Title
Evolution of the International Hyperlink Network

Journal
Journal of Global Information Technology Management, 19(3)

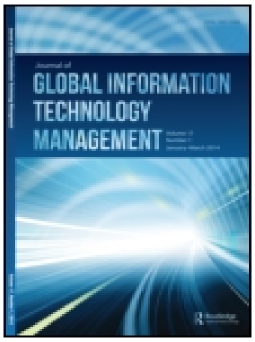
ISSN
1097-198X

Authors
Barnett, George A
Park, Han Woo
Chung, Chung Joo

Publication Date
2016-07-02

DOI
10.1080/1097198x.2016.1217135

Peer reviewed



Journal of Global Information Technology Management

ISSN: 1097-198X (Print) 2333-6846 (Online) Journal homepage: http://www.tandfonline.com/loi/ugit20

Evolution of the International Hyperlink Network

George A. Barnett, Han Woo Park & Chung Joo Chung

To cite this article: George A. Barnett, Han Woo Park & Chung Joo Chung (2016) Evolution of the International Hyperlink Network, Journal of Global Information Technology Management, 19:3, 174-189, DOI: 10.1080/1097198X.2016.1217135

To link to this article: http://dx.doi.org/10.1080/1097198X.2016.1217135

Published online: 26 Sep 2016.

JOURNAL OF GLOBAL INFORMATION TECHNOLOGY MANAGEMENT
2016, VOL. 19, NO. 3, 174–189
http://dx.doi.org/10.1080/1097198X.2016.1217135

Evolution of the International Hyperlink Network

George A. Barnett[a], Han Woo Park[b], and Chung Joo Chung[c]

[a]Department of Communication, University of California – Davis, Davis, California, USA; [b]Department of Media and Communication, YeungNam University, Gyeongsan-si, Gyeongsangbuk-do, Korea; [c]Department of Journalism and Mass Communication, Kyungpook National University, Daegu, Korea

ABSTRACT

This study describes the evolution of the international hyperlink network. The World Wide Web is a distributed hypertext system consisting of a virtual network of content and hyperlinks with billions of interlinked pages. Since the Web has no "engineered architecture," it can be understood as a self-organized system with a well-defined structure of linkage that implies an underlying social structure. This article examines the evolution of the Web's emergent social structure and communication network at the level of nation-states. It reviews the literature on the international hyperlink network and then focuses on changes between 2009 and 2010 using data on the frequency of bilateral hyperlinks between nations. The article discusses special problems associated with the top-level domain *.com* as well as other generic top-level domains that do not refer to specific nations whose domain names refer to commercial or vanity applications.

KEYWORDS

Communication network; international hyperlink; Internet; telecommunications; World Wide Web

Introduction

Information technology is transcending geography and flattening the world (Kim, Lee, & Joshi, 2013). Linkages between countries have changed significantly as the global information infrastructure has evolved over the past decade (Seo & Thorson, 2012). Since early research on hyperlink patterns that mapped server networks and determined the level of authority or visibility of websites (Huey, 2005), there has been little research examining the structure of international Internet hyperlinks. For example, in a recently published volume called *The Hyperlinked Society: Questioning Connections in the Digital Age*, the authors made no mention of international hyperlinks or globalization (Turow & Tsui, 2008). One reason for this is that the Internet is a packet-switched network, unlike the telephone, which devotes a single circuit to each message. Consequently, the paths of individual messages cannot be determined (Barnett & Park, 2005). An alternative approach that permits examination of the international Internet's structure is the analysis of interdomain hyperlinks (Barnett, Chon, Park, & Rosen, 2001).

A hyperlink is the technological capability enabling one website to link seamlessly with another—usually through the click of a mouse (Barnett & Park, 2005; Chung, Barnett, & Park, 2014). Hyperlinking between websites functions as a navigational tool allowing for various combinations of information (Park & Thelwall, 2006). The World Wide Web can be defined as a distributed hypertext system consisting of a network of content and hyperlinks with billions of interlinked pages (Kleinberg & Lawrence, 2001). The Web has no engineered architecture and can be understood as a self-organized system with a well-defined structure of linkage that implies an underlying social structure (Shumate & Lipp, 2008).

CONTACT Chung Joo Chung cjchung@knu.ac.kr Department of Journalism and Mass Communication, Kyungpook National University, Daegu, Korea.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/ugit.

The Web is a huge, complex network where webpages are the nodes and hyperlinks are the lines between them. Hyperlink networks have technological and social implications as the skeleton of the Internet. Because of the multiple meanings of hyperlinks, understanding the mechanisms of hyperlink networks requires considering social contexts and clarifying the meaning of hyperlinking (Huang & Sun, 2015). This article examines the evolution of the Web's emergent social structure at the level of nation-states. It reviews the literature on the international hyperlink network and then focuses specifically on changes that occurred between 2009 and 2010.

International Hyperlink Network Research

According to Rosen, Barnett, and Kim (2011), the first large-scale study of the international Internet was the examination of bilateral hyperlinks among the countries of the Organisation for Economic Co-operation and Development (OECD). The number of interdomain hypertext links embedded in domains associated with all 29 OECD countries (top-level country code domains such as *.ca* for Canada) and six generic top-level domains (*.com, .net, .int, .gov, .edu*, and *.org*) was gathered for July 1998 (OECD, 1998). These countries accounted for approximately 96% of all Internet traffic. Non-OECD members were not included in the analysis. Because no single top-level domain (TLD) represented Internet traffic for the United States, *.edu, .us*, and *.gov* were combined to designate the United States (U.S.). Other generic top-level domains (gTLDs), such as *.com, .org, .int*, and *.net*, were not included in the U.S. group because they were not exclusively from the U.S.

The results indicated that *.com* was the most central node, followed by *.net*. The U.S. was the most central country—acting as the network's hub or the nucleus of the World Wide Web—followed by the United Kingdom, Canada, Germany, and Australia. Iceland and Turkey were the most peripheral countries in the network. A reasonable explanation for this structure is that the Internet was developed in the U.S., and bandwidth costs are low there. At that time, the U.S. accounted for 58% of all Internet hosts, and 94 of the top 100 websites were based there (Cukier, 1999). The correlation between centrality and gross domestic product (GDP) was .974 ($p < .000$), indicated that a nation's position in the network was a function of its total wealth. Cluster analysis revealed that the OECD nations and gTLDs comprised a single group centered on the *.com*/*.net* dyad. There were no subgroups due to geography, language, or culture (Rosen et al., 2011).

Barnett et al. (2001) reported that the structure of the Web was related to a number of exogenous variables and older networks. Older networks included the international telephone, air traffic, trade, science citations, and international student flow networks. Other variables included language and asynchrony (defined as the time-zone difference between national capitals). Physical distance, however, was not related to the structure of international hyperlinks. The cost of communicating via the Internet was unrelated to distance. The combined effects of transportation, telecommunications, science, asynchrony, and either trade or student flow accounted for between 62% and 64% of the variance in network structure with transportation being the most significant determinant. These results led the authors to conclude that the Internet was an autopoietic system (Barnett, 2005), growing through the self-replication of existing telecommunications networks, but evolving to accommodate the physical displacement of actors and the ability to rapidly exchange and store vast amounts of information other than voice information (Barnett et al., 2001).

