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Postprint: A Study on the Global Information Dissemination Landscape Based on Social Network Analysis and Traffic Analysis

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Abstract

[Purpose/Significance] Based on global publicly available traffic data, this study explores the current state of the international information dissemination landscape. [Method/Process] By incorporating actual website visit traffic and utilizing the information inflow and outflow patterns of national/regional Internet news platforms, this study employs social network analysis and traffic analysis methods to examine 288 news information service websites and related dissemination channels from 144 countries/regions. It calculates information service volume, information acquisition volume, and external dissemination volume, and based on these metrics, explores the absolute and relative positional relationships between countries/regions. The data results present the latest characteristics of the global information dissemination landscape and depict information dissemination power at the country/region granularity. [Results/Conclusion] Traffic analysis and social network analysis can effectively reveal the latest positional relationships of countries/regions within the global communication landscape, extending the quantitative research findings of world-systems theory regarding the global network communication structure, and empirically demonstrating the practical potential for developing countries in Internet governance and the expansion of international discourse power.

Full Text

A Study on Global Information and Communication Pattern Based on Social Network and Traffic Analysis

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Abstract:
[Purpose/Significance] This study explores the current status of the international information and communication pattern based on global public traffic data. [Method/Process] By introducing actual website access traffic and analyzing information inflow and outflow through national (regional) internet news platforms, we examined 288 news and information service websites and related communication channels from 144 countries and regions using social network analysis and traffic analysis methods. We measured information service volume, information acquisition volume, and external communication volume to explore absolute and relative positional relationships among countries/regions. The data reveal the latest characteristics of the global information and communication pattern and portray information communication power at the national/regional granularity. [Result/Conclusion] Traffic analysis and social network analysis effectively present the latest positional relationships of countries/regions within the global communication pattern. This study extends the quantitative research findings of world system theory on global network communication patterns and empirically demonstrates the realistic possibilities for developing countries in internet governance and international discourse expansion.

Keywords: global communication pattern; flow analysis; social network analysis; world system theory; international information and communication

1. Introduction

Information, also translated as "message," "intelligence," or "knowledge," was defined by Claude E. Shannon, the founder of information theory, in his 1948 publication *A Mathematical Theory of Communication* as "that which produces a difference" or "any meaningful difference" [**?**]. When information flows "across national boundaries and between two or more national and cultural systems" [**?**], it forms cross-border information flow. This process initially emerged alongside infrequent trade activities, such as commercial messages transmitted along maritime and land-based Silk Roads. By the mid-to-late 19th century, the laying of submarine cables enabled stable, frequent, and large-scale information flows across the globe, with the relational networks formed during this process constituting the earliest network information communication structures. As information society has developed, the concept of information communication networks has been applied across various disciplines, continuously expanding its connotation and extension.

Information theory applied mathematical statistics to information science, transforming information into an abstract quantity that could be measured and enabling quantitative research on information network structures. Existing studies have utilized diverse data forms—including trade data, personnel exchange data, global telecommunications data, and global bandwidth—to investigate network

structural characteristics, influencing factors of information networks, and the relational roles of information producers within these networks. These studies have described the features and fundamental patterns of information flow in global communication networks. However, most existing network analysis research has focused on the Web 1.0 and Web 2.0 eras. With the advent of the Web 3.0 era and the development of new applications and technologies such as social networks and encryption technologies, previous studies have struggled to capture the characteristics of new technologies and outline the features of global network structures.

To address these issues, we adopt a PageRank-inspired approach by calculating the information access volume of news websites across various countries/regions to construct a communication network covering major global countries and regions. Simultaneously, based on this network, we introduce social network analysis methods to conduct country-granularity communication power analysis, further exploring the application of this method within world system theory.

2. Theoretical Framework

2.1 World System Theory' s Macro-level Description of Network Structure

World system theory, proposed by Immanuel Wallerstein in the 1970s, synthesizes dependency theory and the French Annales School, emphasizing the examination of global relational networks as an economic-social and political-cultural system. As a holistic analytical method encompassing political, economic, and cultural dimensions, the theory examines the power positional relationships of nations and related entities within an interdependent hierarchical structure based on labor division. Wallerstein divided the modern world system into core, semi-peripheral, and peripheral states, arguing that the essential characteristic of the modern world system is "the development of the core-periphery division of labor and the rise and fall of hegemonic powers" [**?**].

