

Article

From Protectionist to Regulator: Policy-Driven Transformation of Digital Urban Networks in China's Online Gaming Industry

Xu Zhang ¹, Yingmin Huang ^{2,*} and Xiaohua Zou ³

¹ School of Civil Engineering and Surveying & Mapping Engineering, Jiangxi University of Science and Technology, Ganzhou 341000, China; zhangxu.geo@mail.jxust.edu.cn

² School of Architecture and Design, Jiangxi University of Science and Technology, Ganzhou 341000, China

³ Regional Development Research Institute, Guangzhou Academy of Social Sciences, Guangzhou 510410, China; zouxiaohua_hg@126.com

* Correspondence: huangyingmin693@163.com

Abstract: In the digital era, data-driven production organizes digital urban networks. This study explores the critical role of government policies in shaping these networks, focusing on China's evolving policy contexts. While existing research has mainly emphasized qualitative analyses, this paper quantitatively assesses the impact of policy changes on digital urban networks, specifically through the lens of China's online gaming industry. The study aimed to elucidate the relationship between the policy environment and digital urban networks. By examining China's transition from protectionist to regulatory policies, this research employed a social network analysis and valued exponential random graph models (ERGMs) across two key phases: the competitive protection phase (2014–2017) and the systematic regulatory phase (2018–2022). The findings revealed a significant transformation in urban network structure, shifting from a centralized model dominated by a few core cities to a decentralized, multi-centered network. The key factors influencing this evolution include the institutional proximity and cross-regional collaborations. This study offers valuable insights into how policy shifts affect urban networks in the digital economy, contributing both theoretically and practically to future policy design.

Keywords: digital economy; policy context; protectionist policies; regulatory policies; urban networks



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1. Introduction

The digital economy, driven by advancements in information and communication technology (ICT), is a key driver of modern economic growth, reshaping the spatial and structural dynamics of cities and regions [1,2]. Unlike traditional industrial economies, it fosters new urban networks by facilitating the cross-border flow of information, capital, talent, and innovation, creating complex, interconnected systems essential for regional development [3,4]. By enhancing resource exchange, promoting innovation, and boosting global competitiveness, these networks significantly influence the future of urban areas. Understanding how the digital economy impacts urban networks is crucial for advancing urban and regional studies, particularly in rapidly urbanizing economies such as China [5,6]. In China, expansive digital infrastructure and strategic government policies have played a pivotal role in shaping urban networks and the broader spatial organization of economic activities [7,8]. Through coordinated efforts, China exemplifies how policy and infrastructure can influence the digital economy's impact on urban development [9,10].

Existing research has examined the effects of the digital economy on urban networks and regional development, highlighting how data-centric production transcends the traditional constraints of time and space. This leads to the emergence of digital urban networks and facilitates intra- and interregional information linkages through “local buzz” and “global pipelines” [11–14]. Scholars have emphasized the role of government policies in creating a supportive environment for digital industries, particularly through incentives that

drive industrial agglomeration and urban growth [10,15,16]. In developing countries such as China, policy-driven development has been especially impactful, as evidenced by strong support for digital infrastructure and diverse industrial policy contexts [9,10,17]. Initially, the Chinese government implemented protectionist measures to shield domestic industries from foreign competition. As the digital economy matured, these policies evolved into a systematic regulatory framework [10]. Such changes not only supported the growth of China's digital market, but also positioned it as a key driver of national innovation [9].

Despite these advances, a gap remains in the literature regarding quantitative empirical analyses of how specific policy factors influence the formation and evolution of digital urban networks. Previous studies have predominantly relied on qualitative methods, such as literature reviews and case studies, which fail to fully capture the complex dynamics involved [9,10,18]. To address this gap, this paper presents a detailed quantitative analysis of China's online gaming industry—one of the most policy-sensitive sectors in the digital economy. The scope of this research extends beyond the online gaming industry, focusing on the broader implications of government policy on urban networks. By examining how different policy phases, from protectionist to regulatory, influence the spatial organization of industries, this study offers new insights into how policy frameworks shape digital urban networks. These findings are not only relevant to China, but they also provide valuable lessons for other emerging digital economies facing similar challenges.

This study aimed to elucidate the relationship between the policy environment and digital urban networks, with the hypothesis that changes in policy contexts impact the transformation of these networks, influencing characteristics such as the structure and stability. By employing a social network analysis and valued exponential random graph models (ERGMs) on digital production project data, this study traced structural changes in urban networks across two key policy phases: the competitive protection phase (2014–2017) and the systematic regulatory phase (2018–2022). Unlike previous research, which focused on qualitative methods, this study introduced a quantitative framework to systematically analyze the relationship between policy shifts and urban network dynamics. The results reveal how different policy contexts affect spatial distribution, network density, and intercity connectivity. This approach not only deepens the empirical understanding of policy influences on urban networks, but also provides a comprehensive framework for future research.

The remainder of this paper is organized as follows: Section 2 reviews the literature on the digital economy and urban networks, summarizes how policy contexts influence the digital economy, and explains the changes in China's online gaming industry policy context. Section 3 describes the research data and methods used in this empirical analysis. Section 4 presents the characteristics of and differences in digital urban networks across various policy phases, summarizing how protective and regulatory policies shape urban spatial flows. Finally, Sections 5 and 6 discuss the findings and offer conclusions based on the empirical analysis.