Halavais (2000) examined the role of geographic borders in the hyperlink patterns of 4,000 websites and found that websites were most frequently linked to other sites in the same country. When they did link across national borders, it was usually to hosts in the U.S. Therefore, real-world social structures are inscribed in online networks despite the fact that geographical borders may be removed from cyberspace. Brunn and Dodge (2001) analyzed interdomain hyperlinks among 174 countries and six nongeographic domains to determine the geography of hyperlinks. They searched for the most and least connected regions and countries with a special focus on Africa and Asia. They treated a website's incoming and outgoing links separately and developed descriptive statistics and cross-tabulation analysis by country and region. Ciolek (2001) examined the direction and volume of hyperlinks among 10 East Asian countries and found that, while Japan had the greatest volume of hyperlinks, 92% were directed to other Japanese websites. Singapore imported 27% of its links, and Indonesia attracted 30% of all pages with international links from the other countries. Based on the assumption that sites are fully navigable internally, and interlinkage between sites is the main factor determining the accessibility of Web-wide content, Bharat, Chang, Henzinger, and Ruhl (2001) found that there was a much higher number of intranational site links than international site links. Typically, only 1% of links were to websites in another country. When the links among the most central countries were removed, geographical, linguistic, and political factors affected the structure of the Web.

Barnett and Park (2005) expanded on earlier research by gathering data on the number of bilateral interdomain hyperlinks among nations. They investigated 47 nations, including all OECD member countries (except Poland), and six gTLDs. Notable additions included Brazil, India, China, Russia, South Africa, Israel, Singapore, and Indonesia. The data were collected in January 2003. TLDs represented approximately 98% of Internet traffic. Again, because no single TLD completely represents the U.S., *.edu, .mil, .us*, and *.gov* were combined to represent the U.S. (*.usa*).

In 2003, the hyperlink network was completely interconnected. As in 1998, the U.S. was the most central country, followed by Australia, the United Kingdom (U.K.), China, Japan, Canada, and Germany. The most peripheral countries were Uruguay, Luxemburg, the United Arab Emirates (UAE), Thailand, and Slovakia. When link direction was considered, the U.S. was the largest in terms of in-degree centrality, followed by Indonesia, India, Italy, and France, while Uruguay, the UAE, and the Czech Republic were the most peripheral. While Germany, the U.K., the U.S., and Australia had the most out-degree centrality, the UAE and India were the most peripheral. Again, the results revealed a single group centered on the *.usa-.au* dyad, the two most central nodes (Barnett & Park, 2005).

Barnett and Park (2005) compared the hyperlink network to one represented by bilateral bandwidth capacity. Bandwidth describes the physical network that transports packets of data from point to point, as opposed to Transmission Control Protocol/Internet Protocol (TCP/IP), for which geography is irrelevant (Townsend, 2001). These connections are nondirectional. The densities of the bandwidth networks for the countries indicated that 18.5% of the possible direct hyperlinks were present. The U.S. was by far the most central country, followed by the U.K., Germany, Hong Kong, Singapore, Japan, and France; the most peripheral were Iceland, Lithuania, Morocco, Croatia, and Guatemala. There were three major groups: (1) English-speaking countries (U.S., U.K., Canada, Australia, and New Zealand), Northern Europe (Scandinavia, Belgium, and the Netherlands), and East Asia; (2) Latin America; and (3) Franco-German Europe (France, Germany, Austria, Italy, Spain, Switzerland, and the Czech Republic). The network resembled a wheel, with the U.S. at the hub and spokes extending out to individual countries and clusters of nations. The U.S. dominated Internet flow because of its position in the network. While there were links entirely within Europe or the Asia-Pacific region, and limited links within Latin America, intercontinental links primarily went through the U.S. Further, even the connections within specific regions may have been routed through the U.S. because of limited within-region bandwidth. Clearly, the U.S. was in a position to act as an information broker or gatekeeper.

Townsend's (2001) examination of Internet bandwidth produced the similar conclusion that "every region and nearly every country has a direct Internet connection to the U.S. and direct connections between other countries are less common. Furthermore, direct connections between different major regions such as Asia and Europe are practically nonexistent" (p. 1701). This structure indicates that the U.S.'s Internet infrastructure functions as a massive switching station for traffic that originates and terminates in foreign countries.

Hyperlink and bandwidth networks correlated at .412 (p = .000) (Barnett & Park, 2005). Additionally, there was a strong relationship (r = .847, p = .000) between the centralities of both networks, indicating that the physical infrastructure of the Internet is an important determinant of which countries communicate via this medium.

Park, Barnett, and Chung (2011) examined the structure of the international hyperlink network in 2009 and how it had changed since 2003. Data were collected in May 2009 using Yahoo. Yahoo had indexed about 47 billion websites at that time (http://www.worldwidewebsize.com). Over 9.3 billion hyperlinks among 33.8 billion sites from 273 TLDs were examined. Again, three TLDs reserved for the exclusive use of American institutions—*.edu, .gov*, and *.mil*—were combined with *.us* to form a node for the U.S. Because *.com, .org*, and *.net* are not exclusive to the U.S., they were not included. This might have resulted in an underestimate of the centrality of the U.S. and other countries that rely heavily on gTLDs.

The international hyperlink network was completely interconnected in 2009. The U.S. had the largest in-degree centrality, followed by Germany, U.K., France, Japan, and Spain. Germany, U.K., Japan, France, and Spain, but not the U.S., had the highest out-degree centralities. The G7 and several EU countries had centrality in the 2009 network. In addition, Brazil and Russia emerged as core countries integrating more peripheral nations. Brazil linked South America, and Russia linked the former Soviet Republics. Additionally, it appears that for the first time there were regional, cultural, and linguistic groupings: a Latin American group, cliques centered on Russia and China, and a Scandinavian group, as well as a core group (Park et al., 2011).

Park et al. (2011) investigated changes in the World Wide Web by comparing hyperlink relations among the same 47 countries for 2009 and 2003. The results for the two points in time were similar. The U.S. was still the most central country, along with Germany, U.K., France, Japan, and Spain. Semiperipheral countries included the Netherlands, Austria, Switzerland, Belgium, Australia, Brazil, Mexico, China, India, and Russia. The UAE, Israel, Estonia, Uruguay, and Luxembourg were the most peripheral. Various measures of centrality correlated at an average of .80, suggesting stability in the network.

The overall correlation between the 2009 and 2003 networks was only .406 ($p < .01$). There were some interesting changes. First, the international hyperlink network became more highly centralized. The composite Gini score of the 2009 network was 0.466; it was only 0.291 in 2003. The greatest departures from the predicted changes were for the most central countries. Europe as a whole, especially Germany, became much more central. The out-degree centralities of the U.K., France, Spain, Italy, and Japan grew more than expected. Moreover, the in-degree centralities of the U.S., Germany, U.K., France, Japan, and Spain grew more than expected. Second, Brazil, Russia, India, and China revealed various changes. Brazil grew more than predicted while Russia grew as predicted. China had fewer outward links than expected. This was probably due to internal domestic growth or the use of the Chinese language, which limits its contact with the West. India had fewer inward links than expected. Third, the centralities were distributed as a power curve (Barabási, 2002), suggesting disproportionate growth in the number of hyperlinks by the more central countries, supporting the idea of preferential attachment (Barabási & Albert, 1999). Fourth, while there was only one group in 2003, regional, cultural, and linguistic groupings had formed in Latin America, Scandinavia, and around China and Russia, suggesting that hybridization, increased centralization toward core-peripheral countries, and increased autonomous diversification of semiperipheral countries had occurred (Choi, 2011; Park et al., 2011; Vaughan & Romero-Frias, 2010).

Investigating the structure of global Internet connectedness, Seo and Thorson (2012) attempted to measure key structural changes in bandwidth and the centrality of digital nodes in the Middle East and North Africa. Using a combination of bandwidth metrics and centrality indicators, they showed how the global information infrastructure evolved between 2002 and 2010, and how several countries in the Middle East rose to prominence as good nodes mediating strong intraregional networks.

