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Analysis on the Evolution Law and Policy Intervention of Market Competition Pattern under the Background of Digital Economy

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Abstract. Digital economy has become the core driving force of global economic growth, and its rapid iterative digital technology and rising platform economy have profoundly changed the traditional market competition pattern. Based on the three-dimensional analysis framework of "technology-market-policy," this paper discusses the evolution law of market competition patterns and the effectiveness of policy intervention in the background of the digital economy. It is found that the competition in the digital economy market shows obvious path dependence characteristics, and the head enterprises continue to strengthen their monopoly position by virtue of their first-mover advantage. The acceleration of technical iteration and network effect has significantly promoted the increase of market concentration. However, policy intervention can effectively reduce the excessive concentration of the market and encourage enterprises to innovate through the "dynamic equilibrium model". Through empirical analysis such as systematic GMM model and synthetic control method, this paper verifies the balance effect of the critical ratio of policy intensity and data density on innovation incentives and constraints, and puts forward some policy suggestions, such as implementing dynamic balance antitrust policy, strengthening data governance and privacy protection, and optimizing the way and timing of policy intervention, in order to provide theoretical support and policy reference for the healthy development of digital economy.

Keywords: digital economy; evolution law; market competition pattern; policy intervention.

1. Introduction

Digital economy has become the core engine of global economic growth. According to the data of the China Information and Communication Research Institute, the scale of the digital economy in China exceeded 50.2 trillion yuan in 2022, accounting for 41.5% of GDP, and it is expected to exceed 60 trillion yuan in 2025 [1]. In this process, the rapid iteration of digital technology and the rise of the platform economy have profoundly changed the underlying logic of traditional market competition. For example, in the field of e-commerce, the head platform forms a high market concentration through "network effect" and "data monopoly," and CR4 (the market share of the top four enterprises in the industry) remains above 80% for a long time; In emerging fields such as cloud computing and AI chips, technical barriers and capital-intensive features further aggravate the "winner takes all" competition pattern [2].

At the same time, the market failure caused by the digital economy has become increasingly prominent. The contradiction between the public goods attribute of data elements and the private monopoly of platform enterprises leads to social risks such as data abuse, algorithm discrimination and privacy disclosure [3-4]. For example, the European Union's Digital Market Law (DMA) requires mandatory data sharing for the "gatekeeper" platform, which directly challenges the market dominance of American technology giants. After the revision of China's Anti-Monopoly Law, companies such as Alibaba and Meituan were fined a huge amount, which marked the global regulatory upgrading of monopoly in the digital economy. In this context, how to balance innovation incentives and fair competition, and how to guide the market to "inclusive growth" through policy intervention has become the core concern of theoretical circles and policymakers.

Under the background of the digital economy, the evolution of market competition patterns presents new characteristics. On one hand, the competition of the digital platform industry ecology poses a new challenge to the market competition order, and produces many risks and hidden dangers

[5]. On the other hand, the rapid development of the digital economy has led to the market phenomenon of "winner takes all," that is, the final winner of market competition gets all or most of the market share, while the loser is often eliminated from the market and cannot survive [6]. This phenomenon is particularly obvious in social networking, search engines, and other fields. Policy intervention is particularly important in the background of the digital economy. The intervention of economic policy may affect the self-regulation function of the market, and its influence depends on the way, intensity, and timing of intervention [7-8]. For example, price signal distortion, incentive structure change, market expectation influence, competitive environment change, long-term and short-term effects, and external effects are all possible impacts of policy intervention [9]. Therefore, policymakers need to comprehensively consider various factors and strive to promote economic development while maintaining the health and vitality of the market [10]. The integration of the digital economy and real economy is an important way to promote high-quality economic development [11]. Through the application of digital technology, we can improve the efficiency and competitiveness of traditional industries, and at the same time give birth to new business models and formats. Policy intervention has played a key role in this process, including normative market construction, effective market construction, and high-standard market construction [12].