2. Literature Review

2.1. Urban Networks and the Digital Economy

Research on urban networks has significantly evolved, focusing on how the flows of people, goods, capital, and information shape the spatial structure of cities and regions. Castells' theory of the "space of flows" redefined cities as dynamic "nodes" and "hubs" within interconnected networks, highlighting the importance of these flows in fostering complex intercity connections essential for regional economic development [19]. Similarly, Sassen's concept of "global cities" underscores urban centers as strategic locations for global economic activities, where specific functions and services converge to drive innovation and competitiveness [20]. Friedmann's theory of "world cities" further complements this perspective, emphasizing the interconnectedness of cities through global networks and suggesting that urban areas serve as critical nodes in a larger economic system [21]. The GaWC group, led by Taylor, advanced the study of world urban networks through the

“chain network model”, focusing on advanced producer services [22,23]. This shift led to an increased interest in corporate networks, which describe the connections between enterprises across cities and capture the micro-foundations of urban networks [24]. These corporate networks lay the groundwork for economic interactions and knowledge transfers, positioning enterprises as key agents in urban network formation [23].

As urban networks continue to develop, the concept of the “network city” has emerged. Camagni posits that network cities differ from traditional hierarchical urban structures, which are characterized by close horizontal and vertical connections among network nodes, with complementary functions and collaboration promoting overall development [25]. Roberts and Bertolini assert that network cities are polycentric urban areas supported by both physical networks, such as transportation and communication, and virtual networks, such as information systems [26,27]. However, these definitions do not fully capture urban networks in the digital economy. With the rise of the digital economy, driven by advancements in ICT, urban networks have further evolved. The digital economy enables cross-regional connections that transcend traditional geographical constraints, reshaping cities into fluid, globally interconnected digital networks [3,4]. Digital technologies play a pivotal role in transforming traditional urban networks by facilitating the flow of production factors—such as talent, technology, and knowledge—driven by the demands of digital production and innovation [11]. This paper defines the digital urban network as a network structure organized around digital production or information, with data at its core.

Existing studies have examined digital urban networks from various sectoral perspectives, though they do not explicitly define their object of study as proposed here. For instance, Hoyler and Watson revealed the barycentric nature of the global digital film production network [12]. Zhang et al. found that digitization spurred the clustering of online video networks in central cities and their proliferation in smaller cities [13]. He et al. demonstrated how information flow in digitized virtual spaces reconfigures urban systems through an analysis of digital creative communities [28]. These studies suggest that digital urban networks are increasingly accommodating remote, small, and medium-sized cities, while also linking certain network characteristics to specific government policies. However, they have not integrated changes in government policy and the transformation of digital urban networks into a comprehensive analytical framework, nor have they explored the types of policy contexts that lead to specific changes in digital urban networks. The next section aims to address this gap by discussing the potential impact of government policies on the digital economy.

2.2. Impact of the Policy Context on the Digital Economy

Government policies are crucial in shaping industrial agglomeration and urban growth. Studies have highlighted the powerful dynamics of government actions in forming urban networks [29], with governments often acting proactively as key players in this organization [30]. In the digital economy, the influence of government policy is particularly significant. Rather than directly instructing network actors (e.g., cities or firms), governments can influence digital urban networks through a broader policy context [31–33]. By shaping the development environment, policies affect digital industry clustering and the spatial distribution of economic activities, especially through digital infrastructure development and targeted industrial policies [10].

In developing countries, inadequate infrastructure poses major challenges to digital entrepreneurship [17]. Given the digital economy’s reliance on robust Internet communications, ensuring a stable power supply and reliable connectivity is essential for the efficient flow of data and other production factors [34]. Such infrastructure improvements help reduce regional disparities in communication and collaboration, fostering the growth of technologies such as cloud computing and the Internet of Things [35]. Industrial policies significantly impact the agglomeration and growth of the digital economy. These policies encompass government-initiated measures in industry, trade, technology, and education, aiming to promote economic growth by strategically reallocating resources [36]. Many

middle-income and emerging countries have developed national policies to enhance control over digital companies, resources, and data flows [37,38]. In a complex global value chain environment, these countries craft industrial policies to help strategic sectors gain technological advantages and navigate intricate industrial networks [39].

Different stages of digital economy development create distinct policy contexts. In the early stages of China's digital economy, the policies focused on protecting domestic industries from foreign competition through content censorship and national security measures [9]. This protectionist approach fostered the growth of local digital companies, facilitating their integration into the global value chain and technological advancements [40,41]. Notably, this context allowed digital giants such as Tencent and Alibaba to dominate the domestic market, driving innovation in data management, industrial digitalization, and machine learning [9,10]. With the shift from protective to regulatory policies, the government intensified its oversight of digital economy enterprises to align digital infrastructure, platform ecosystems, and market dynamics with national development objectives [42–44]. The companies that thrived under protectionist policies have now become central to national digital economy innovation, providing platform services to regional enterprises, particularly small and medium-sized businesses, and thus, promoting industry modernization [9]. The policy processes in sectors such as online games, digital finance, car sharing, and electronic music align with this description [9,10,45]. Given the high sensitivity to policy changes, we focus on the online game industry in the next section and provide a further policy analysis on it.

2.3. Understanding the Policy Context of China's Online Game Industry

The development of China's online gaming industry has been significantly shaped by evolving policies within the digital economy, leading to distinct policy contexts at various stages of growth. The early policies emphasized protectionism, implementing stringent regulations for game publication and distribution, including a rigorous approval process to shield domestic companies from foreign competition [9]. Since 2010, China has progressively refined its legal framework. In 2014, localized management measures were introduced, which expedited approvals and lowered capital turnover requirements. This change facilitated the rapid growth of domestic gaming companies by reducing entry barriers and fostering innovation [46]. In 2018, a regulatory shift occurred when the State Administration of Press and Publication assumed control of the industry, introducing stricter content reviews along with limits on gaming time and spending for minors [46]. This transition marked a shift from protectionist to regulatory policies, aligning the industry with broader national goals.