Following Wallerstein, prominent world system theorists such as Abu-Lughod, Frank, and Chase-Dunn further developed the theory. Frank [**?**] proposed that entities within the system are interrelated, and that development and underdevelopment are not simply relative quantities but mutually influential relationships within a broader system. Chase-Dunn et al. expanded the applicability of world system theory, suggesting that "world systems are networks among societies, specifically including networks of bulk goods, precious goods, political-military networks, and information networks, with interactions within these networks constituting changes in internal structure" [**?**]. Although these scholars differ in their specific research questions and methodologies, they all agree that unequal exchange between information-rich and information-poor countries is closely associated with the global economy.

While Wallerstein repeatedly emphasized that world system theory is a holistic analysis not intended for examining specific situational domains and even ques-

tioned Chase-Dunn' s analysis, world system theory as a theoretical paradigm and research method has been tested and applied in geography, sociology, international relations, and other social sciences [**?**].

2.2 Micro-level Portrayal of Global Information Communication Networks

As global information connections have become increasingly tight, scholars have attempted to "quantify" the global information communication network from various perspectives. Network analysis has become a common method in social system structure research, with studies on global network communication structures typically following two steps: first, network depiction, and second, analysis of network relational structures.

In early research, scholars such as E. Östgaard and J. Galtung [**?**, **?**, **?**] used global news agencies and their international news output to depict global communication networks, proposing the issue of imbalanced information flow between different countries. For many years thereafter, research on global communication networks primarily expanded upon trade or migration network models. For example, G. A. Barnett and R. Y. Wu [**?**] used UNESCO' s international student statistics yearbook to outline global knowledge dissemination networks, while G. A. Barnett [**?**] used international telephone volumes to map global telecommunications network patterns. Although these studies effectively outlined the characteristics and influencing factors of global communication networks at the time, they were essentially extensions of structural models from trade or population mobility domains, with limited applicability to internet communication patterns.

With the popularization of the internet, research on internet communication networks began to emerge. The most widely used method involved hyperlinks to depict global information communication networks. For instance, G. A. Barnett and H. W. Park [**?**] used Alta Vista to collect the number of hyperlinks embedded in websites from different countries, then used hyperlinks and bandwidth to depict network structures. H. Seo and S. J. Thorson [**?**] used TeleGeography' s global internet geography data to measure transnational internet connections. H. W. Park et al. [**?**] used country code top-level domain (ccTLD) presence in search engine results to depict global communication networks. G. J. Golan and I. Himelboim [**?**] applied mass communication models to depict the social network communication relationships of Twitter accounts from five major international media outlets.

In analyzing network relational structures, network analysis methods have been widely applied. Scholars have proposed various centrality measures, such as degree centrality, eigenvector centrality, closeness centrality, and PageRank centrality. Notably, G. A. Barnett [**?**] used NEGOPY correlation analysis, multidimensional scaling (MDS), and cluster analysis to study relationships among nodes. H. Seo and S. J. Thorson [**?**] and H. W. Park et al. [**?**] used centrality

and density analysis to study network structures.

While these methods could relatively completely depict global communication networks during the Web 1.0 and Web 2.0 eras, the rise of technologies and applications such as encrypted connections and social media has created two problems: (1) In encrypted networks, influenced by search engine referrals and social network sharing, hyperlink-based analysis of inbound and outbound links may lead to missing information sources, affecting accuracy; (2) With the integration of multi-directional social media and traditional unidirectional mass media communication patterns, institutional media and self-media interact, making network communication patterns more complex, with stronger participation from groups of different nationalities and ethnicities.