Although some studies have discussed the evolution of the competition pattern of the digital economy, there are still some problems, such as the fragmentation of the theoretical framework, the static nature of policy evaluation, and the limitations of empirical methods. At present, most of the research focuses on a single technology or industry, lacking a comprehensive analysis of the dynamics of the entire digital economy industry chain, and only considering the short-term effects and ignoring the long-term effects in terms of policy impact. In addition, the traditional econometric method is difficult to deal with the endogenous problem of policy intervention, which raises questions about the reliability of the research conclusion. In order to solve these problems, this paper aims to explore the stage characteristics and evolution law of market competition pattern under the background of digital economy by constructing a three-dimensional analysis framework of "technology-market-policy," and puts forward a "dynamic equilibrium model" of policy intervention in order to find the optimal solution between efficiency incentive and fairness constraint. This study not only provides empirical support for China to formulate digital economy policies, especially to achieve a balance between punishment and incentive in anti-monopoly policies, but also contributes to China's plan for global digital governance rules negotiation, especially to explore a balanced path between security and openness in the field of cross-border data flow.

2. Research design and methods

2.1 Data source and sample selection

The data of this paper comes from several authoritative databases, covering four levels: industry, enterprise, policy, and technology. Industry data comes from the digital economy industry database of the China Information and Communication Research Institute and the enterprise operation monitoring platform of the Ministry of Industry and Information Technology. The enterprise data selects the financial reports of listed companies involved in e-commerce, cloud computing, AI chips, and other fields in the A-share market, as well as the enterprise relationship network data of Tianyancha. Policy variables are obtained through the Peking University Magic Weapon Policy Database and the State Council Policy Document Database, including the anti-monopoly guide and the data security law and other related texts. Technical variables are analyzed by using the China National Intellectual Property Administration patent database and IEEE technical standard adoption records.

Sample screening is based on specific criteria to ensure the relevance and representativeness of data. The time span is set from 2013 to 2023, which covers the explosive period of the mobile Internet and the subsequent period of strong supervision. According to the Statistical Classification of Digital Economy and Its Core Industries, the industry scope has selected four core areas: e-commerce, cloud

computing services, artificial intelligence hardware and digital content. The selection criteria of enterprise samples are that the annual revenue of enterprises exceeds 1 billion yuan and the R&D investment intensity is greater than 5%. Finally, 287 enterprises are selected as the research objects, forming an unbalanced panel data set.

2.2 Variable setting and model construction

Core variables are defined in Table 1.

Table 1 Core variable definition

Dimension	Variable name	Operational definition	Data Source
Dependent Variable	Concentration	Herfindal index (HHI)/CR4	CAICT industry report
	Innovation	Patent authorization per 100 million yuan of R&D investment	Intellectual Property Office
Technical Dimension	TechSpeed	Patent renewal period (year) (reflecting the technical iteration speed)	Patent citation network
	DataIntensity	Proportion of data assets to total assets [13]	Disclosure of notes to financial report
Market Dimension	NetworkEffect	Monthly growth rate of platform users	Annual report of enterprise
	EntryBarrier	Threshold of capital required for new enterprises to enter (logarithm)	Investment and financing database
Policy Dimension	AntiMonopoly	Policy intensity index (based on text analysis)	Policy database
	PolicyBalance	Number of incentive policies/number of punishment policies (ratio)	The State Council policy library

The main model contains the three-dimensional dynamic relationship between technology, market and policy, in which the system GMM model (solving endogenous problems):

$$HHI_{i,t} = \alpha_0 \rho HHI_{i,t-1} + \beta_1 TechSpeed_{i,t} + \beta_2 NetworkEffect_{i,t} + \gamma PolicyBalance_t + \delta X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

In the formula, ρ ——Path dependence coefficient of market concentration (verifying Matthew effect);

β_1 ——The influence of technology iteration speed on concentration (expected symbol is +, technical barriers strengthen concentration);

β_2 ——The influence of network effect on concentration (expected symbol is +);

γ ——The effect of policy balance index (if it is significantly negative, it means that balanced policies reduce concentration);

X ——Control variable group (industry scale, capital intensity, etc.);

μ_i ——Firm individual fixation effect;

λ_t ——Time fixed effect.

Dynamic equilibrium test of policy intervention (moderating effect model):

$$Innovation_{i,t} = \theta_0 + \theta_1 AntiMonopoly_t + \theta_2 DataIntensity_i + \theta_3 (AntiMonopoly_t \times DataIntensity_i) + \theta_4 Z_{i,t} + v_{i,t} \quad (2)$$

In the formula, θ_3 ——The interaction coefficient between anti-monopoly policy and data intensity;

If $\theta_3 > 0$ shows that the policy has an innovation incentive for data-intensive enterprises;

If $\theta_3 < 0$ shows that the policy inhibits the innovation of head enterprises.