In response to these evolving policy requirements, online gaming enterprises have become central to the formation and transformation of urban networks within the digital economy. Game developers collaborate with operators to commercialize their products, establishing production–operation projects that are critical for industry functioning [47]. These collaborations involve transferring games to operationally capable companies under revenue-sharing agreements based on project outcomes. Subsequently, game operators initiate operation–publication projects with publishers, who organize game content according to regulatory requirements and secure the necessary licenses for release [48]. These processes facilitate the spatial flow of key production elements—such as knowledge, capital, and creativity—between enterprises, laying the groundwork for the construction of digital urban networks.

3. Research Framework

3.1. Research Design

This study adopted a quantitative approach to investigate how transformations in government policy influence the structure and evolution of digital urban networks within China's digital economy, using the online gaming industry as a case study. The primary objective was to analyze how policy shifts—from protectionist to regulatory phases—reshape

the spatial configuration and interconnectivity of these networks. The research hypothesis posits that these policy transformations significantly alter the overall structure of the digital urban network, leading to changes in network density, centrality, and collaboration patterns among cities. To test this hypothesis, this study employed network indicators to visualize spatial patterns, a social network analysis (SNA) to evaluate the topological structure of digital urban networks, and valued exponential random graph models (ERGMs) to identify the driving factors behind the formation and evolution of intercity connections. These methods facilitated a comprehensive examination of how policy changes impact network dynamics and structural characteristics during different policy phases.

3.2. Data Collection

This study constructed the digital urban network using data from online gaming production projects in mainland China, covering the period from 2010 (when the first law on game distribution and publication was enacted) to September 2022. The dataset was sourced from publicly available information on the websites of the State Administration of Press and Publication and the China Audio-Video and Digital Publishing Association's Game Working Committee, collected via a web crawler tool. It includes details such as game titles, development companies, operation and publishing service providers, and publication dates. Initially, 16,650 online gaming projects were collected, but filtering was applied to ensure geographic relevance and data quality.

Data items involving organizations outside mainland China and those with unverifiable geographic locations were excluded. Additionally, data prior to 2014 were removed, as the early stages of China's online gaming industry primarily represented overseas games, with limited domestic production and collaboration. A turning point occurred in 2014, when policy changes shortened the publishing cycle, leading to a surge in domestic collaborations. The final dataset comprised 16,411 entries, with 11,208 from 2014 to 2017 (the competitive protection phase) and 5203 from 2018 to 2022 (the systematic regulatory phase). By comparing urban networks from these two phases, this study analyzed how different policy contexts shape spatial flow patterns among cities in the digital economy.

Given that the research data encompassed enterprises of various scales within the online gaming industry, and that these enterprises generate different levels of elemental flows when organizing urban networks, this study used the registered capital of the enterprises involved in the same game as a reference indicator. The Jenks.py tool (version 0.4.0) in Python (version 3.1.1) was employed to assign scores from 1 to 5 based on the project scale, from smallest to largest. Relevant information about the registered cities and capital of the enterprises was obtained through official websites and other online sources. The statistical data used in the analysis of influencing factors were sourced from the China City Statistical Yearbook, with variable values representing the annual average for each phase.

3.3. Methodology

3.3.1. Methodology for Measuring Network Indicators

In this study, the connections formed through digital production in the online gaming industry were treated as enterprise project collaborations, and were mapped to the cities where the participating enterprises were located. To analyze the structure of the digital urban network, a network matrix was constructed to capture the spatial interactions between cities. Two key indicators were employed to evaluate the network: the contact intensity, which measures the strength of interactions between cities, and the centrality, which assesses the relative importance of each city within the network. These indicators are essential for visualizing the spatial configuration of the network and understanding the regional organizational patterns that emerged during the two policy phases.

(1) Contact intensity

If online gaming enterprises in city a and city b engage in a digital production project, it is considered that an urban network connection between a and b has been established. By summing up all network connections, the contact intensity between a and b is obtained:

$$C_{a-b} = \sum_p^n (A_{a-b,p} + B_{a-b,p}) \quad (1)$$

where C_{a-b} represents the contact intensity between city pair a and b , p represents the digital production cooperation between city a and city b , n represents the total number of cooperative projects, and A and B respectively denote production–operation projects and operation–publication projects.

(2) Centrality

Summing the contact intensity of a certain city with all other cities in the network yields the centrality of that city:

$$SE_a = \sum_b^o C_{a-b} \quad (2)$$

where SE_a represents the centrality of city a , b is the city that has cooperative projects with city a , o is the total number of cities that have service connections with city a , and C_{a-b} is the contact intensity between city pair a and b . The calculation considers the case of $a = b$ (i.e., intra-city connections).

3.3.2. Social Network Analysis (SNA)

A social network analysis (SNA) is a method used to study social structures and the relationships between individuals [48]. In this study, an SNA was applied to analyze the topological structure of urban networks formed by digital production activities in China's online gaming industry. The analysis focused on three main aspects: basic network statistics, which reflect foundational metrics such as the network size and the average path length between cities; network clustering characteristics, which measure the degree of agglomeration and information accessibility among cities; and network compactness characteristics, which evaluate the density of the network and its "small-world" properties, indicating how efficiently cities are interconnected. These metrics are essential for understanding how the digital urban network's structure evolves in response to shifting policy environments, transitioning from protectionist to regulatory phases.

