of variables

Variance decomposition is the process of decomposing the fluctuations of the endogenous variables of a system according to the degree of contribution and influence of each variable, so as to measure the degree of mutual influence between the variables.

3. Empirical measurement

3.1. Coupling coordination degree measurement and analysis

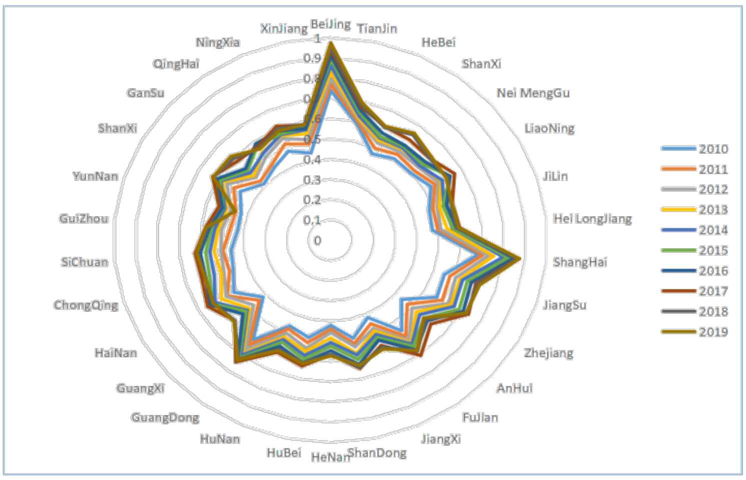

Figure 1: Radar map of coupling coordination by province, 2010-2019

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Based on the coupling coordination model, we use two indicators, the digital economy and total factor productivity, to calculate the coupling coordination degree of each province for the decade 2010 to 2009 by R The coupling coordination degree of each province for the decade from 2010 to 2019 is calculated.

Based on the base data obtained, we make a radar plot of the coupling coordination of each province in this decade, as shown in the Figure 1.

We can see from the figure: in the past decade, the overall coupling coordination degree of each province in China has been on an upward trend, but the ranking of each province has not changed much. Beijing, Shanghai and Guangdong have been maintaining a high coupling coordination degree, while Xinjiang and Yunnan have a relatively low coupling coordination degree. Subsequently, we used ArcGis software and selected data for two years, 2010, and 2019, to make the spatial distribution of coupling coordination degree, as shown in Figure 2.

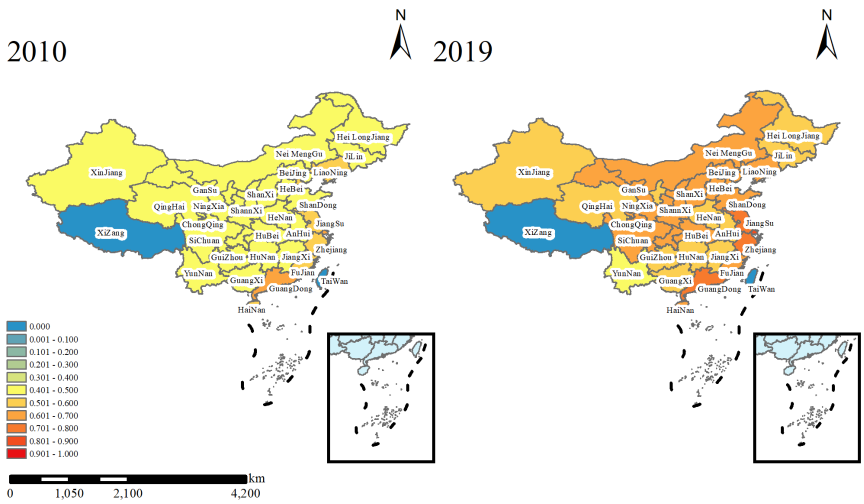

Figure 2: Spatial pattern of coupling coordination by province in 2010 and 2019

The coupling and coordination degree of digital economy and total factor productivity of each province shows an overall increasing trend, and the coupling and coordination degree of the central and eastern regions increases very obviously. In order to further verify our findings, we use the K-nearest neighbor algorithm to cluster the coupling coordination degree of each province, and the results are shown in Table 2.

Table 2: Results of cluster analysis of coupling coordination by province in 2010 and 2019

	2010	2019
First category	Beijing, Shanghai	Beijing, Shanghai
Second category	Tianjin, Guangdong	Tianjin, Jiangsu, Zhejiang, Fujian, Guangdong
Third category	Liaoning, Jiangsu, Zhejiang, Fujian, Hainan	Hebei, Shanxi, Inner Mongolia, Liaoning, Shandong, Hubei, Hainan, Chongqing, Sichuan, Shaanxi, Gansu
Fourth category	Hebei, Shanxi, Inner Mongolia, Jilin c Heilongjiang, Shandong, Hubei, Hunan, Chongqing, Sichuan, Shaanxi, Ningxia	Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hunan, Guangxi, Guizhou, Qinghai, Ningxia, Xinjiang
Fifth category	Anhui, Jiangxi, Henan, Guangxi, Guizhou, Yunnan, Gansu, Qinghai, Xinjiang	Yunnan

The clustering results are highly consistent with the results we obtained from the analysis of the figure and with the actual development of our country.

3.2. Panel vector autoregressive model measurement with

On the basis of coupling analysis, the dynamic relationship between digital economy and high-quality economic development is further explored through the PVAR model. Eviews8 as well as Stata16 software were used to establish PVAR models for the two-system integrated indicators of digital economy and high-quality economic development in 30 provinces (except Tibet, Hong Kong, Macao and Taiwan) from

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2010 to 2019. In the following analysis, tfp stands for the indicator of high-quality economic development and digital stands for the integrated indicator of digital economy.