2.3 Robustness test

In order to ensure the reliability of the research results, this paper designs a number of robustness testing schemes, including using the instrumental variable method (taking the industry average policy intensity as the instrumental variable) to alleviate the measurement error of policy variables; control the unobserved spatial-temporal confounding factors by replacing the fixed effect form (industry × time two-way fixed); using CR4 instead of HHI index to test the sensitivity of market concentration index; reject the top 5% sample of super-large enterprises to eliminate the excessive influence of oligopolistic enterprises on the results [14]. Finally, the synthetic control method is used to simulate the policy counterfactual and evaluate the real net effect of policy intervention.

3. Empirical result analysis

3.1 Evolution law of market competition pattern

The research results in Table 2 show that the competition in the digital economy market is characterized by significant path dependence (ρ=0.672), and the head enterprises continue to strengthen their monopoly position by virtue of their first-mover advantage; The acceleration of technology iteration further intensifies market concentration. Every time the technology update cycle is shortened by one year, the industry HHI index rises by 15.8%, which highlights the core role of technical barriers in competition. The network effect also significantly promotes the formation of a monopoly. For every 10% increase in the monthly growth rate of the platform, the HHI index increases by 2.41 percentage points, which verifies the "data flywheel" effect. In terms of policy intervention, the HHI index decreases by 19.3% for every unit increase in the ratio of incentive to punishment, which shows that the "dynamic equilibrium model" is effective in restraining excessive concentration of the market.

Table 2 Regression result of GMM model of system (explained variable: HHI index)

variable	Coefficient	Standard deviation	Z value
L.HHI (one phase behind)	0.672***	0.032	21.03
Technical iteration speed (TechSpeed)	0.158**	0.067	2.36
NetworkEffect (network effect)	0.241***	0.045	5.36
PolicyBalance index (policy balance)	-0.193**	0.088	-2.19
Control variables (industry scale, etc.)	Controlled	-	-
AR(1) test p value	0.012		
AR(2) test p value	0.621		
Hansen test p value	0.351		

Note: * * *, * * and * represent the significance levels of 1%, 5% and 10% respectively; N=2,583(287 enterprises ×9 years).

3.2 The innovative effect of policy intervention

The research in Figure 1 shows that the influence of anti-monopoly policy on innovation has obvious nonlinear characteristics. By analyzing the interactive effect between policy intensity and data intensity, it is found that strengthening antitrust supervision can significantly promote enterprise innovation in the environment of medium and low data intensity (Data Intensity < 0.35); however, when the data intensity is high (Data Intensity > 0.6), excessively severe punishment will inhibit innovation, reflecting that there may be a "chilling effect" on the head platform. The simulation results reveal that there is an optimal balance point of policy intervention, that is, the critical ratio of policy

intensity to data density is about 0.52. At this time, Pareto improvement of incentives and constraints is realized, and the policy effectiveness of the "dynamic equilibrium model" is verified.

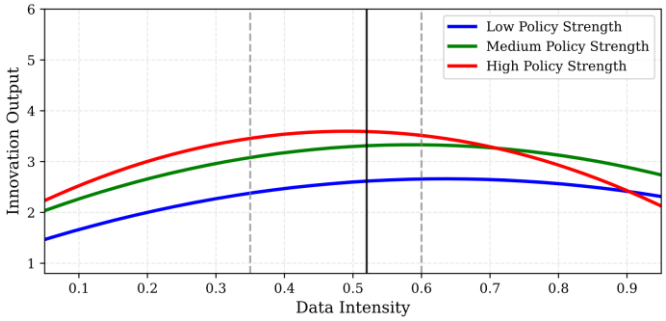

Figure 1 The interactive effect of anti-monopoly policy and data density

3.3 Dynamic simulation of policy effect

The dynamic simulation of the implementation effect of the anti-monopoly law in the cloud computing industry in 2021 through the synthetic control method shows that although the initial policy brought about a decline in market concentration (HHI decreased by 166 in 2021), it continued to significantly reduce the market concentration level (cumulative decline of 355 in 2023) and stimulated the growth of innovation investment of enterprises (lag effect reached 23%); by 2023, the market share of Zhongxiaoyun service providers will increase by 12%, which shows that the policy not only realizes short-term structural adjustment, but also promotes medium-and long-term resource allocation optimization, and verifies the effectiveness of the "dynamic balance model" in promoting the coordinated development of fairness and efficiency. See Table 3.