- (1) Basic network statistics include three indicators: the number of nodes, the number of ties, and the average degree. The numbers of nodes and ties are derived from the network matrix, while the average degree represents the average number of network ties per node (the number of cities divided by the number of nodes). A higher average degree indicates more average partners and a greater diversity of cooperative forms.
- (2) Network clustering characteristics include the degree centralization and the average distance. The formula for degree centralization is as follows:

$$C_{deg} = \frac{\sum_{v \in V} (C_d(v) - \bar{C}_d)^2}{|V| - 1} \quad (3)$$

where $C_d(v)$ is the degree centrality of node v , $\bar{C}_d$ is the average degree centrality of all nodes, and V is the number of nodes. The degree centralization value ranges from 0 to 1, with higher values indicating that the network is more clustered around a few cities. The formula for the average distance is as follows:

$$L = \frac{\sum_j^n d_{ij}}{n(n-1)} \quad (4)$$

where d_{ij} represents the shortest path length between node i and node j , and n represents the number of nodes in the network. A smaller average distance value indicates more efficient information flow within the network.

- (3) Network compactness characteristics include the network density, closure, and small worldness. The formula for network density is as follows:

$$D = \frac{j}{n(n-1)/2} \quad (5)$$

where j represents the total number of actual connections in the network and n represents the total number of city nodes in the network. A higher density indicates a higher degree of node participation and a more compact overall structure. The formula for closure is as follows:

$$Transitivity = \frac{3 \times |T|}{\sum_{v \in V} k(v)(k(v)-1)/2} \quad (6)$$

where $|T|$ is the number of triadic closures, i.e., the number of nodes with two common neighbors that are also connected to each other. $k(v)$ is the degree of node v , and V is the number of nodes. Closure measures the proportion of closed triads in the network, reflecting the tendency to form small groups or communities. A higher value indicates that the network nodes are more inclined to form triangular alliances, which signifies a stronger and more stable cooperative relationship compared to a loose network.

The small worldness is typically not measured by a single formula, but is determined by comparing the average path length and clustering coefficient of the network with those of a random network. A higher small-world value indicates a greater degree of compactness and stronger information dissemination within the network.

3.3.3. The Valued Exponential Random Graph Models (ERGMs)

In the empirical analysis of urban networks, it is common to incorporate econometric tools alongside network metrics to examine the factors influencing network formation and evolution. As research advances, factors such as urban endowments, the inter-city multidimensional proximity, and endogenous network dynamics have gained prominence. This paper quantitatively identified the influencing factors of the digital urban networks by fitting valued exponential random graph models (ERGMs) to the network matrix. ERGMs analyze both endogenous factors (such as the network structure) and exogenous factors (such as city-level characteristics) that shape intercity collaborations. This method is particularly effective for revealing how government policies impact the spatial distribution of urban ties and the underlying dynamics driving network evolution.

(1) Model Setting

A valued exponential random graph model (valued ERGM) [49] is a type of generative network model derived from social network analysis methods. The advantages of this model lies in the ability to comprehensively consider the effects of endogenous network structures, city node attributes, and city relationship attributes on the probability of network edge formation, thereby explaining the influencing factors of network evolution. The model formula is as follows:

$$P_{r\theta;h,\eta,g}(Y=y) = \frac{h(y)\exp(\eta(\theta) \times g(y))}{k_{h,\eta,g}(\theta)} \quad (7)$$

where $P_{r\theta;h,\eta,g}(Y=y)$ is the realization probability, Y is the real network, y is the generated network, $g(y)$ is the model statistic, $\eta(\theta)$ is the fitting parameter, $k_{h,\eta,g}(\theta)$ is the normalization constant, and $h(y)$ is the reference distribution. For the selection of the reference distribution, valued ERGMs provide options such as the Bernoulli distribution, binomial

distribution, Poisson distribution, geometric distribution, and discrete distribution [50]. Given that the network in this study needed to consider weighted edges, with the edge weights being non-negative and exhibiting bimodal characteristics as well as distinct “core nodes” and “peripheral nodes”, the reference distribution was set as the binomial distribution (binomial). The simulation of the valued exponential random graph model was implemented through the “ergm.count” package (version 4.1.1) in R (version 4.3.1).

(2) Variable Selection

The variable types in valued ERGMs include network configurations, node variables, and edge covariates, corresponding respectively to the network endogenous structural dynamics, urban node endowments, and multidimensional proximity in the influencing factors of the network (Table 1). First, the *sum*, *transitiveweights*, and *degree* are selected as the three network configuration variables. Among these, the *sum* is equivalent to the intercept term in a regression model, and the *transitiveweights* and node *degree* test whether the network evolution is influenced by transitivity effects and preferential attachment. Urban node endowments are represented by the *capital*, *PGDP*, and *RD* investment to examine their impact on the urban network. In this context, the capital variable assigns a value of 1 to provincial capitals and municipalities directly under the central government, and 0 to other cities. The multidimensional proximity is examined using four dimensions—institutional proximity, cultural proximity, geographic proximity, and social proximity. Institutional proximity is represented by whether the two service-linked parties belong to the same province (*province*); cultural proximity is represented by whether they belong to the same dialect region (*dialect*); geographic proximity is represented by calculating the Euclidean distance matrix of the nodes in the network (*distance*); and social proximity is represented by the binary matrix from the previous phase (*path*).

Table 1. Valued ERGM variables and indicators.

Variable Types	Model Variable	Mechanism	Indicator Selection	Hypothesis
Network configurations	sum	Basis effect	<i>sum</i>	Equivalent to the intercept term in the regression model.
	transitiveweights	Transmission effect	<i>transitiveweights</i>	Whether networks tend to form ternary closure structures.
	degree	Preferential attachment	<i>degree</i>	Whether star nodes will be more inclined to generate more connections.
Node variables	nodefactor	Matthew effect	<i>capital</i>	Whether nodes with stronger attributes are more inclined to generate connections.
	nodecov		<i>PGDP</i> <i>RD</i>	
Edge covariates	nodematch	Homology effect	<i>province</i> <i>dialect</i>	Whether nodes with similar attributes tend to be more connected.
	edgecov	Synergy effect	<i>distance</i> <i>path</i>	Whether other relationships between nodes predispose nodes to be connected.