An important issue that remains unresolved in international hyperlink research is how imperfect spatial information alters the structure of the network (Grubesic & Murray, 2005). Past research has not included gTLDs, creating an inherent bias in the analysis of international hyperlink network links in the examination of links among country code top-level domains (ccTLDs). That is, such research does not account for the geographic locations of *.com, .net*, or *.org*. As a result, the connectivity of the U.S. and other nation-states that rely heavily on domains other than ccTLDs is

Table 1. Summary of international hyperlink research.

Prior Publications	Analytical Focus	Year of Hyperlink Data
Barnett and Park (2005)	Internet hyperlink, bandwidth	2003
Shumate and Dewitt (2008)	NGO hyperlink	2005
Park et al. (2011)	Internet hyperlink	2003, 2009
Barnett et al. (2011)	Internet hyperlink, Web content	2009
Rosen et al. (2011)	Internet hyperlink	n/a
Lee and Park (2012)	Interlink of world class university	2010
Hsu and Park (2012)	Authorship, subject topic, website format.	2010
Chung et al. (2014)	Dotcom web community	2009
Choi and Park (2014)	Internet host	2010
Barnett and Park (2014)	Internet hyperlink, bandwidth, shared website	2010
Barnett et al. (2015)	Internet hyperlink, international student flow	2010
Huang and Sun (2015)	Homeowner forum	n/a
Ruiz and Barnett (2015)	Ownership of up and downstreams	2011

underreported. The gTLDs were not included because of the difficulty of determining which countries these websites reside in and who links to them (Rosen et al., 2011).

Based on the assumption that decomposing *.com* would produce a more accurate description of the international hyperlink network, Barnett, Chung, and Park (2011) investigated adjusting hyperlink networks using information from Alexa.com regarding the percentage of international Internet users for the most frequently visited gTLDs. They decomposed the three gTLDs (*.com*, *.org*, and *.net*) into the countries in which their users reside and distributed the links proportionally to the ccTLDs. Then, they compared their results with those obtained using traditional methods. The adjusted hyperlink network showed significant changes in the centrality of several countries. The U.S.'s out-degree centrality increased dramatically, and its centrality changed more than that of any other country. Moreover, the notability of several countries in Asia—such as China, Japan, and India—increased probably due to factors such as economic ties with the U.S. and the Chinese-language search engines *baidu.com*, *qq.com*, and *taobao.com*. On the other hand, centrality decreased among countries that did not rely heavily on gTLDs, such as those in Europe. Correlations between the two sets of centrality scores showed that the addition of TLDs did not significantly change network centralities. The correlations ranged from .90 to .93, depending on the measure. Cell-wise correlation indicated that there were systematic differences between the two networks (r = .755, p = .000). The top 20 residuals involved the U.S. (13), China (5), Japan (4), U.K. (2), France (2), Korea (2), Germany (1), Spain (1), Canada (1), and India (1) (Barnett et al., 2011; Rosen et al., 2011).

Although the study by Barnett et al. (2011) more precisely defined countries as nodes on the Internet by decomposing gTLDs based on where their users reside, these adjustments were not based on the volume of hyperlink connections. Rather, they were based on the proportion of Internet users from each country that used certain websites. The hyperlinks to and from gTLDs were distributed to various countries based on their residents' website use, assuming that this was an accurate proxy for the distribution of hyperlink connections. However, this might not be the case. Table 1 shows a chronicle review of international hyperlink research.

Methods

International hyperlink connectivity was collected using Yahoo.com in May 2009 and November 2010. Frequencies of hyperlinks between pairs of countries were measured in terms of webpage counts. For example, Yahoo returned the number of webpages ending with *.jp* (Japan) that had at least one hyperlink to a page ending with *.uk* (U.K.). During the data collection process, LexiURL (Thelwall, 2009) was used to automatically send numerous scripts to Yahoo and organize the returned data. The same data sets were previously used in different contexts: the ego network of the *.com* domain (Chung et al., 2014), international online content flow (Choi & Park, 2014), and

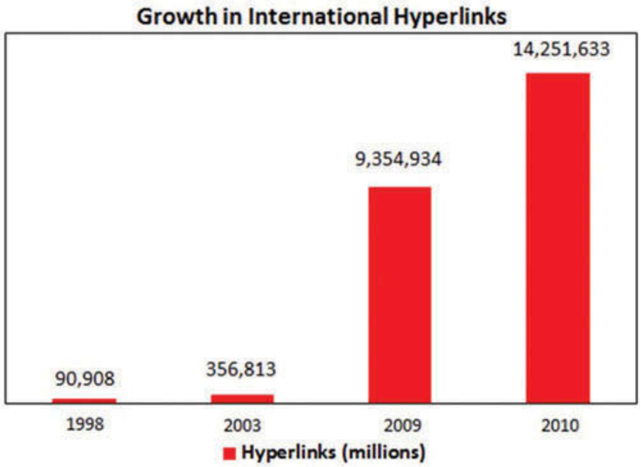


Figure 1. International hyperlinks in 1998, 2003, 2009, and 2010.

international student exchange (Barnett, Lee, Jiang, & Park, 2015). Figure 1 shows the growth in international hyperlinks by data collection period.

Network Analysis

Social network analysis focuses on relationships among social entities and on the patterns and implications of these relationships (Wasserman & Faust, 1994). Instead of analyzing individual behaviors, attitudes, and beliefs, social network analysis focuses on social entities in interaction with one another and on how these interactions constitutes a structure that can be analyzed in its own right (Wasserman & Galaskiewicz, 1994). The connections among geographically separated locations via hyperlinks are best analyzed using network analysis (Barnett et al., 2011). The process is integral to revealing large-scale structures based on patterns of global interaction (Barnett et al., 2001).

Various procedures—including calculating system density, measures of centrality (Freeman, 1979), Bonacich's (1972) eigenvector measure, hierarchical cluster analysis, and metric multidimensional scaling (MDS)—were used to provide a rich description of the international hyperlink network. Compared to traditional network analytics (e.g., centrality and path distance), MDS attempts to express relational data in two-dimensional space using the concept of Euclidean distance that follows a route "as the crow flies"; it has proved useful for discovering certain types of global community power and highlighting the existence of international-level hubs (Scott, 2000). Network analyses and diagrams were created using the social network analysis package UCINET 6 and its component program NETDRAW (Borgatti, Everett, & Freeman, 2002).

Quadratic assignment procedure (QAP) correlation and regression coefficients, calculated using UCINET 6 (Borgatti et al., 2002), were used to examine how the structure of the hyperlink network changed between 2009 and 2010. Hyperlink connectivity, including incoming and outgoing data between countries, was compared to evaluate the strength of the relationship between the two networks. In addition, the degree of centralization was measured using the Gini coefficient.

