Mapping the "Worlds" of the World Wide Web

(Re)Structuring Global Commerce Through Hyperlinks

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The World Wide Web is barely 10 years old and already spans the globe, comprising more than a billion public pages and 3 million servers. It is a decentralized information space, created and controlled by many different authors, and has much lower barriers to entry than conventional information media. The authors analyze the connections between 180 different Internet "nations" using data on the number of Web pages and hyperlinks gathered from a commercial search engine in 1998. They also analyze and describe the geography of the hyperlinks, revealing the most and least connected regions and countries, with a particular focus on African and Central Asian countries. A metric is created, the Hyperlink Index, which is similar to the Export-Import Index common in economics and used to measure the flows of physical goods.

The introduction and rapid diffusion of the World Wide Web (WWW) have fashioned new dimensions in global awareness and commerce (Leinbach & Brunn, 2001). Four distinguishing features separate these global exchanges from other economic transactions. First, the WWW has as its basis the production, presentation, and dissemination or trade of information, in particular, visual and symbolic messages for local, regional, and global consumers. Second, speed is the essential component of the exchanges or hyperlinks of information, such that the information generated can be accessed by anyone with a computer, an Internet connection, and appropriate technological skills and transmitted instantly to potentially everyone everywhere, regardless of time zone, residential location, age, gender, language, political persuasion, or economic status. Third, WWW hyperlinks or networks are international to the extent that traditional barriers to world trade, such as tariffs, distance, isolation, or core and periphery location, cease to be significant. Barriers to sending or

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receiving may be few or nonexistent. Fourth, state membership in this form of electronic commerce is extraregional and international to the extent that rich and poor, large and small, traditional and future-focused, democratic and tyrannical states participate in exporting and importing information. These issues have benefited from research and inquiry by social and policy scientists with interests in international trade, transboundary flows, electronic commerce, visualization, and spatial systems.

The major objective of our article is to describe, map, and analyze the spatial structures of the Web hyperlink connections among the world's states. This mapping of hyperlink trade or exchange is becoming an increasingly important component of global commerce and the dynamic world political map. Hyperlinks are connections between pages; that is, they tie the Web together. This enables users to traverse from one page to another simply by clicking on the hyperlink. Hyperlinks are socially designed information structures created by Web authors and can be thought of as a virtual citation.

Our central query is, Who is linked with whom and how much? For example, With what countries are Austria and Thailand linked? A secondary set of questions includes, What kinds of hyperlink patterns exist globally and among the world's major geographic regions, such as sub-Saharan Africa, Europe, and Southeast Asia? Are there any differences between and within major world regions, and, if so, are they similar to existing international trade networks, for example, between rich regions or between European powers and former colonial possessions in Africa and Asia? Also, what kinds of linkages have emerged since the end of the Cold War in countries in Eastern Europe and the former Soviet Union, states that now seek entry in an economically restructured world? The answers to these questions about state, regional, and international hyperlink flows, volumes, directions, and densities were unknown when we embarked on this exploratory research. A number of related studies that have analyzed the hyperlink structure of the Web are useful, including those studies by Bray (1996); Larson (1996); Pirolli, Pitkow, and Rao (1996); Marchiori (1997); Dodge (1998); Gibson, Kleinberg, and Raghavan (1998); Clever Project (1999); Albert, Jeong, and Barabási (1999); Shiode and Dodge (1999); and Broder et al. (2000). However, they have not employed a geographical basis, which is the focus of this article.

A HYPERLINKED WORLD

The hyperlinked world is unlike any other world connecting places. First and foremost, it is dependent on various types of information being produced and exchanged among places. The linkages connecting places generating and receiving the many kinds of information transmitted electronically are different from those engaged in the production, consumption, and exchange of raw

materials such as wheat and coal or those places producing and consuming manufactured products such as motor vehicles and computers.

A second major feature of the places linked by information technologies, such as the WWW, is the element of speed. The rapid and nearly instant dissemination of information diminishes the importance of place, and especially the place where it is produced. The language that information is produced in may also be a significant barrier; the dominant language of the Web is English, particularly for commercial information.[1] A third feature of the hyperlinked world is that it is a point-oriented world. That is, places or sites are more important than territory or area. Information is produced from points and sent by networks throughout a system or systems (Castells, 1996). A fourth distinguishing feature of the hyperlinked world that separates it from previous linked worlds is the emphasis on the visual, that is, the production, consumption, and exchange of symbols, photographs, images, maps, and graphics of all kinds. What is on the Web can potentially be seen by all viewers and users at any time and in any location. It is there to be saved, shared, and sent.