4. Results

4.1. Topological Structure of Urban Networks

This study employed the UCINET software (version 6.689) to compute the topological structure indices of the digital urban network matrix, comparing characteristics across different policy phases (Table 2). During the competitive protection phase, the policies focused on protecting domestic enterprises and fostering rapid growth in the online gaming industry. In this phase, the digital urban network comprised 144 city nodes and 1038 urban ties, but the average number of connections per node (average degree) was low, indicating that cooperation was concentrated among a few core cities with similar collaboration forms. The degree centralization and average distance were 0.630 and 2.246, respectively, suggesting that the network clustered around these core cities to enhance the information flow efficiency. The network density stood at 0.050, reflecting a relatively loose structure with low participation.

Table 2. Indicators of the topological structure of the digital urban network.

Phase	Basic Network Statistics			Network Clustering Characteristics		Network Compactness Characteristics		
	Nodes	Ties	Avg Degree	Deg Centralization	Avg Distance	Density	Closure	Small Worldness
Competitive protection phase	144	1038	7.208	0.630	2.246	0.050	0.228	5.489
Systematic regulatory phase	122	906	7.426	0.534	2.318	0.061	0.327	5.990

In the systematic regulatory phase, the policies shifted towards systematic regulation, enhancing the supervision and management of the online gaming industry. The National Press and Publication Administration improved the regulatory environment, promoting standardized development. During this phase, the digital urban network consisted of 122 city nodes and 906 urban ties (Table 2). Despite the reduction in network size, the average number of connections per node increased from 7.208 to 7.426, indicating more diverse partnerships and varied collaboration forms. Both the degree centralization and the average distance decreased, signifying a reduced reliance on core cities and a more dispersed flow of information. The network density rose to 0.061, with a small worldness increase to 5.990, indicating a more compact structure with stable collaborative frameworks and stronger small-world properties.

The digital urban networks in the two phases exhibited significant structural differences shaped by distinct policy contexts. The competitive protection phase facilitated a rapid, centralized network organization, resulting in a large-scale urban network with low overall participation and a dependency on core cities for communication efficiency. Conversely, the systematic regulatory phase fostered diversity and stability in network collaboration, with increased density and stability despite a smaller network size, gradually reducing the reliance on a few core cities.

4.2. Regional Organizational Characteristics of the Urban Networks

From a geographical perspective, urban networks display organizational patterns at various regional scales, which are often explained by the “buzz and pipelines” theory. Building on this framework, this study identified three regional organizational characteristics: “local buzz”, “regional interaction”, and “national pipelines”. Using the “Fourteenth Five-Year Plan for National Economic and Social Development of the People’s Republic of China” and local planning documents, 19 urban agglomerations were delineated, including a “non-urban agglomeration” category. Connections within individual cities were categorized as “local buzz”, while connections within urban agglomerations were termed “regional interaction”, and connections across urban agglomerations were referred to as “national pipelines”. This classification aided in analyzing the regional organizational characteristics of urban networks. In the heatmap, the values for “regional interactions” and “national pipelines” are normalized, with a maximum value of 20. The colors along the diagonal indicate the intensity of “regional interactions” (from bottom left to top right), while the rest of the area reflects “national pipelines”. To enhance clarity, the regions are sorted according to the strength of the “regional interaction”, with those closer to the lower left corner representing stronger interactions.

During the competitive protection phase, government policies focused on supporting the digital economy, leading to notable regional organizational characteristics. In terms of “local buzz”, Shanghai, Beijing, Shenzhen, Hangzhou, and Guangzhou exhibited the strongest intra-city connections, with Shanghai consistently leading (Table 3). The number of cities in the top three tiers was significantly higher than in the systematic regulatory phase (six cities), highlighting a greater reliance on a few core cities. For “regional interaction”, the Yangtze River Delta (YRD) region displayed the strongest interactions, followed by the Beijing-Tianjin-Hebei (BTH) region and the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) (Figure 1). The most prominent “national pipelines” were between the YRD

and BTH (green and blue areas in the heatmap), while other areas had fewer connections (mostly light yellow).

Table 3. Cities of different tiers by urban centrality (intra-city).

Tier Phase	Tier.1	Tier.2	Tier.3	Tier.4	Tier.5
Competitive protection phase	Shanghai; Beijing	Shenzhen	Hangzhou; Guangzhou; Nanjing	Chengdu; Wuhan; Xiamen; Suzhou; Changsha; Hefei	Ledong; Jinhua; Fuzhou; Tianjin and the remaining 95 cities
Systematic regulatory phase	Shanghai	Beijing; Shenzhen	Hangzhou	Guangzhou; Nanjing; Wuhan; Chengdu; Xiamen	Suzhou; Hefei; Chengmai; Fuzhou and the remaining 76 cities