In summary, whether as a theoretical paradigm or research method, using the framework of world system theory to study transnational information flow issues and depict global communication patterns and order has become a common practice. Existing research has presented the characteristics and changes in global communication network structures over the past 30 years and made significant contributions to understanding influencing factors of communication patterns. However, with the emergence of new business forms and applications such as large social platforms, computational communication, and transnational internet companies, questions about their impact on global communication patterns and the new characteristics of current global communication patterns remain unexplored by previous research.

Based on this, our study focuses on large-scale websites with information distribution attributes, employing traffic analysis methods to analyze the media radiation range, information acquisition sources, and external communication capabilities of various countries based on media website traffic details. This approach outlines the latest global internet pattern in 2021, ultimately attempting to answer the following questions: (1) What characteristics did the global internet communication pattern exhibit in 2021? (2) Does the current global internet communication network structure still conform to the basic model proposed by world system theory?

3. Data Collection

Alexa is a website data analysis company under Amazon.com. Using the entire internet user population as its sample, Alexa extracts browsing behavior (including both human users and machine crawlers) from websites through browser toolbars and web browser extensions over the past three months to analyze website popularity and traffic characteristics. The specific data acquisition steps are as follows:

First, we manually annotated major websites from Alexa' s 2021 latest global media industry rankings and comprehensive national website rankings, selecting 500 influential media websites to form a media website list.

Second, to minimize duplicate calculations caused by multi-level social media propagation and factors such as the number of internet users in each country, we excluded search engines (e.g., google.com), social media platforms (e.g., reddit.com), and portal websites (e.g., South Korean portal daum.net) from the media website list, forming a mass media website list.

Third, we used manual verification to eliminate different sub-sites of the same website and uniformly record redirect websites with different domains under their final single domain that generates traffic.

Finally, we selected websites ranked within Alexa' s top 10,000 and media websites with above-median Alexa traffic from the initial 500 websites, forming a list of 288 important media websites from 60 countries and regions.

Through the publicly available Alexa API interface provided by Webmaster Home (站长之家), we obtained the following specific data: (1) Website ranking data, including daily, weekly average, monthly average, and three-month average global rankings and rankings in different countries (smaller numbers indicate greater influence); (2) Website traffic data, including UV (unique visitor) and PV (page view) for daily, weekly average, monthly average, and three-month average periods (Alexa notes that UV and PV data are approximate and for reference only—we selected PV rather than UV because large websites in our study have high user stickiness with relatively fixed user groups, and PV better reflects content richness and user browsing behavior); (3) Country/region data, including website ownership and user access sources; (4) Access behavior data, including three-month visitor nationality analysis, PV traffic nationality/region details, and page view proportions.

4. Model Building and Data Analysis

To address the research questions, we employed traffic analysis and social network analysis methods.

4.1 Traffic Analysis Method

Human thinking is influenced by the information it receives, manifested not only in the information itself but also in the entire process of information production, dissemination, and reprocessing by media and communication channels. Information communication networks serve as fundamental tools for production control and social control by this "will to power" that continuously extends across horizontal geographical space [**?**]. For traditional media, agenda-setting, media priming, and framing play key roles in information shaping. For internet media, beyond content production, information importance ranking and source indexing also significantly impact information dissemination [**?**], forming a supplement to information construction. This is reflected not only in internal information ranking within media websites but also in search engines and social media' s traffic diversion and ranking.

Faced with complex network communication environments, traffic has become one of the most objective indicators available to general researchers for reflecting information weight. Drawing inspiration from PageRank's approach—which uses the number and quality of hyperlinks between webpages to roughly analyze webpage importance—this study considers the characteristics of international communication and assigns the computational unit to sovereign countries/regions.

For a given country/region k, its news websites are aggregated as Sk, where pvi represents the three-month average PV volume of website i, and Rik represents the proportion of website i' s traffic from country/region k. The total number of studied countries/regions is K.