Results

2010 International Hyperlink Network

The network density of all 273 TLDs in the hyperlink network was .657, meaning 65.7% of possible links among the TLDs existed. As expected, *.com* was the most central node with over six billion

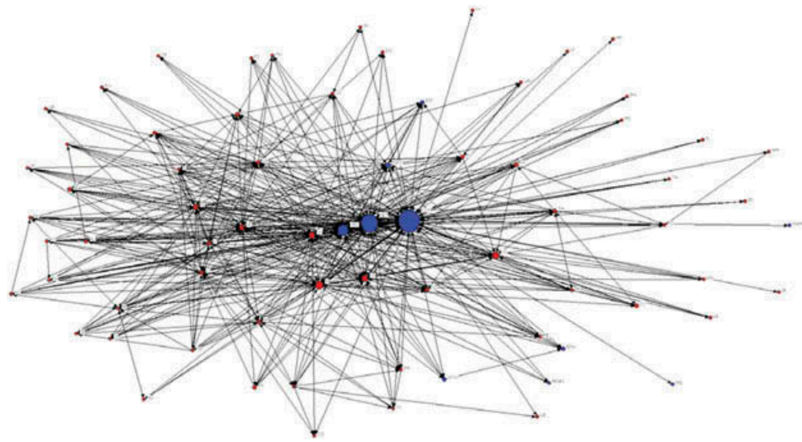


Figure 2. 2010 international hyperlink network. All TLDs with a 0.1% share of international hyperlinks are represented. The size of a node is equal to the number of received links. Blue nodes are gTLDs and red ones are ccTLDs. One million links are required for a line. The thicker the line, the greater the number of links it represents.

inward links and over three billion outward links, meaning that 32.8% of all hyperlinks either came from or went to this node. It was followed by *.jp* (Japan) with over 1.2 billion inward links and 760 million outward links—12.5% of all hyperlinks. After that was *.net* with 1.1 billion inward and 2.3 billion outward links, or 7.0%. The TLDs that followed were *.org* with 734 million inward and 1.3 billion outward links (6.2%), *.uk* (U.K.) with 600 million inward and 456 million outward links (3.6%), *.de* (Germany) with 378 million inward and 369 million outward links (3.5%), and *.cn* (China) with 358 million inward and 580 million outward links (3.3%). The Gini coefficient for the distribution of links was .996, indicating that links in this network were very concentrated among a few domains. All TLDs with a .1% share of international hyperlinks are graphically presented in Figure 2.

The network density of the 251 ccTLDs was .660. Japan (*.jp*) was the most central country with over 227 million inward and 79 million outward links, or 9.0% of international hyperlinks. Japan was followed by *.uk* with over 264 million inward and 100 million outward links—9.0% of the total international links; *.de*, France (*.fr*), and *.es* (Spain). The Gini coefficient for the distribution of international links was .996, indicating that the hyperlinks in this network were very concentrated in a few countries.

Table 2 presents the centralities of 87 countries after the 120 most widely used websites in the gTLDs (*.com, .org*, and *.net*) were decomposed and allocated to the ccTLDs based on the procedures described by Barnett et al. (2011). According to Alexa.com, each of these websites had been used by at least 0.5% of Internet users worldwide on a daily basis for the previous 3 months. Only 87 of the 251 ccTLDs were altered by this adjustment. This network was completely interconnected. Its density was 1.0. The distribution of hyperlinks was more equitable for these nodes. The Gini coefficient was .762. Since much of the information system and technology research in academia has been dominated by a U.S.-centric perspective (Palvia, 2013), the U.S. was the most central node, with 13.2% of the hyperlinks and 500 million inward and 751 million outward links. Japan was next at 10.9%, with 636 million inward and 382 million outward hyperlinks. Japan was followed by China, U.K., and Germany. These results are graphically displayed in Figure 3.

Figure 3 shows that the network developed regional clusters. These include groups for Latin America, the former Soviet Republics, Scandinavia, the Middle East, and a dyad composed of Taiwan and Hong Kong. These regional clusters were connected to the core through more central countries from those regions. For example, Mexico, Argentina, and Brazil connected the other countries of Latin America to the most central nations; Russia and certain Eastern nations linked the former

Table 2. Degree centralities of the 2010 international hyperlink network with decomposed ccTLDs.

	OutDegree	InDegree	NrmOutDeg	NrmInDeg	NEigen	Share
JP	636623104	381763488	5.474	3.282	66.79	0.109
USA	500266816	751407616	4.301	6.46	77.93	0.132
UK	449071776	291715808	3.861	2.508	43.39	0.079
CN	398050880	471424320	3.422	4.053	55.16	0.085
DE	290733216	276464288	2.5	2.377	33	0.06
ES	218801552	154106576	1.881	1.325	19.64	0.039
IT	210407920	137932256	1.809	1.186	20.86	0.037
FR	205917648	239409696	1.77	2.058	25.41	0.046
IN	167366992	162995840	1.439	1.401	19.17	0.033
BR	157886912	108329936	1.357	0.931	15.82	0.028
CA	140657824	166327712	1.209	1.43	18.55	0.033
KR	133915328	113811000	1.151	0.979	14.39	0.023
TW	125765096	73299096	1.081	0.63	13.58	0.021
AR	84576856	44414076	0.727	0.382	6.37	0.015
MX	83020432	73060840	0.714	0.628	8.23	0.016
AU	78376784	81267664	0.674	0.699	9.23	0.016
NL	60164980	74387480	0.517	0.64	7.36	0.014
RU	52823760	87329472	0.454	0.751	7.08	0.015
HK	52240184	41858292	0.449	0.36	5.45	0.01
PL	49429020	59086016	0.425	0.508	6.09	0.012
ID	37264228	31109928	0.32	0.267	4.12	0.007
SE	35790520	53572264	0.308	0.461	4.64	0.009
CZ	30619322	21906576	0.263	0.188	2.36	0.006
TH	27988792	30211240	0.241	0.26	3.29	0.006
BE	26693144	73291216	0.23	0.63	6.98	0.012
TR	25496280	38213216	0.219	0.329	3.48	0.007
MY	22802902	22054258	0.196	0.19	2.66	0.005
AT	22564956	52483272	0.194	0.451	4.77	0.009
UA	22086968	18521700	0.19	0.159	1.61	0.004
PK	21714342	17942320	0.187	0.154	2.4	0.004
IR	19533240	17448388	0.168	0.15	2.18	0.004
NO	18588004	20874948	0.16	0.179	2.09	0.004
VN	18482678	13420874	0.159	0.115	2.17	0.003
DK	17573832	31178818	0.151	0.268	2.41	0.005
VE	15447977	17495352	0.133	0.15	1.55	0.004
PT	15063316	29080100	0.13	0.25	2.4	0.005
CO	14553610	22677632	0.125	0.195	1.91	0.004
SA	14523790	13144900	0.125	0.113	1.62	0.003
HU	14499775	15380553	0.125	0.132	1.54	0.003
PH	14118309	18067400	0.121	0.155	1.85	0.003
IE	14013159	36403448	0.12	0.313	3.5	0.006
ZA	13567186	19777148	0.117	0.17	1.83	0.004
SG	13512439	23060840	0.116	0.198	1.96	0.004
GR	13137794	19574744	0.113	0.168	1.81	0.004
EG	12817766	10434590	0.11	0.09	1.39	0.002
CL	12226680	28167220	0.105	0.242	1.6	0.005
FI	11809544	14112576	0.102	0.121	1.32	0.003
PE	10732663	13607084	0.092	0.117	1.08	0.003
CH	10629109	50723784	0.091	0.436	4.5	0.009
RO	9938601	20468874	0.085	0.176	1.68	0.004
NG	8673939	7019454	0.075	0.06	0.95	0.002
SK	8139560	14371597	0.07	0.124	0.69	0.002
DZ	7757231	6309696	0.067	0.054	0.85	0.001
BD	6422671	5249187	0.055	0.045	0.71	0.001
IL	5776591	6823070	0.05	0.059	0.71	0.001
AE	2416734	4936447	0.021	0.042	0.44	0.001
AO	2381703	1965446	0.02	0.017	0.26	0
BY	2363690	4271387	0.02	0.037	0.26	0.001
UY	2348043	5686874	0.02	0.049	0.28	0.001
MA	2176369	2128312	0.019	0.018	0.2	0
CM	1848281	2203221	0.016	0.019	0.22	0
SI	1694767	3853652	0.015	0.033	0.34	0.001
EE	1606571	2045917	0.014	0.018	0.15	0

(*Continued*)

Table 2. Degree centralities of the 2010 international hyperlink network with decomposed ccTLDs. (*Continued*)