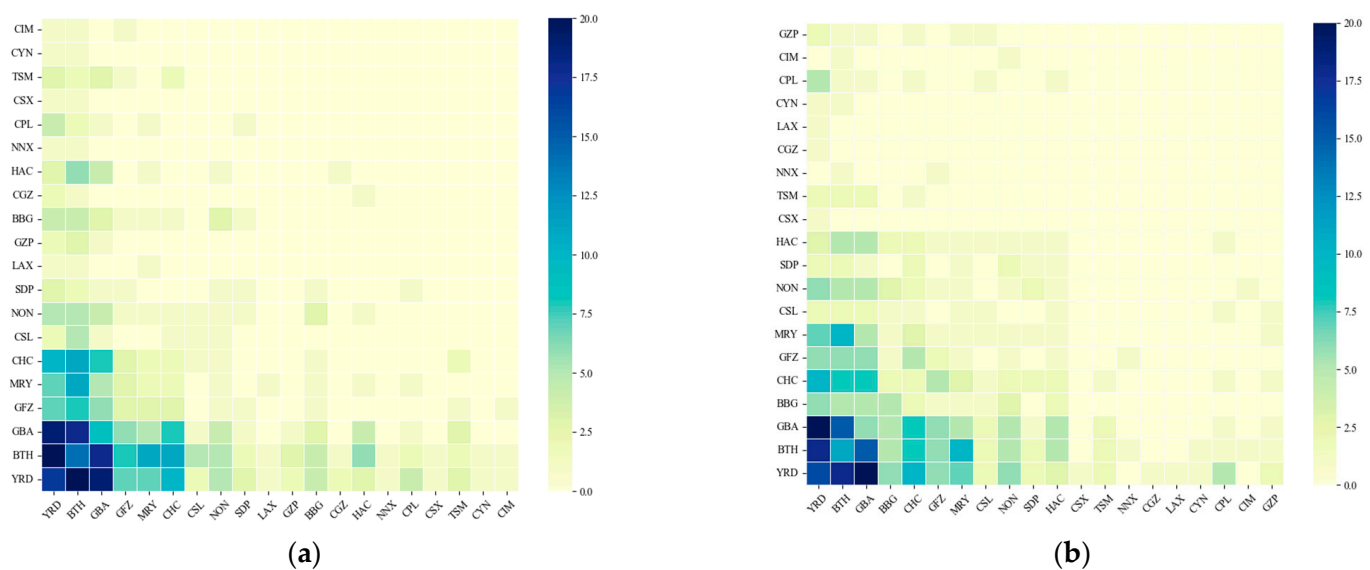


Figure 1. Heatmap of the regional connections of the digital urban network. (a) Competitive protection phase; (b) systematic regulatory phase.

In the systematic regulatory phase, as the policy context shifted towards systematic regulation, the regional organizational characteristics of urban networks also changed. Although Shanghai maintained its leading position in “local buzz”, Beijing’s influence declined, and the number of top-tier cities decreased to four, indicating a reduced reliance on a few core cities (Table 3). The YRD continued to show the strongest “regional interaction”, while the Beibu Gulf Urban Agglomeration (BBG) significantly improved in this regard. For “national pipelines”, the connections between the YRD and GBA became the strongest, with an increasing number of regions engaging in long-distance connections (the light green color in the heatmap increased).

When comparing the two phases, the competitive protection phase relied more on a few core cities and their leading “regional interactions”, resulting in an overall low network participation. In contrast, during the systematic regulatory phase, the reliance on core cities decreased, and a wider range of cities participated in “national pipelines”. This shift in policy context profoundly affected the regional organizational patterns of urban networks. Systematic policy control fostered more balanced digital economy development across a broader region. Notably, the advancement of the BBG in “regional interaction” and the rising status of Ledong and Chengmai in “local buzz” are linked to proactive local policies. The 14th Five-Year Plan of the BBG emphasizes accelerating digital economy development and implementing the “Digital Beibu Gulf” construction plan, demonstrating the significant influence of policy context on the digital economy and its organizational network.

4.3. Spatial Configuration of the Digital Urban Networks

The spatial configuration of the digital urban networks was analyzed using the natural breaks method in ArcGIS 10.6, classifying the urban centrality and contact intensity into four levels. During the competitive protection phase, the core nodes, included Beijing, Shanghai, Shenzhen, Hangzhou, Guangzhou, Nanjing, and Shijiazhuang, formed a radial structure centered on Beijing, with seven of the top ten connections linked to it. This emphasizes Beijing's dominant role in coordinating intercity resource sharing as the national political center.

In the systematic regulatory phase, the network evolved into a multi-core structure, with Shanghai, Beijing, Shenzhen, Hangzhou, Guangzhou, Chengdu, and Nanjing as the core cities (Figure 2b). The rise of Shanghai and Chengdu as prominent centers indicates a shift from reliance on a single core city. This phase also saw increased first-level connections among core cities (thickest blue lines), reducing the gap in contact intensity and fostering more balanced intercity collaborations. The “triangle” structure formed by the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta regions transitioned into a “diamond” structure, with Chengdu emerging as the western center, although the connections to Chengdu remained relatively weak compared to those of the other core cities.