Technology, culture, economy, and politics are integrally involved in the hyperlinked world issues described above (Brunn, 1998; Brunn & Cottle, 1997; Brunn, Jones, & O'Lear, 1999). These ingredients were important previously in global commerce for agricultural products and energy sources, but now, they have some potentially new configurations. Exactly what these structures look like on a global scale is in many respects still unknown, and scholars are still grappling with how to measure, analyze, and map the structures. Despite interesting empirical research on the size and structure of the WWW, mainly from the computer science community, a number of questions remain unanswered. Among them are,

- Are the leading countries generating and receiving the most hyperlinks also the leaders in world trade? Are those with the poorest trade links also those with the fewest hyperlinks produced and received?
- How important are cultural ties in hyperlinked densities? Is regional proximity important, as in the case of Europe?
- Are the global economic powers also the leaders in hyperlinked connections? And what are the major linkages of emerging regional powers, such as Mexico in Central America and India in South Asia?
- What are the most and least connected states? Are those that have the most outgoing or export linkages also those that have the fewest incoming links?
- Do the maps of outgoing and incoming hyperlinked regions look the same?
- Do countries link primarily with other countries in their region, or is distance not a barrier to their connectivity?
- Are colonial and postcolonial trade patterns evident in hyperlinks? For example, are African countries still predominantly connected with Europe?
- What kinds of linkage patterns exist among formerly isolated regions, for example, the new states in Central Asia and those in former East Europe?
- What is the balance of outgoing and incoming hyperlinks among the world's states? In what regions are the imbalances the greatest?

- What are the relationships between the number of hyperlinks and development indices, for example, population size, per capita GNP, or percentage living in cities?
- What would a Hyperlink Index (similar to an Export/Import Index) reveal about global linkages?
- And, finally, how might we graphically illustrate the hyperlinked worlds? Can we use traditional choropleth maps showing state territories? Does a hyperlinked world have cores and peripheries? What kinds of technological and hyperlinked gaps persist?

LITERATURE REVIEW

A vast disciplinary and multidisciplinary literature that analyzes salient economic patterns and regional variations has emerged in the past several decades in the social sciences. Geographers, political scientists, economists, and sociologists have used a variety of different data sets and methodologies to classify countries using various income, demographic, employment, trade, transportation, political stability, and quality of life indicators (Brams, 1966; Ginsburg, 1961; Russett, 1967; Singer & Small, 1973). Some of these have been concerned with identifying global patterns, others with regionalizing economic development, and still others with mapping the distinguishing features in major world regions (Berry, 1961). These studies are valuable in that they set a precedent for looking at linkages and the volumes of interaction between and among places. In particular, those that consider movement, such as transportation and communication, and international trade are useful for our purposes (Barnett & Salisbury, 1996; Brunn & Leinbach, 1991; Kellerman, 1993; Louch, Hargittai, & Centeno, 1999; Nierop, 1994).

The foundations for our research on the spatial structures of the Internet and Web content come from research by Norris (1998a, 1998b, 1999a, 1999b) and others (Bray, 1996; Ciolek, 1998; Lawrence & Giles 1998, 1999; Organization for Economic Cooperation and Development [OECD], 1999c; Paltridge, 1999). These studies provide descriptive analyses of country data sets or specific components of the WWW pages of individual states. The aim of these studies is to analyze the content and structure of the Web, generally from the technical perspective of computer science and information retrieval and with the goal of improving the search and navigation of Web space. In terms of searching the Web, the use of hyperlink structures can aid in the identification of relevant information from keyword searches used in current search engines (Marchiori, 1997; Spertus, 1997). The Google search engine (http://www.google.com/), developed by researchers at Stanford University (Brin & Page, 1998), is a successful commercial application of hyperlink information as a factor in relevancy ranking of results. There is also research that tries to identify hub pages for a given topic, using hyperlinks structure (see Clever Project, 1999; Gibson et al.,