	OutDegree	InDegree	NrmOutDeg	NrmInDeg	NEigen	Share
LY	1595199	35308088	0.014	0.304	4	0.006
KZ	1198693	4122137	0.01	0.035	0.17	0.001
EC	1098069	6251862	0.009	0.054	0.27	0.001
NI	733309	1002206	0.006	0.009	0.1	0
SD	674483	558831	0.006	0.005	0.07	0
HN	651437	1450146	0.006	0.012	0.11	0
PA	641250	4457599	0.006	0.038	0.16	0.001
CR	611035	5868279	0.005	0.05	0.26	0.001
TN	544047	389963	0.005	0.003	0.05	0
KW	493259	615713	0.004	0.005	0.06	0
PY	430568	2054667	0.004	0.018	0.09	0
IQ	353135	307014	0.003	0.003	0.04	0
QA	350981	441510	0.003	0.004	0.04	0
GT	340918	1354986	0.003	0.012	0.06	0
KE	316873	429439	0.003	0.004	0.05	0
OM	297554	324769	0.003	0.003	0.03	0
AZ	283644	358619	0.002	0.003	0.03	0
SV	241664	1064616	0.002	0.009	0.04	0
DM	142661	152066	0.001	0.001	0.02	0
JO	125141	360972	0.001	0.003	0.04	0
BH	77795	89375	0.001	0.001	0.01	0
YE	76734	109562	0.001	0.001	0.01	0
SY	62438	86991	0.001	0.001	0.01	0
CI	35785	50261	0	0	0.01	0
Mean	54239896	54239892	0.466	0.466	6.46	0.011
S.D.	113931224	111618104	0.98	0.96	13.8	0.023

Note. Network Centralization (Outdegree) = 5.065%; Network Centralization (Indegree) = 6.064%.

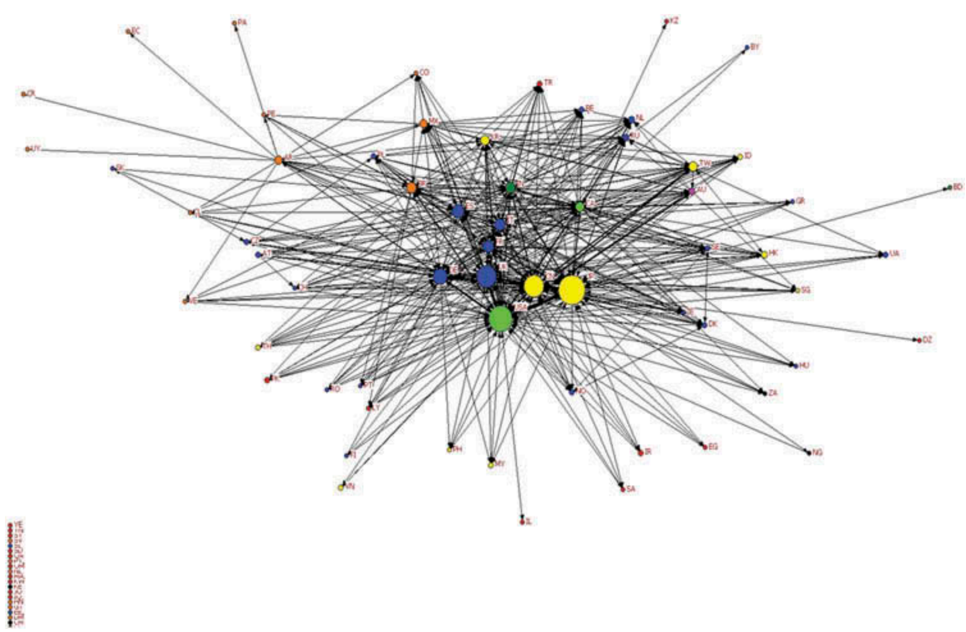


Figure 3. 2010 international hyperlink network after decomposing gTLDs. The size of a node is equal to the number of received links. Nodes are color coded as follows: blue is Europe, yellow is East Asia, light green is North America, dark green is South Asia, orange is Latin America, red is the Middle East and North Africa, black is the rest of Africa, and magenta is Oceania. One million links are required for a line. Thicker lines indicate a greater number of links.

Soviet Republics (*.ee, .kz, .by*, and *.az*) to the core; and China linked Taiwan and Hong Kong to the most central countries. This regionalization of the hyperlink network is a fairly recent development. Barnett and Park (2005) found no such clustering in the network.

Changes in the Network Between 2009 and 2010

The QAP correlation between the network in 2009 and 2010 was .981 ($p < .000$), indicating that the overall network structure was quite stable. It should be noted that previous research (Park et al., 2011) only examined changes among 47 ccTLDs, while this research examined changes among all 273 TLDs. The results for the residuals indicate that countries that grew as sources two standard deviations more than expected were *.com*, Japan, U.K, and China. Germany, *.edu*, Poland, and Russia grew slowly, more than two standard deviations less than predicted. As receivers of hyperlinks, China, Japan, Libya, and Montenegro grew more than two standard deviations than predicted from 2009. Germany, *.org, .us*, and *.com* grew by at least two standard deviations less than expected. Figure 4a graphically illustrates the relationships among the residuals. Nodes with greater-than-predicted link growth are marked yellow, and nodes with less-than-predicted link growth are marked blue. An examination of Figure 4a makes it possible to discern to whom the ties of the nodes with the greatest residuals were linked. Note that *.com* links were distributed to a wide variety of domains, accounting for its great growth, while the blue nodes that grew less than predicted had fewer ties to other domains.

Figure 4b presents a graphic representation of the residuals between 2009 and 2010 for the decomposed network. The size of each node represents the total 2009 hyperlinks to and from that node. The QAP correlation between the 2 years was .931 ($p < .000$), indicating that the hyperlink network among countries was less stable than the network with the gTLDs included. Countries with more than two standard deviations of positive residuals were the U.S., U.K., Japan, and China. They had added more hyperlinks than predicted since 2009. Countries with the greatest negative residuals (greater than two standard deviations less) were Oman, Bahrain, Thailand, Ireland, Columbia, Panama, Costa Rica, Guatemala, Honduras, and Canada. The correlation between the eigenvalue centralities of 2009 and 2010 was .679 ($p < .000$) (Bonacich, 1972). The residuals indicate that the U. S., U.K., Japan, and Germany became relatively more central, while China became relatively less central. This could be the result of the preferential use of the central countries' websites (Barabási, 2002) and the growth in China's use of Mandarin websites that are shared with only a few peripheral nations (e.g., Hong Kong and Taiwan).

Discussion

This article shows how the structure of the international hyperlink network has changed since 1998. In particular, it describes the hyperlink structure using the most recent huge data available and how it has changed over the last few years. The international hyperlink network was found to be highly concentrated around a few central domains, the identity of which depends on the selected lens. In the overall network, *.com* was by far the most central node, accounting for 32.8% of all hyperlinks. An additional 13.2% can be attributed to other gTLDs such as *.org* and *.net*. Among ccTLDs, Japan, U.K., Germany, and China accounted for another 22.9%. Together, these seven nodes accounted for almost 75% of the world's 14.3 billion hyperlinks. When only ccTLDs were examined, the six most central nodes (*.jp, .uk, .de, .fr, .es*, and *.usa*) accounted for 38.5% of the hyperlinks. When focusing only on the 87 nodes with the decomposed website data included, the five most central nodes (*.jp, . uk, .de, .cn*, and *.usa*) involved 56.5% of the links.