We define key concepts as follows: (1) Information Service Volume (ISN): The sum of three-month average traffic (PV) of news websites owned by a country/region, representing the information volume provided externally. Calculation formula: 公式 (1) ; (2) Information Acquisition Volume (OIN): The sum of traffic from a country/region' s internet users accessing major news websites and domestic big data crawlers, representing the total information acquisition volume. Calculation formula: 公式 (2) ; (3) External Communication Volume (OPN): The access traffic to target news websites is segmented, with domestic traffic excluded to form "external communication" traffic. Calculation formula: 公式 (3) . We subsequently analyze the international communication behavior characteristics and positional relationships of major countries/regions in the international communication field based on these three metrics.

4.2 Social Network Analysis Method

We used UCINET v6.212, a social network analysis (SNA) software, to organize and cluster the 288 globally influential media websites based on their countries/regions of origin, forming network nodes at the country/region level. A country/region' s website traffic serves as "out-degree" flow, while its internet users' access behavior serves as "in-degree" flow. Through descriptive statistical analysis and centrality analysis, we depicted the global communication pattern.

Centrality analysis expresses the degree to which a node (in this study, a country/region) is at the center of the entire network, determined by its relationships with others and its ability to influence or control other nodes [**?**], thereby judging the node' s importance in the entire communication network. (1) Degree Centrality: A node' s degree centrality represents the sum of its direct connections with others. In international information communication relationships, degree centrality can represent the sum of inbound and outbound degrees of major news websites owned by a country/region. Higher degree centrality indicates greater communication power and influence in the international communication field. (2) Closeness Centrality: Closeness centrality reflects how close a node is to other nodes in the network. A non-core member must depend on others when transmitting messages; therefore, a node closer to other nodes is less dependent on others [**?**]. It should be noted that while degree centrality focuses on a node'

s relationships with others, closeness centrality emphasizes a node' s control ability within the overall network. In network calculations, the overall trends of these two measures are consistent, but since neither considers the scale of exchange or interaction between actors, some data may be affected. Therefore, in subsequent analysis, we retained only valuable data and excluded nodes with overly small sample sizes to prevent result confusion.

5. Results

5.1 Descriptive Statistics of Major Countries' International Communication Capabilities

Analysis of the 288 media websites from 60 countries/regions reveals the number of media outlets owned, information service volume, information acquisition volume, and external communication volume for each country/region, as shown in Table 1 . In terms of website distribution, the United States owns the most important media websites (69), followed by China (21), India (19), the United Kingdom (16), Russia (13), France (12), Germany (10), Australia (8), and Spain (7).

Regarding information provision volume, China holds an absolute advantage ranking first, followed by the United States, the United Kingdom, India, Russia, Brazil, Germany, Iran, France, Spain, Turkey, Japan, and Australia. The traffic data obtained for individual countries/regions represents global internet users' visits to that country/region' s major media websites. Generally, higher information provision volume indicates stronger agenda-setting capacity and communication power, though this data also strongly correlates with the number of internet users in the country/region.

From the perspective of internet user access behavior, China, the United States, India, Japan, and Brazil rank top five in "in-degree"traffic, indicating the highest frequency of news website visits by internet users in these countries. They are followed by Germany, South Korea, Canada, Australia, Russia, Turkey, Greece, and Iran—directly related to these countries'internet development levels, number of internet users, news consumption habits, and internet management policies.

In terms of external communication volume, the United Kingdom and the United States are nearly tied for first place, forming the top tier (the UK slightly higher, though major UK websites like reuters.com operate headquarters in the US, generating enormous US traffic counted as external communication). Other countries with substantial external communication volume include Russia, India, China, Germany, Spain, France, and Australia.

5.2 Social Network Analysis of Global Communication Pattern

Based on incomplete Alexa statistics, 288 websites from 60 countries/regions cumulatively provide information to 144 major nodes. We conducted in-depth analysis of the global communication network using social network analysis. It

should be noted that since Alexa' s country/region traffic data only includes top-ranked countries/regions, we obtained data for 143 countries/regions total, with some small countries/regions aggregated under an "Other" node.

5.2.1 Degree Centrality Analysis Degree centrality is the most direct indicator of how frequently a country/region connects with others in the international communication network—the more connections, the higher the degree centrality. Table 2 presents degree centrality analysis for major countries/regions, revealing asymmetry between information service provision and user access traffic.