1998; Terveen & Hill, 1998). The concept of small world networks from the field of sociology (Collins & Chow, 1998; Kochen, 1989), popularized as "six degrees of separation," has recently been applied to Web hyperlink analysis (Adamic, n.d.; Albert et al., 1999; Broder et al., 2000). Researchers Albert, Jeong, and Barabási analyzed the graph properties of hyperlinks from Web samples, and their widely reported conclusions were that "despite its huge size, our results indicate that the Web is a highly connected graph with an average diameter of only 19 clicks" (Albert et al., 1999, p. 130). In the most comprehensive research to date on Web structure, Broder and colleagues analyzed a Web sample of 200 million pages and some 1.5 billion hyperlinks (derived from the AltaVista [http://www.altavista.com] search-engine index). Their overall result was described by the researchers as the "bow tie" theory of the Web, where the hyperlink structure of pages divides into four distinct components. The central knot of the Web bow tie is formed by a strongly connected core making up some 30% of pages, and 24% are classified as *origination pages*, which have hyperlinks into the core, but the core does not link back out to them. A further 24% are *destination pages*, which can be reached by hyperlinks from the core but do not themselves link back into the core. Finally, a significant 22% of pages were found to be completely disconnected from the core.

Also of relevance to our project is the work known as bibliometrics, using cocitation analysis, a field pioneered by researchers in the information and library science disciplines (Garfield, 1970; White & McCain, 1998). Results from bibliometric analysis have also been visualized using abstract maps (McCain, 1990; Small & Garfield, 1985).

DATA AND METHOD

Analysis of the diffusion, and one might say globalization, of the Internet has been an active area of quantitative research by several scholars (Batty & Barr, 1994; Elie, 1998; Hargittai, 1998, 1999; Paltridge, 1999; Petrazzini & Kibati, 1999; Press, 1997; Zook, 2001, this issue) and international organizations (International Telecommunication Union [ITU], 1998; OECD, 1999c). The empirical analysis of much of this work is based on five main classes of measures: connections, wired-ness (teledensities or PC penetration), hosts, bandwidth of network links, and domains.[2] Our research examines a new dimension of global linkages, that is, looking at hyperlinks between countries.

There is no centralized intergovernmental or international database providing the number of hyperlinks among the world's states. What data are available and useful come from private sources, predominantly the commercial Internet search engines. We found the AltaVista search engine to be particularly useful because it had the largest and most comprehensive index (see Lawrence & Giles, 1998) at the time that we conducted our study (December 1998).

Web hyperlinks are by their very nature directional. There are two directions: incoming and outgoing. And we also know from the data how many links exist between what pairs. We refer to these flows as Incoming Linkages or IL, that is, those received from other country domains, and Outgoing Linkages or OL, those sent to other country domains. These OL are created by the page author; they are visible to readers and are used actively in navigation. There can also be any number of IL for a site. These IL may or may not have been created by the author, and they are not visible. Moving up the scale to the level of Internet domains, let us illustrate the nature of IL and OL with an example between a simple pair of domains, France and the United Kingdom. France has 28,000-plus OL to the United Kingdom. From the United Kingdom's perspective, these are IL. In turn, the United Kingdom has almost 23,000 OL with France; these are IL to France. One might then argue that France's balance of hyperlink trade is unfavorable in that it has a greater proportion of hyperlinks to the United Kingdom, meaning French users are more likely to import content from the United Kingdom.

Because we were interested in who (what country) was connected with whom and how much, we inquired into the number of pairs (or hyperlinks) among all the geographic entries. That is, how many hyperlinks are there with Afghanistan and Austria or between Austria and Zambia? We were not interested in the content of those hyperlinks nor the quality and accuracy of information generated. Also, we chose not to consider if the site was private or official, poorly constructed or embellished, old or recent. We were only interested in incoming and outgoing hyperlinks and the number of pages generated. One must also be aware that the use of country domains varies, with users in certain nations preferring to register their Web content with a generic, top-level domain (particularly .com) rather than a local, country-specific code. This is noticeable for several domains, including .US (United States) and .CA (Canada) (OECD, 1999c). Also, the use of a country code domain to identify Web content does not necessarily mean that the content is produced and maintained by people within that territory; in particular, it does not mean those Web pages are actually stored on Internet servers geographically located within the countries. So Web location, as indicated by domain names, does not necessarily tally with geographic location. These caveats need to be born in mind and mean that results in this article are exploratory.