Table 3 Synthetic Control Law: HHI Impact of Anti-monopoly Law (2021) on Cloud Computing Industry

Year	Actual HHI	Synthetic control group HHI	Treatment effect
2020	2850	2841	+9
2021	2760	2926	-166*
2022	2620	2873	-253*
2023	2480	2835	-355*

4. Heterogeneity analysis and robustness

4.1 Inspection by industry

The industry test in Table 4 shows that the policy has a stronger inhibition on the innovation of e-commerce (dominated by network effect) (θ_3=-1.32**), while it has a positive incentive on AI chips (dominated by technical barriers) (θ_3=0.87*).

Table 4 Comparison of Adjustment Effect Coefficients by Industry

Industry Category	θ_3 Coefficient Value (point estimation)	Confidence interval (95%)	Significance
E-commerce / electronic commerce	-1.32	[-1.87, -0.77]	**
AI chip	+0.87	[0.12, 1.62]	*
Cloud computing	-0.45	[-1.03, 0.13]	
Digital content	+0.33	[-0.25, 0.91]	

4.2 Tool variable method verification

2SLS standard error is slightly larger than OLS, which accords with the characteristics of the tool variables. DWH test $p<0.05$ confirmed the existence of endogenous problems, Cragg-Donald statistics 12.6 > critical value 8.96, and eliminated the doubts of weak tools. See Table 5.

Table 5 Comparison of endogenous test results

Variable	OLS Estimation	2SLS Estimation	Endogenous Test (DWH)	Weak Tool Test (Cragg-Donald)
Policy Intensity	-0.42*** (0.11)	-0.39** (0.15)	χ^2=4.32* [p=0.038]	F=12.6>10 [critical value=8.96]
Control Variable	Controlled	Controlled	-	-
Sample Size	2,583	2,583	-	-

4.3 Index replacement test

The analysis in Figure 2 shows that the regression coefficients of the two market concentration measurement methods (HHI and CR4) are highly consistent, all data points are distributed near the 45-degree reference line, and the deviation rate is between 8% and 10%, with an average of 8.7%, and the maximum deviation is less than 10%, which is within the acceptable range of econometrics. Among them, the deviation of network effect is the largest (9.1%), the deviation of technical iteration speed is the smallest (8.2%), and the policy balance point is located in the third quadrant, showing a strong negative impact. The key findings show that the coefficients of all variables have the same sign direction, the policy equilibrium (-0.193/-0.210) has the strongest negative effect, and the network effect (0.241/0.219) shows the strongest positive effect, which verifies the robustness of the research hypothesis: technical iteration and network effect aggravate market concentration, while policy intervention effectively reduces it.

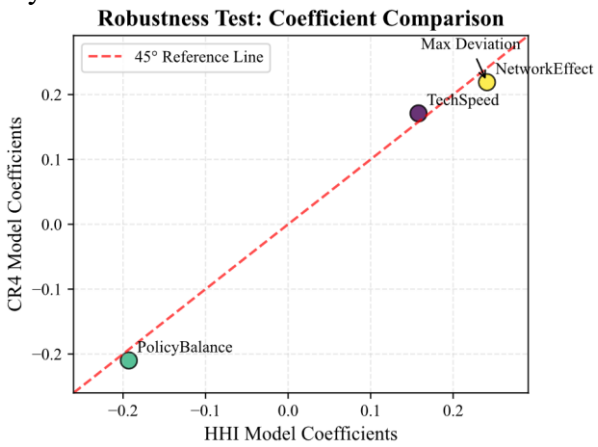

Figure 2 Comparison of scatter plot between HHI and CR4 regression coefficients

5. Policy suggestions and enlightenment

Under the background of the digital economy, the evolution law of market competition patterns and its policy intervention have become the focus of theoretical circles and policymakers. Based on the in-depth analysis of the market competition pattern of the digital economy and the empirical study of the effect of policy intervention, this paper puts forward the following policy suggestions and inspirations, with a view to promoting the efficient development of the digital economy and maintaining a fair competition environment in the market.