In terms of out-degree centrality, the United States, Japan, Italy, and the United Kingdom show higher centrality, indicating more active direct or indirect external information provision. The US ranks first in out-degree centrality, objectively demonstrating the highest absolute number of connections between US websites and other countries/regions, placing it at the center of communication linkages. In terms of in-degree centrality, India, the United States, Japan, Brazil, Germany, and South Korea show decreasing coreness. India ranks first, indicating its central position in information acquisition pathways, related to its large internet user base, numerous domestic news media websites, and linguistic diversity.

It should be noted that countries/regions show unbalanced out-degree and in-degree centrality. India is particularly notable (ranking 1st in in-degree but 13th in out-degree), indicating active internet user access but relatively weaker information provision capacity from domestic websites.

5.2.2 Closeness Centrality Analysis Closeness centrality reflects how close a node is to other nodes in the network, with higher values indicating more core local positions. Table 3 shows that China has relatively high closeness centrality but relatively low degree centrality (both in-degree and out-degree), primarily due to its enormous domestic traffic. When viewing the global network as a whole, China' s node exerts significant influence due to its massive absolute traffic. The United Kingdom shows high closeness centrality but relatively low degree centrality, mainly related to its convergence with US control in the communication network and fewer absolute association edges provided.

India exhibits high degree centrality but relatively low closeness centrality, indicating it is a key node closely connected with others but not at the core of the overall network. Additionally, countries like Russia and France show low closeness centrality but high degree centrality, suggesting these countries are embedded in highly concentrated regional networks (such as the Commonwealth of Independent States circle and Spanish-speaking countries circle), related to geopolitical culture and geopolitics.

5.3 Major Findings on Global Communication Pattern

Through network relationship analysis of 288 websites across 144 countries/regions, we identified the positional relationships of major countries/regions in the communication field, as shown in Figure 1 [Figure 1: see original paper]. The results indicate that the current network communication pattern generally conforms to world system theory assumptions at the macro level but demonstrates new characteristics at the micro level.

First, the relative position of a country/region node is determined by its constituent basic nodes. In recent years, due to trends of media commercialization, globalization, conglomeration, and networking, multimedia business groups have formed with high integration among telecommunications, computer, internet, and media companies, leading to increasingly concentrated media ownership [**?**]. This has further strengthened the aggregation of radiating capacity for centrally positioned countries in the network.

Second, both centralization and multi-centralization characteristics coexist. Centralization refers to the aforementioned aggregation effect, while multi-centralization manifests in: (1) certain central nodes acting as relays and transmitters, consistent with traditional mass communication models; (2) specific circles formed by geopolitical and geo-cultural factors; and (3) "self-sufficient" nodes formed primarily due to cultural factors.

Third, the aggregation and control power of the global information communication network are more pronounced than in the global economic and trade pattern. This aggregation and control power refers to the radiation and influence of central network nodes on peripheral nodes. The data show that core nodes in the current global network communication pattern have more concentrated radiating power, while more peripheral nodes are in a "being influenced" state. This differs from the economic and trade pattern and relates not only to economic level, education level, demographic factors, and geopolitics but also significantly to the aggregation of search engines and social media platforms.

Overall, compared with early research, the current global communication pattern shows continuity and still generally conforms to world system theory' s division of sovereign state power relations, while also exhibiting numerous new characteristics in both external communication volume and centrality analysis.

6. Robustness Check

In the global information communication pattern, countries/regions have uneven distribution of network bandwidth, number of internet users, and infrastructure structure. The United States, China, India, Russia, Germany, and France occupy important positions in external communication traffic and centrality distribution, while numerous other countries/regions forward information through these nodes. First, the traffic data referenced in this study are three-month averages; second, the country/region-level traffic data are aggregated from website

traffic, inherently possessing certain robustness.

To further ensure that empirical conclusions are not affected by specific countries/regions, we conducted separate analysis after excluding data from country/region groups with small communication traffic volumes (the "Other" node). Results show that the overall centrality comparison trends remain unchanged from the original data, as shown in Table 4 .