These findings are consistent with world systems theory, which suggests that the global system can be characterized by unequal exchanges between information-rich and information-poor countries (Chase-Dunn & Grimes, 1995; Choi, 2011; Wallerstein, 1974). Building on what the McNeills have drawn from the history of the human Web (McNeill & McNeill, 2003, pp. 5–8), Van Dijk (2012,

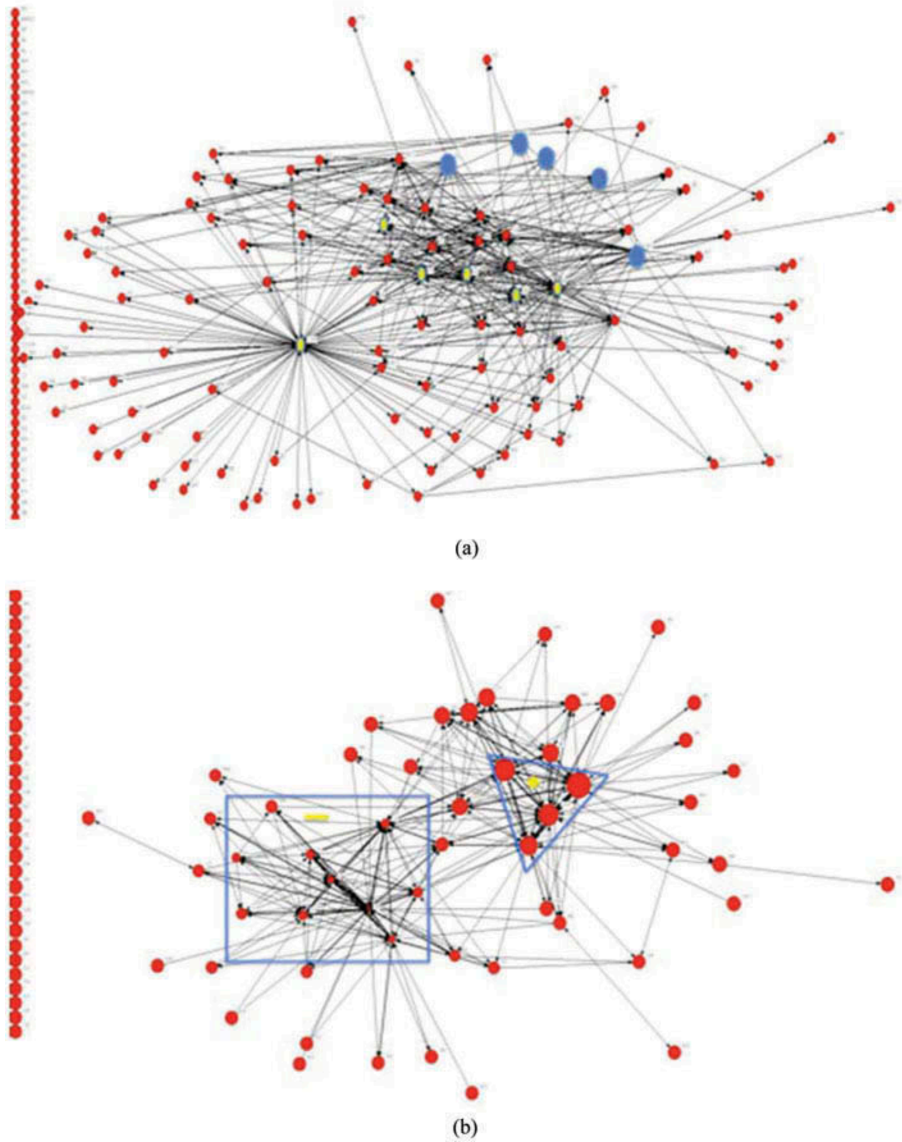


Figure 4. Residual values of 2010 international hyperlink network (all TLDs). (a) Absolute values of residuals, 2009–2010. (b) Decomposed absolute values of residuals, 2009–2010.

p. 104) recently made a similar point that "the basic idea of those who think that the Internet is decentralizing on a global scale and necessarily undermines the national state is just as one-sided as the opposite idea of the centralization of control by the national state. The state will not wither away or even dissolve into virtual relationships of horizontal types of organization appearing on the Internet. Both visions are one-sided, since networks consist not only of (horizontal) connections but also of (vertical) centers and nodes."

In a recent analysis of the Web visibility of several world-class universities, Lee and Park (2012) also reported that there are many subsystems that make up the world system. One distinctive implication drawn from the academic system is that universities in English-speaking countries dominate the central positions in various Web structures, whereas those in non-English-speaking countries are located on the periphery of these structures. Interestingly, in an analysis of hyperlink patterns in the global banking industry, Vaughan and Romero-Frias (2010) reported that major Asia-Pacific banks, including Chinese financial institutions, attracted more in-links than U.S. bank websites during the recent world financial crisis. Thus, the Internet may provide a multilayered structure for the world system, but the traditional core-periphery model might still be represented in the patterns of disparity in global Web links. Therefore, the findings of current research should be interpreted with caution.

The 2010 network had regional clusters in Latin America, the former Soviet Republics, Scandinavia, the Middle East, and Chinese East Asia. Choi (2011) reported similar results. These regional clusters are not directly connected to the rest of the world, but are connected indirectly through a core in the region. The world systems theory labels these regions as semi-peripherals. The former Soviet Republics are linked mostly to Russia and a few other Eastern nations, which then link them to the rest of the world. As another example, Mexico, Argentina, and Brazil link the other Latin American countries to more central nations. However, regional clustering suggests that world systems theory is inadequate for describing the complexities of the international hyperlink network. Factors other than economic relations among nations—such as culture, language, and geography—also determine the structure of the hyperlink network (Barnett & Sung, 2006).

Overall, despite the growth of over five billion hyperlinks between 2009 and 2010, the network's structure is quite stable. The QAP correlations were .981 for the total network and .931 for the decomposed network. The greatest changes involved *.com* and the central ccTLDs, but Libya and Montenegro grew as well. It is interesting to note that Libya grew more than expected based on the 2009 data, with *.com* accounting for its greatest increase in hyperlinks. Considering the media focus on Libya's revolution against Gaddafi being led by social media—and especially considering that Facebook is the most widely used website in the country—the increase in *.com* domains can be said to be a symptom of that. However, hyperlink connectivity in the rest of the Middle East and North Africa did not reflect this trend. Finally, Montenegro's growth was most likely a result of its independence from Serbia, achieved in 2006.

For the network with the decomposed gTLDs, the most central countries grew more than predicted. This may be attributed to the preferential attachment of the central countries' websites (Barabási & Albert, 1999). Preferential attachment is the tendency of the Web to grow such that new links tend to be made with nodes that already have links; in this way, well-connected nodes receive new connections in greater numbers than those that are less connected. Middle Eastern and Central American countries grew less than predicted. Ireland and Canada also grew less than expected. Ireland's lack of growth could be attributable to unfavorable economic conditions in the country.

While this article describes how the international hyperlink network has changed over time, it might not account for evolutionary Internet ecology in its examination of hyperlink connections among nations. However, according to Monge and colleagues (Monge, Heiss, & Margolin, 2008; Monge & Poole, 2008; Weber & Monge, 2011), evolution involves more than simply change occurring over time. Researchers study the evolution of networks at the individual, population, and community levels. When discussing the evolution of the hyperlink network, individuals are specific websites with unique Web addresses. Populations are composed of individual sites that perform similar functions and compete with each other for the attention of users and hyperlinks with other websites. Their growth may be limited by the carrying (bandwidth) capacity of the network. Finally, the community level of evolutionary theory, sometimes called community ecology, examines how different nodes (websites) and populations of nodes (TLDs) interact at both levels in a common environment. In this case, the global system of the World Wide Web is determined in part by the physical infrastructure of the Internet (Monge & Poole, 2008). Community-level research considers the interactions (hyperlinks) that occur at the population and node levels but further considers interactions with the environment. Populations are considered as interdependent. As they evolve, however, they interact with one another while simultaneously being influenced by environmental factors, such as the global economy, geopolitical factors, and changes in technology.