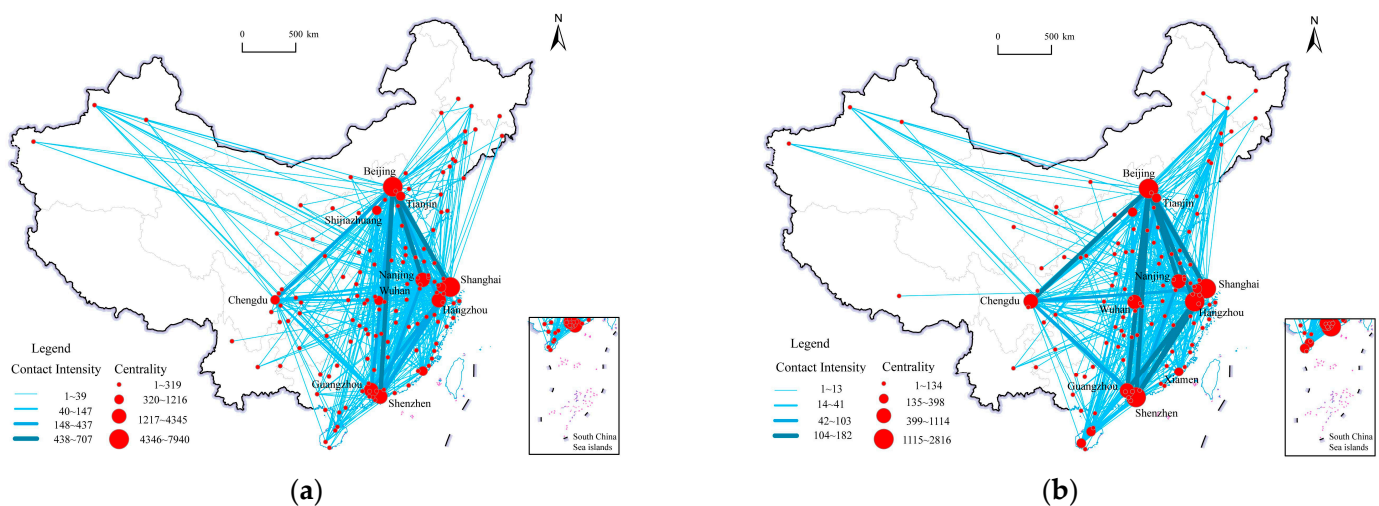


Figure 2. Spatial configuration of China's digital urban network under the (a) competitive protection phase and the (b) systematic regulatory phase. These dots or polylines are part of the South China Sea and indicate coral reefs and coastlines in Chinese territory. They are part of the standard map of China and are not related to the research data in this paper.

The evolution from a centralized to a more decentralized network structure reflects significant changes. In the competitive protection phase, the digital urban network was primarily centered around Beijing and Shanghai, resulting in uneven spatial development. In contrast, the systematic regulatory phase shifted toward a multi-centered model, with Chengdu and Nanjing emerging as new focal points, thereby reducing the reliance on earlier core cities. Additionally, peripheral regions like Xinjiang and Hainan experienced notable growth in both phases, benefiting from enhanced digital infrastructure and favorable policies that mitigated geographical barriers and facilitated integration into the national network. These changes illustrate how policy shifts can foster a more balanced urban network and promote the inclusion of peripheral cities within the broader digital economy.

4.4. Influencing Factors of Urban Networks

This study employed valued exponential random graph models (valued ERGMs) to analyze the factors influencing urban networks across the two phases. Models 1 to 3 present the fitting results for the competitive protection phase urban network matrix, while Models 4 to 6 cover the systematic regulatory phase (Table 4). A comparison of

the AIC and BIC values indicated that the models incorporating both endogenous and exogenous dynamics closely matched the actual networks. The formation and stability of urban network connections are influenced by endogenous structural dynamics, city characteristics, and multidimensional proximities.

Table 4. Fitting results of valued ERGMs for the network matrix.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
<i>sum</i>	−5.844 *** (0.159)	−25.076 *** (1.948)	−20.632 *** (2.093)	−5.926 *** (0.162)	−23.577 *** (2.763)	−19.350 *** (2.814)
<i>transitiveweights</i>	0.069 (0.126)		−0.182 (0.134)	−0.306 *** (0.109)		−0.523 *** (0.115)
<i>degree</i>	0.033 *** (0.001)		0.024 *** (0.001)	0.042 *** (0.001)		0.025 *** (0.002)
<i>capital</i>		1.012 *** (0.078)	0.831 *** (0.083)		1.064 *** (0.085)	0.872 *** (0.099)
<i>PGDP</i>		0.072 (0.108)	0.408 *** (0.112)		0.053 (0.150)	0.188 (0.155)
<i>RD</i>		0.789 *** (0.041)	0.250 *** (0.045)		0.660 *** (0.052)	0.354 *** (0.058)
<i>province</i>		0.733 *** (0.180)	0.851 *** (0.186)		1.708 *** (0.188)	1.829 *** (0.184)
<i>dialect</i>		0.050 (0.098)	0.056 (0.103)		−0.011 (0.111)	−0.048 (0.115)
<i>distance</i>		−0.036 *** (0.009)	−0.047 *** (0.010)		0.035 *** (0.009)	0.018 * (0.010)
<i>path</i>					1.504 *** (0.118)	0.747 *** (0.121)
AIC	−36,522.111	−36,496.765	−36,734.154	−34,199.705	−34,479.538	−34,729.363
BIC	−36,502.015	−36,449.874	−36,673.866	−34,179.832	−34,426.544	−34,663.121

Note: *** and * denotes significance at $p < 0.001$ and $p < 0.05$. Numbers in parentheses are standard errors.

During the competitive protection phase, the policy emphasis was on free market expansion, significantly impacting the network formation. The endogenous structural dynamics showed a significant positive coefficient for *degree* (0.033), indicating self-organizing dynamics characterized by preferential attachment (Model 1). New nodes were more likely to connect with existing nodes, reflecting the spillover of local service resources from core cities. The exogenous dynamics revealed that city characteristics, such as administrative level (*capital*) and research and development (RD) investment, positively influenced the network evolution (Model 3). Capital cities emerged as key nodes in digital economy cooperation, and cities with strong innovation capabilities gained advantageous positions.

In the systematic regulatory phase, the focus shifted to industry regulation and standardization, leading to new impacts on urban network evolution. While the endogenous structural dynamics still exhibited self-organizing characteristics, the influence of policy aspects on network formation increased significantly. The coefficient for *capital* rose from 0.831 to 0.872, and the coefficient for *province* increased sharply from 0.851 to 1.829, highlighting a growing dependence on the institutional environment (Model 6). National-level regulatory measures and localized management practices influenced the online gaming industry. Additionally, the geographical *distance*, which previously had a negative coefficient (Model 3), showed a significant positive coefficient (Model 6), indicating a trend toward cross-regional connections. The significant positive coefficient of the social proximity variable (*path*) underscores the role of path dependency in network evolution, with past cooperation facilitating intercity link formation (Model 6).