3.2.1 Test of smoothness and co-integration test

(1) Smoothness test

First, in order to reduce the heteroskedasticity problem in the analysis process, the original composite indexes are first logarithmically processed. After processing, in order to prevent pseudo-regression problems in the regression process, unit root tests are performed on the two time-series composite indicators to ensure the smoothness of the data. In this paper, HT test, IPS test, and LLC test are selected to test the three methods, and it is found that the series after logarithmization is non-stationary, but all tests pass after first-order difference, indicating that the first-order difference series is stationary. The specific results are shown in Table 3.

Table 3: Unit root test results

Variables	HT Inspection	IPS Inspection	LLC Inspection
lntfp	1.0139	0.8605	-1.5360*
lndigital	0.7169	-1.1547	5.4406***
D1lntfp	0.1346***	-3.0762***	-5.0708***
D1lndigital	-0.0928***	-28.6778***	-12.9623***

(2) Cointegration test

Since the original series is non-stationary, and the series is stationary (homogeneous) after the completion of the first-order difference, it is necessary to conduct cointegration test on the results after the first-order difference. According to the results of the first-order difference, the Pedroni test and Johansen test, the test results p-value is less than 0.05, rejecting the original hypothesis that there is no cointegration relationship, that is, there is a cointegration relationship between the two, Johansen test on the results are shown in Table 4.

Table 4: Johansen cointegration test results

Original hypothesis	Fasher joint trajectory statistic (p-value)	Fasher joint eigenroot statistic (p-value)
0 covariates	3734*** (0.0000)	3085*** (0.0000)
At least one covariate	2618*** (0.0000)	2618*** (0.0000)

3.2.2 Optimal lag order selection

According to the AIC, BIC and HQIC criteria, the optimal lag order of the model is determined as order 1, thus establishing the PVAR(1) model.

3.2.3 GMM estimation

The PVAR model can decompose the impact of each variable on the endogenous variables under the condition of controlling other variables constant. Previously, we have determined the optimal lag order to be 1, selected the lag variable as the instrumental variable, and used GMM to estimate.

3.2.4 Granger causality test

In order to investigate whether there is a causal relationship between digital economy development and high quality economic development, Granger causality tests are conducted for two variables with a lag of 1 period.

3.2.5 Impulse Response Analysis

In this paper, in order to study the variation mechanism of the two variables of economic quality development and digital economy development, we use 200 Monte Carlo simulations to obtain the impulse response function graphs of these two variables for 10 periods, as shown in Figure 3.

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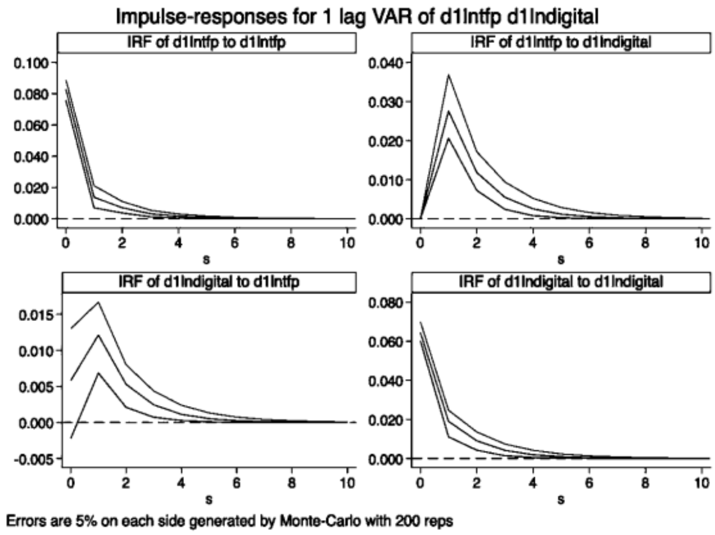

Figure 3: Impulse Response Graph

The middle line in the figure is the impulse response function, and the lines on either side are the 95% confidence intervals formed by 200 Monte Carlo simulations. Looking at the plots in turn, we can see that a rapid positive impact of economic high quality development on its own shock in the short term, which indicates good economic inertia and significant self-reinforcing effect in the short term, but the impact of this shock becomes smaller and gradually tends to zero as the period goes on.

The positive impact of economic high quality development on the development of digital economy has an obvious rapid growth trend in the beginning period, and then turns to a decreasing positive impact and gradually tends to stabilize, which indicates that economic high quality development has a positive contribution to the digital economy.

The impact of digital economy development on economic high quality is similar to the impact of economic high quality development on digital economy, which starts to show a rapid positive impact and tends to stabilize over time, and the combination of the two indicates that economic high quality development and digital economy development play a mutually reinforcing role, which is consistent with the results of Granger causality test.

The impact of the digital economy on itself shows a rapid positive impact in the early stage, and tends to stabilize after 4 periods.

4. Conclusion

The coupled and coordinated development indicators are highly consistent with the changes in the digital economy indicators. This indicates that the development of digital economy has a significant enhancing effect on high-quality development. According to the research results, we can see that the coupling coordination degree is better in the more developed regions of digital economy with higher level of high-quality development; from the spatial distribution of the coupling coordination degree, we can find that the coupling coordination of Hubei in the central region took the lead in the coordinated development stage in 2015, which matches the rapid digital development of Hubei and Sichuan in the previous paper. By 2019 the central region, except Ningxia, all enter the stage of coordinated development, which is in addition to the provinces' own development, but also can not be separated from the driving effect of Sichuan and Hubei; through the PVR model, we can easily find that while the digital economy promotes high-quality development, the high-quality development of the region will also have a huge impact on the digital economy of the region, and from the degree of impact, the development of the digital economy has a The degree of influence of high quality development is greater.

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