Communities are collections of interacting populations. Populations have a common structure and purpose. Online, this common structure and purpose is manifested in the hierarchy of Web addresses. Organizational forms are at the core of evolutionary studies, providing the building blocks for each level of study. While the definition of organizational form, as well as the process by which new forms emerge, is unclear, it could be based on structural characteristics, such as network density, centrality, and clustering (Monge et al., 2008).

Over time, the structure or form of the hyperlink network has evolved through an ongoing circle of online life: birth as new websites (and ccTLDs, such as *.me* for Montenegro) come online and death as they cease to operate (e.g., *.su*, the ccTLD for the Soviet Union). In addition, population boundaries change as new domain names, such as *.biz* and *.asia*, are established. Thus, from an evolutionary perspective, the international hyperlink network represents an evolution from previously existing forms. Barnett et al. (2001) concluded that the Internet evolved through the self-replication of existing telecommunications networks, but with changes to accommodate the physical displacement of actors around the world and the ability to rapidly exchange and store vast amounts of information. It is clearly a self-organizing system (Shumate & Lipp, 2008). The structural properties of the international hyperlink network have evolved over time. The network grew from about 90 million hyperlinks in 1998 to a population of about 47 billion websites in 2009 and over 14 billion hyperlinks in 2010, growing from a unified English-language network among economically developed countries to a global network using many different languages with regional and cultural clusters. The Internet has become less dependent upon English, as evidenced by the growth of non-English-language sites exceeding that of English sites since 2004 (Choi, 2011).

The process of variation, selection, and retention extends from Darwin's variation-selection-retention model of biological evolution and helps to explain how forms develop (Weber & Monge, 2011). Variation is a departure from existing routines or traditions (patterns of use), or other changes in form. Variation can occur through intentional action or can result from disturbances in the system, such as environmental change or technological innovation. Certain variations typically prove more beneficial or successful than others. As a result, some variations are retained while others are eliminated. Thereforel selection is the process of eliminating certain variations that are not as good as the alternatives (Weber & Monge, 2011). New websites that have functional advantages replace existing sites. Selection occurs for two primary reasons: (1) external influence from outside the nation or (2) internal factors within the country, such as improvements in the information infrastructure or changes in information policy. The third evolutionary process, retention, is defined as the preservation, duplication, and reproduction of selected variations over time. Retention occurs as websites reproduce successful competencies and new forms are duplicated. Since many websites provide access to the same types of information, not all of them can be successful.

Thus, future studies should look more closely at changes in the international hyperlink network over time from an evolutionary perspective, as proposed by Monge and colleagues (2008). Future studies should also specify changes in the structure of the network at the website, national, and international levels. Moreover, they should examine variations in the patterns of use of this network—specifically, how new sites and domains emerge while others are eliminated. Future research should also examine the structure of the international Internet from various perspectives other than the hyperlink connections among a nation's domain names. Such perspectives might include the actual, physical bilateral bandwidth between countries and the structural equivalence of nations based on their common website use in IT, business, politics, and academia (Chung et al., 2014). For example, research on social networking services (e.g., Facebook, Twitter, and Weibo) might represent the process of forming hyperlink networks among users or organizations as an emerging means for communicating, collaborating, sharing, and organizing (Hsu, Park & Park, 2013; Jung, No, & Kim, 2014; Xiao, Li, Cao, & Tang, 2012; Zhang, Zhang, Ordóñez, De Pablos, & Sun, 2014). Research on the website connections of businesses or NGOs will provide insight into information or knowledge sharing in globally linked networks. Finally, by using multiple measures (e.g., keyword searches of online documents through Google Maps) to identify pairs of countries, it would be possible to triangulate the social structure of the international Internet and provide a more robust description of the network and its evolution, which could facilitate better predictions regarding the role of the Internet in the global community.

References

Barabási, A. (2002). *Linked: The new science of networks*. Cambridge, MA: Perseus.

Barabási, A., & Albert, R. (1999). Emergence of scaling in random networks. *Science*, *286*(5439), 509–512. doi:10.1126/science.286.5439.509

Barnett, G. A. (2005). An introduction to self-organizing systems. In G. A. Barnett & R. Houston (Eds.), *Advances in self-organizing systems* (pp. 3–32). Cresskill, NJ: Hampton Press.

Barnett, G. A., Chon, B. S., Park, H. W., & Rosen, D. (2001). The structure of international Internet flows in cyberspace. *Netcom*, *15*(1–2), 61–80.

Barnett, G. A., Chung, C., & Park, H. W. (2011). Uncovering transnational hyperlink patterns and Web-mediated contents: A new approach through cracking .com domain. *Social Science Computer Review*, *29*(3), 369–384. doi:10.1177/0894439310382519

Barnett, G. A., Lee, M. S., Jiang, K., & Park, H. W. (2015). The flow of international students from a macro perspective: A network analysis. *Compare: A Journal of Comparative and International Education*. Online First.

Barnett, G. A., & Park, H. W. (2005). The structure of international Internet hyperlinks and bilateral bandwidth. *Annals of Telecommunication*, *60*, 1115–1132.

Barnett, G. A., & Park, H. W. (2014). Examining the international internet using multiple measures: New methods for measuring the communication base of globalized cyberspace. *Quality & Quantity*, *48*, 563–575. doi:10.1007/s11135-012-9787-z

Barnett, G. A., & Sung, E. (2006). Culture and the structure of the international hyperlink network. *Journal of Computer-Mediated Communication*, *11*(1), 217–238. doi:10.1111/j.1083-6101.2006.tb00311.x

Bharat, K., Chang, B. W., Henzinger, M., & Ruhl, M. (2001). *Who links to whom: Mining linkage between Web sites*. Paper presented at the 2001 IEEE International Conference on Data Mining (ICDM), San Jose, CA.

Bonacich, P. (1972). Factoring and weighting approaches to status scores and clique identification. *The Journal of Mathematical Sociology*, *2*, 113–120. doi:10.1080/0022250X.1972.9989806

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *UNICET 6 for Windows: Software for social network analysis* [computer program]. Needham, MA: Analytic Technologies.

Brunn, S. D., & Dodge, M. (2001). Mapping the worlds of the World Wide Web: (Re)structuring global commerce through hyperlinks. *American Behavioral Scientist*, *44*, 1717–1739. doi:10.1177/00027642010440100011

Chase-Dunn, C., & Grimes, P. (1995). World systems analysis. *Annual Review of Sociology*, *21*, 387–417. doi:10.1146/annurev.so.21.080195.002131

Choi, S. (2011, November). *Cultural imperialism on the Internet?* Paper presented at the National Communication Association, New Orleans, Louisiana.

Choi, S., & Park, H. W. (2014). Flow of online content from production to consumption in the context of globalization theory. *Globalizations*, *11*(2), 171–187. doi:10.1080/14747731.2014.904172

Chung, C., Barnett, G. A., & Park, H. W. (2014). Inferring international dotcom Web communities by link and content analysis. *Quality & Quantity*, *48*, 1117–1133. doi:10.1007/s11135-013-9847-z

Ciolek, T. M. (2001, September). *Networked information flows in Asia: The research uses of the Alta Vista search engine and 'Weblinksurvey' software*. Paper presented at the Internet Political Economy Forum 2001: Internet and Development in Asia, The National University of Singapore, Singapore.