In summary, while common influencing factors such as the preferential attachment effect and the positive impact of urban characteristics were observed in both phases (Models 3 and 6), notable differences arose in the influence of institutional proximity and geographical distance. As policy regulation intensified, the importance of institutional environments

within the same province became more pronounced, while the characteristics of the digital economy promoted long-distance urban connections.

5. Discussion

In the digital economy era, data-centric digital production has transformed digital urban networks, which are significantly influenced by policy environments. This study analyzed the network of the online gaming industry through a quantitative framework, contributing new insights compared to the existing research on digital urban networks.

While prior digital urban network studies have highlighted the decentralization of creative community networks [29], the agglomeration in digital music networks [46], and the inclusion of marginal cities in online video networks [13], a common theme is that digitization has altered the traditionally vertically integrated production model, accelerating the emergence of a polycentric pattern in urban networks. The findings of this paper reflect this characteristic of digital urban networks. However, while these studies acknowledge the significant impact of policy on digital urban networks [29,46], they do not explore this connection in depth. By incorporating the policy context into the analytical framework, this paper delineated the evolutionary stages based on policy changes. It found that digital urban networks underwent a significant transformation as policies shifted from protectionism to systemic regulation. Continuous policy adjustments enabled the Chinese government to develop an extensive national online gaming market while subsequently controlling the expansion of the urban network, ultimately forming a higher-quality polycentric network. Additionally, this paper included policy-related indicators of influencing factors in the quantitative analysis. The results reveal that the administrative hierarchy and institutional proximity impact network improvement, emphasizing that administratively centered urban networks and the communicative advantages of similar policy contexts significantly drive network evolution. This indicates that this paper not only identifies the trend in polycentric transformations in digital urban networks, but also elucidates how these transformations are influenced by policy factors.

In comparison to existing literature on the influence of policy on urban networks, which often emphasizes the proactive role of government policies—such as European governments constructing and refining integrated urban networks by acting as key players [30], or forming urban networks through policy cross-referencing [31]—the role of government in the digital economy is less direct. Instead, it regulates and guides the digital economy sector through industrial policies. For instance, Brisbane's gaming cluster has gradually formed a networked community under policy guidance [51]. However, research on the impacts of policies related to the digital economy often relies on qualitative case studies [9,10,51], lacking empirical evidence within a quantitative analysis framework. This paper addresses that gap by demonstrating that the shift from a concentrated to a decentralized network structure illustrates the potential of policy interventions to redistribute economic activities across broader geographic areas. These findings have significant implications for urban network theory, suggesting that the spatial configuration of digital urban networks is shaped not only by economic forces, but also by the policy context. For policymakers, the results underscore the importance of a balanced approach to regulation and development. While the competitive protection phase facilitated rapid growth by safeguarding domestic industries, it also resulted in spatial imbalances that could hinder long-term regional development. Conversely, the systematic regulatory phase illustrates the advantages of a more nuanced policy approach that promotes regional inclusivity and encourages the broader participation of cities in the digital economy.

6. Conclusions

The findings of this study reveal the profound influence of government policies on the evolution of urban networks in China's digital economy, particularly within the online gaming industry. By comparing the competitive protection phase and the systematic

regulatory phase, we observed significant transformations in the structure and function of urban networks within China's evolving policy contexts.

6.1. Impact of Policy Changes on Urban Network Structure

The transition from the competitive protection phase to the systematic regulatory phase marked a shift from a concentrated, core-city-dependent network structure to a more decentralized, multi-centered configuration. During the competitive protection phase, protectionist policies and rapid market expansion led to a “radial” network centered around core cities such as Beijing and Shanghai. These cities became primary hubs for intercity connections, creating a network that was expansive, yet centralized. This reliance on core cities resulted in uneven spatial development, with peripheral cities playing minimal roles in the broader network. In contrast, the systematic regulatory phase introduced stricter regulations and standardized policies by the National Press and Publication Administration, fostering a more balanced urban network. This phase saw a reduction in the dominance of core cities and an increase in participation from a wider range of cities across China, with cities such as Chengdu emerging as significant nodes. This evolution underscores the effectiveness of systematic policy interventions in promoting regional development and reducing the reliance on a few dominant urban centers.

6.2. The Role of Digital Production in Urban Networks

This study constructed the urban network using data from industry digital production projects, reflecting the characteristics of digital production in the digital economy. This approach better aligns with the practical organization of urban networks through micro-level enterprise activities compared to traditional gravity and headquarter-branch models. The results demonstrate that digital production significantly enhances connections between remote and central regions. For example, digital economy industries in areas such as Xinjiang, Hainan, and Northeast China leverage local tax and policy advantages to establish industrial bases while integrating into the national organizational network through information technology and Internet communication, thus overcoming geographical barriers to communication efficiency. Notably, the geographical distance matrix's role shifted from a significantly negative coefficient in the competitive protection phase to a positive coefficient in the systematic regulatory phase, providing empirical support for the role of digital production in facilitating long-distance urban information transmission.

This study offers a comprehensive perspective on the digital economy and urban networks. However, it identifies two critical issues: despite rapid information flow and policy incentives that facilitate the integration of border areas into the urban network, the network's spatial layout remains incomplete. Many central inland cities have not achieved a high network status and should leverage their resources to strategically develop digital economy industries with robust local policy support. Additionally, although the density and structural stability of the urban network improved in the systematic regulatory phase, the transmission effect remains significantly negative. This suggests many open triangular structures within the network, indicating a need for enhanced stability. Regional central cities, particularly those excelling in “local buzz” and “regional interaction”, must fully utilize their leadership roles to promote connections with surrounding regional cities and gradually extend these connections to the national network.

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