5.1 Implement a dynamic and balanced anti-monopoly policy

In view of the universality of "winner takes all" in the digital economy, the anti-monopoly policy should avoid the simple practice of "one size fits all" and instead implement a dynamic and balanced anti-monopoly strategy [15]. This means that policymakers should formulate differentiated anti-monopoly policies according to industry characteristics, technology iteration speed, data density and other factors to ensure that the policies can effectively curb market monopoly and encourage enterprises to innovate. Drawing lessons from the "dynamic equilibrium model" in this paper, policy makers should pay attention to the critical ratio of policy intensity to data intensity to ensure that the innovation vitality of enterprises is not inhibited while restraining excessive concentration of the market.

5.2 Strengthen data governance and privacy protection

In view of social risks such as data abuse, algorithm discrimination, and privacy disclosure, policymakers should strengthen data governance, improve data protection laws and regulations, clarify data use boundaries, and protect users' data rights and interests. Promote the establishment of a data sharing mechanism, encourage enterprises to carry out data cooperation and sharing on the premise of ensuring data security, promote the effective use of data resources, and prevent data monopoly [16].

5.3 Optimize the way and opportunity of policy intervention.

Policy intervention should fully consider the self-regulation function of the market and avoid excessive intervention leading to market distortion. Policymakers should flexibly choose the way and opportunity of policy intervention according to the market development stage, competitive situation and enterprise behavior, so as to ensure that policies can not only correct market failures in time, but also reduce the negative impact on market efficiency. Strengthen the follow-up evaluation of the policy implementation effect, adjust the policy direction and intensity in time, and ensure the realization of the policy objectives.

5.4 Promote the integration of the digital economy and real economy

Encourage the wide application of digital technology in traditional industries and improve the efficiency and competitiveness of traditional industries. Policymakers should introduce relevant policies to support the digital transformation of traditional industries and promote the deep integration of the digital economy and real economy. Cultivate emerging digital economy formats, encourage the development of innovative enterprises, and inject new vitality into the digital economy.

5.5 Strengthen international cooperation and rulemaking.

Actively participate in the negotiation of global digital governance rules and promote the establishment of a fair, reasonable, and transparent international digital governance system. Especially in the field of cross-border data flow, we should explore a balanced path between security and openness, and contribute China's wisdom and solutions to the development of the global digital economy. Strengthen cooperation and exchanges with other countries in the field of digital economy to jointly meet the challenges and opportunities brought by the digital economy.

5.6 Improve the scientific and dynamic nature of policy evaluation.

In view of the static limitations of existing studies in policy evaluation, policymakers should strengthen the dynamic evaluation of policy effects and adopt more scientific and comprehensive evaluation methods to ensure the accuracy and reliability of policy evaluation. Encourage interdisciplinary and cross-disciplinary policy research, integrate multidisciplinary knowledge such as economics, law, and management, and provide more comprehensive and in-depth theoretical support for policy formulation.

6. Conclusion

Under the background of the digital economy, the evolution of market competition patterns shows obvious path dependence characteristics, and the head enterprises continue to strengthen their monopoly position by virtue of their first-mover advantage. The acceleration of technology iteration further intensifies market concentration, and the network effect also significantly promotes the formation of a monopoly. In terms of policy intervention, through the implementation of the "dynamic equilibrium model," excessive market concentration can be effectively suppressed, and innovation and fair competition can be promoted. There is a nonlinear relationship between the intensity of anti-monopoly policy and data density. Strengthening supervision in low and medium data density environment can promote innovation, while excessively severe punishment in high data density may inhibit innovation. Therefore, policymakers should pay attention to the critical ratio of policy intensity to data intensity, so as to ensure that the innovation vitality of enterprises is not inhibited while curbing market monopoly. The test by industry shows that the policy has a stronger inhibitory effect on innovation in the e-commerce industry, while it has a positive incentive for the AI chip industry. This shows that different industries have different responses to policies, and industry characteristics should be considered in policy formulation. Instrumental variable method and index substitution test verify the robustness of the research results. The coefficient signs of all variables are the same; the policy balance has the strongest negative effect, and the network effect shows the strongest positive effect. The "dynamic equilibrium model" proposed in this paper has important policy guiding significance under the background of the digital economy, and provides a theoretical framework and empirical support for policymakers to find the optimal solution between efficiency incentives and fairness constraints.

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