To gather a representative sample data set, the only viable publicly available source is a search engine. For example, OECD (1999c) used the HotBot search engine, Norris (1998a, 1998b, 1999a, 1999b) used Lycos and Infoseek, and Ciolek (1998) used AltaVista. We choose the AltaVista search engine. AltaVista data are provided for 180 domains, that is, 174 countries and 6 nongeographic domains; these are commercial, international, education, military, network, and organizational. Thus, we are dealing with a 180×180 matrix or 32,400 cells. Although no data appeared for many cells, especially small and poor states, for many other combinations, there were multiple linkages.[3] The closed data set

generated 76,735,152 hyperlinks among the 180 domains; the 6 nonstate or nongeographic domains accounted for 32.7 million, or 43%, of all IL and 46.6 million or 61%, of all OL. Although nongeographic domains represent very important components of the hyperlinked world, we eliminated them, as we wanted to focus only on country or territorial domains.[4]

RESULTS AND ANALYSIS

MOST AND LEAST STRONGLY LINKED REGIONS

The regions that generate the most OL and have the most IL are, not surprisingly, those with rich, urban, and industrial countries (Table 1). The 51 countries in Europe alone accounted for almost one half of all OL and 40% of all IL. Seven countries in East Asia, headed by Japan and the Republic of Korea, accounted for another quarter of the OL, but only 3.5% of all IL. The North American region (United States and Canada) contributed another 12% of the OL and 8% of IL. Of the 10 regions, 8 had more OL than IL; East Asia had nearly 5 times more OL than IL. In North America, the linkages were similar. The imbalances were especially significant for poor regions, in particular, South Asia and sub-Saharan Africa, where there were 20 and 10 times, respectively, more IL than OL. The imbalances were also substantial for Central America and the Caribbean, North Africa, and Southwest and Central Asia.

MOST AND LEAST STRONGLY LINKED COUNTRIES

We tabulated the hyperlinks *from* each domain/country *to* each other domain/country. Those with a large number of hyperlinks are well linked, either by OL or IL, or both. We consider the total links minus self, that is, not those internal links, for example, from United Kingdom domains to other United Kingdom domains. In general, there was a positive relationship between the number of IL and OL; the correlation was $r = .38$. Population was not a good predictor of the number of OL and IL for countries in the data set. The correlation between population size and OL was $r = .10$, and between population size and IL, $r = .14$. There was also a weak correlation between population size of a country and the number of pages, $r = .11$. The number of links a country had varied widely. Nine countries had more than 1 million, and another dozen had from a half million to 1 million linkages. There was a very uneven geographical distribution (Tables 2, 3, and 4).

The domains with the most IL hyperlinks, aside from Colombia, which we eliminated from analysis for reasons mentioned above, were Andorra (1.92 million), Poland (1.86 million), United States (1.76 million), United Kingdom (1.67 million), and Canada (1.6 million). At the other end of the spectrum were 12 countries with less than 20,000 IL. The lowest six were Guyana, Zambia,

TABLE 1: Total Outgoing and Incoming Links for Major World Regions

	Outgoing Links		*Incoming Links*	
Region (number of countries)	n	%	n	%
North America (2)	3,565,301	11.8	3,334,654	7.6
Europe (51)	14,637,523	48.6	18,051,852	41.0
Australasia and Pacific (15)	2,309,294	7.0	3,548,573	8.1
Central America and Caribbean (28)	308,890	1.0	2,901,546	6.6
South America (13)	1,021,285	3.4	5,877,916	13.3
North Africa, Southwest and Central Asia (20)	264,411	o.9	1,682,897	3.8
Sub-Saharan Africa (23)	333,985	1.1	3,632,086	8.3
South Asia (5)	25,982		1,167,242	2.6
Southeast Asia (10)	440,423	1.5	2,282,900	5.2
East Asia (7)	7,215,942	24.0	1,532,124	3.5
Total	30,123,036	100.0	44,021,790	100.0