7. Discussion and Implications

7.1 Methodological Contributions

Addressing limitations in previous international information communication network research—such as outdated data sources, single-dimensional depiction, and reliance on plaintext links—we drew on traditional PageRank thinking to introduce actual website access traffic and information inflow/outflow from sovereign country/region internet news platforms, depicting country/region-granularity information communication power. Through traffic and network analysis of the latest global internet communication pattern, we outlined the newest global internet communication landscape. Empirical results demonstrate that using news and information service website traffic as the minimal entry point and countries/regions as research units, the proposed metrics of information service volume, information acquisition volume, and external communication volume effectively portray national/regional communication capabilities and positions within the global communication network.

Compared with previous research, our proposed computational model and data source selection offer three advantages: (1) Using industry rankings and manual screening to maximize inclusion of information service platforms ensures comprehensive and objective data; (2) In designing the information provision volume model, using real traffic analysis effectively addresses difficulties in obtaining encrypted links and social media diversion of large news websites, ensuring objective results; (3) In designing the two key concepts of external communication volume and information acquisition volume, using individual internet users as research units before aggregating them to the country/region granularity accounts for individuals' information selection roles in social media development while macro-processing micro-concepts, enabling quantitative calculation of international communication capabilities.

In terms of application, this study presents the latest international information communication pattern, develops Wallerstein' s world system theory, and empirically demonstrates the realistic possibility of late-developing countries' international communication capacity enhancement and position advancement. The description of relative positions among countries in communication networks also empirically breaks previous stereotypes of binary or unipolar patterns, validating the complex relationships among international communication capacity, geopolitics, geo-culture, and technological strength.

It should be noted that although this study minimized the impact of large platform monopolies and computational communication on news traffic objectivity through website selection and manual correction to avoid duplicate calculations and focus on sovereign states' roles, it included only information distribution websites and excluded instant messaging tools. This is primarily because instant messaging tools use point-to-point encrypted traffic transmission, making public traffic data unavailable. Given China' s large population, overseas Chinese, and numerous annual cross-border travelers who use WeChat and other instant messaging tools, excluding this factor may somewhat affect China' s external communication power calculation. However, since this study also did not include US and Russian instant messaging tools due to encrypted traffic limitations, this limitation does not affect our conclusions.

7.2 Implications for China from the Latest Characteristics of Internet Information Communication Pattern

History has evolved the international communication pattern from the radio era to the satellite era and into the internet era. Information technology and transnational communication centers have become core resources of national power, with communication technology becoming one of the core controlling forces shaping international order. The above results clearly show that the internet information communication pattern is both a "cyber" representation of geopolitical, linguistic, cultural, and historical traditions and a direct manifestation of information technology control power. In such an internet communication pattern, opportunities and challenges coexist. How should China respond?

Undoubtedly, China' s communication power and influence in the global communication pattern are continuously rising, clearly verified by our data on information service volume and information acquisition volume. This is inseparable from China' s rapid information technology development and reflects China' s cultural and institutional advantages. China' s substantive advancement in the international communication field also indirectly validates the effectiveness of world system theory' s description of information communication patterns and its questioning of linear modernization development, while providing empirical evidence for late-developing countries' status advancement.

As a major traffic and communication power, how can China further leverage its traffic advantages to expand communication power from a planar to a network dimension? Beyond the surface of traffic, the fundamental essence lies in information dissemination, and information' s connotation is "meaning." Information' s extension includes three aspects: symbols, carriers, and meaning, where the carrier refers to the medium bearing meaning, symbols are representations of meaning through text and images, and meaning is information itself [**?**]. Cross-border information flow is not about symbol flow or carrier change but essentially about meaning flow. Therefore, we must clearly recognize that network development, artificial intelligence applications, and multimedia processing methods essentially enrich carriers and symbols rather than meaning

itself. Control over meaning itself originates from the bottom layer of the overall network and value identification among groups, which is also an important cause of current knowledge gaps and identification differences and a key to further improving international communication discourse power.

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