Cukier, K. N. (1999, June). *Bandwidth colonialism? The implications of Internet infrastructure on international e-commerce*. Paper presented at INET'99, San Jose, California.

Freeman, L. C. (1979). Centrality in social networks: Conceptual clarification. *Social Networks*, *1*, 215–239. doi:10.1016/0378-8733(78)90021-7

Grubesic, T. H., & Murray, A. T. (2005). Geographies of imperfection in telecommunication analysis. *Telecommunications Policy*, *29*, 69–94. doi:10.1016/j.telpol.2004.08.001

Halavais, A. (2000). National borders on the World Wide Web. *New Media & Society*, *2*, 7–28. doi:10.1177/14614440022225689

Hsu, C. L., & Park, H. W. (2012). Korean and Chinese webpage content: Who are talking about what and how?. *Journal of Computer-Mediated Communication*, *17*, 202–215. doi:10.1111/j.1083-6101.2011.01571.x

Hsu, C. L., Park, S. J., & Park, H. W. (2013). Political discourse among key Twitter users: The case of Sejong City in South Korea. *Journal of Contemporary Eastern Asia*, *12*(1), 65–79. doi:10.17477/jcea.2013.12.1.065

Huang, R., & Sun, X. (2015). Issues and place: The hyperlink network of homeowner forums and implications for collective action. *Chinese Journal of Communication*, *8*(2), 119–141. doi:10.1080/17544750.2014.993409

Huey, T. A. (2005). Thinking globally, eating locally: Website linking and the performance of solidarity in global and local food movements. *Social Movement Studies*, *4*, 123–137. doi:10.1080/14742830500191469

Jung, K., No, W., & Kim, J. W. (2014). Who leads nonprofit advocacy through social media? Some evidence from the Australian marine conservation society's twitter networks. *Journal of Contemporary Eastern Asia*, *13*(1), 69–81. doi:10.17477/jcea.2014.13.1.069

Kim, J., Lee, K., & Joshi, K. (2013). Editorial preface: Globalization of information technology products and services. *Journal of Global Information Technology Management*, *16*(3), 1–6. doi:10.1080/1097198X.2013.10845639

Kleinberg, J., & Lawrence, S. (2001). The structure of the Web. *Science*, *294*, 1849–1850. doi:10.1126/science.1067014

Lee, M., & Park, H. W. (2012). Exploring the Web visibility of world-class universities. *Scientometrics*, *90*, 201–218. doi:10.1007/s11192-011-0515-6

McNeill, J. R., & McNeill, W. H. (2003). *The human Web: A bird's-eye view of world history*. New York, NY: W. W. Norton & Company, Inc.

Monge, P., Heiss, B. M., & Margolin, D. B. (2008). Communication network evolution in organizational communities. *Communication Theory*, *18*, 449–477. doi:10.1111/comt.2008.18.issue-4

Monge, P. R., & Poole, M. S. (2008). The evolution of organizational communication. *Journal of Communication*, *58*, 679–692. doi:10.1111/jcom.2008.58.issue-4

OECD. (1998). *Working paper on telecommunication and information service policies: Internet infrastructure indicators*. Paris, France: OECD.

Palvia, P. (2013). The world IT project: A program on international research and call for participation. *Journal of Global Information Technology Management*, *16*(2), 1–5. doi:10.1080/1097198X.2013.10845633

Park, H. W., Barnett, G. A., & Chung, C. (2011). Structural changes in the global hyperlink network 2003–2009. *Global Networks*, *11*(4), 522–544. doi:10.1111/j.1471-0374.2011.00336.x

Park, H. W., & Thelwall, M. (2006). Web-science communication in the age of globalization. *New Media & Society*, *8*(4), 629–650. doi:10.1177/1461444806065660

Rosen, D., Barnett, G. A., & Kim, J. H. (2011). Social networks and online environments: When science and practice co-evolve. *Social Network Analysis and Mining*, *1*, 27–42. doi:10.1007/s13278-010-0011-7

Ruiz, J. B., & Barnett, G. A. (2015). Who owns the international Internet networks?. *The Journal of International Communication*, *21*(1), 38–57. doi:10.1080/13216597.2014.976583

Scott, J. (2000). *Social network analysis* (2nd ed.). London, UK: Sage.

Seo, H., & Thorson, S. J. (2012). Networks of networks: Changing patterns in country bandwidth and centrality in global information infrastructure, 2002–2010. *Journal of Communication*, *62*(2), 345–358. doi:10.1111/j.1460-2466.2012.01631.x

Shumate, M., & Dewitt, L. (2008). The North/South divide in NGO hyperlink networks. *Journal of Computer-Mediated Communication*, *13*(2), 405–428. doi:10.1111/jcmc.2008.13.issue-2

Shumate, M., & Lipp, J. (2008). Connective collective action online: An examination of the hyperlink network structure of an NGO issue network. *Journal of Computer- Mediated Communication*, *14*, 178–201. doi:10.1111/jcmc.2008.14.issue-1

Thelwall, M. (2009). *Introduction to webometrics*. San Rafael, CA: Morgan & Claypool.

Townsend, A. M. (2001). Network cities and the global structure of the Internet. *American Behavioral Scientist*, *44*, 1697–1716. doi:10.1177/00027640121957998

Turow, J., & Tsui, L. (2008). *The hyperlinked society: Questioning connections in the digital age*. Ann Arbor, MI: University of Michigan Press.

Van Dijk, J. A. G. M. (2012). *The network society* (3rd ed.). London, UK: Sage.

Vaughan, L., & Romero-Frias, E. (2010). Web hyperlink patterns and the financial variables of the global banking industry. *Journal of Information Science*, *36*(4), 530–541. doi:10.1177/0165551510373961

Wallerstein, I. (1974). *The modern world system*. New York, NY: Academic Press.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. New York, NY: Cambridge University Press.

Wasserman, S., & Galaskiewicz, J. (1994). Introduction: Advances in the social and behavioral science from social network analysis. In S. Wasserman & J. Galaskiewicz (Eds.), *Advances in social network analysis* (pp. xi–xvii). Thousand Oaks, CA: Sage.

Weber, M. S., & Monge, P. (2011). The flow of digital news in a network of sources, authorities, and hubs. *Journal of Communication*, *61*, 1062–1081. doi:10.1111/j.1460-2466.2011.01596.x

Xiao, H., Li, W., Cao, X., & Tang, Z. (2012). The online social networks on knowledge exchange: Online social identity, social tie and culture orientation. *Journal of Global Information Technology Management*, *15*(2), 4–24. doi:10.1080/1097198X.2012.11082753

Zhang, J. X., Zhang, H., De Pablos Ordóñez, P. O., & Sun, Y. (2014). Challenges and foresights of global virtual worlds markets. *Journal of Global Information Technology Management*, *17*(2), 69–73. doi:10.1080/1097198X.2014.928559

Author Notes

George A. Barnett is a distinguished professor in the Department of Communication at the University of California–Davis. His research includes international and intercultural communication, and in social networking and other communication networks—notably, the roles of international telephone and Internet communications in social and economic development, cultural change, and the process of globalization. He has served as president of the International Network of Social Network Analysis.

Han Woo Park is a professor in the Department of Media and Communication at YeungNam University in Korea. He has contributed works in the area of Link Analysis/Webometrics from the perspective of Social Network Analysis. Further, he conducts research on various issues focusing on the use of new digital technologies and the role of communication in scientific, technical, and innovative activities.

Chung Joo Chung is an assistant professor in the Department of Journalism and Mass Communication at Kyungpook National University in Korea. His research areas include data science, social networks, and new media technology. His recent research focuses on Big Data, AI, and Government 3.0 from the perspective of Social Science. He has published several articles in prestigious journals.