TABLE 2: Total Links of Countries Minus Internal Links

Number of Links	*Number of Countries*
1.0 to 5 million	9
500,000 to 999,999	12
250,000 to 499,999	15
100,000 to 249,999	60
50,000 to 99,999	40
25,000 to 49,999	22
10,000 to 24,999	13
< 10,000	3
Total	174

Zimbabwe, Kazakhstan, Uzbekistan, and Yemen, with the last 3 having fewer than 10,000 IL each. Slovakia, the Republic of Korea, Bosnia, Mexico, and Thailand were ranked in the middle; each had about 12,000 IL. The top 5 countries had 20% of the total; the top 10, 32%; and the top 15, 40%. There was thus a much greater concentration of states exporting than importing information. Most of the leading OL states were wealthy and urban states. Some of the top IL states were very small in population (Australia and Cocos Islands) and poor (India and Niger).

In general, countries with more OL than IL are high income and have strong industrial economies. It is not surprising that wealthy and highly urbanized countries had more OL, as they already have strong international economies and are leaders in global trade. They also have invested resources to develop and

TABLE 3: Country Domains With Most Hyperlinks

Outgoing Hyperlinks (174 countries = 30,123,036)		*Incoming Hyperlinks (174 countries = 44,021,790)*	
Country	*Number*	*Country*	*Number*
Japan	5,104,154	Andorra	1,919,869
United Kingdom	2,983,292	Poland	1,869,879
Germany	2,518,701	United States	1,767,935
Australia	1,952,927	United Kingdom	1,670,401
Canada	1,821,720	Canada	1,576,710
United States	1,743,581	Germany	1,324,827
Sweden	1,315,997	Indonesia	1,004,691
Republic of Korea	1,054,273	Niger	1,004,691
Italy	854,793	Australia	928,573
France	777,094	Cocos Islands	842,440
Taiwan	725,694	France	820,250
Brazil	711,757	India	802,500
Netherlands	695,953	Ireland	749,635
Switzerland	589,825	Sweden	673,164
Finland	524,673	Netherlands	645,624

NOTE: These tables exclude commercial, organization, education, military, international, and network links.

TABLE 4: Country Domains With Fewest Hyperlinks

Outgoing Hyperlinks (174 countries = 30,123,036)		*Incoming Hyperlinks (174 countries = 44,021,790)*	
Country	*Number*	*Country*	*Number*
Djibouti	42	Yemen	6,131
Togo	44	Uzbekistan	7,806
Aruba	55	Kazakhstan	9,107
French Polynesia	78	Zimbabwe	10,169
Albania	82	Zambia	11,331
East Timor	85	Guyana	12,375
Congo	94	Tanzania	13,732
Seychelles	113	Mozambique	14,035
St. Kitts and Nevis	114	Kyrgystan	16,668
Nigeria	115	Uruguay	17,424
Suriname	117	Cambodia	18,672
Benin	136	Vietnam	18,945
Belize	165	Paraguay	21,547
Oman	165	Tajikistan	22,648
Northern Mariana Islands	173	Belize	23,083

NOTE: These tables exclude commercial, organization, education, military, international, and network links.

TABLE 5: Countries With Most Hyperlinked Pages (total for 174 country domains, 45,231,069)

Country	*Number*
Germany	5,760,926
Japan	4,291,142
United Kingdom	3,554,483
Canada	2,556,128
Sweden	2,237,539
Australia	2,095,633
United States	2,083,383
Italy	2,042,109
Finland	1,477,440
Netherlands	1,400,750

disseminate Web information and technologies. Developing countries tend to have more IL than OL because they do not have strong and long histories in global commerce, and they are newcomers in Web technological development and in producing and exporting Web-based knowledge.

We also calculated the size of the hyperlinks, that is, the number of Web pages. There is great unevenness in the number of pages generated by the 174 geographic domains (see Table 5). There was not always a strong positive relationship between the number of Web pages and OL or IL. The correlation between OL and the number of pages was high, $r = .92$, whereas the correlation between IL and number of pages was lower, $r = .43$. Although these relationships were positive, there were a number of country domains that produced more Web pages than one would expect, especially given their population size. The imbalances are especially apparent in a number of ministates, which are hosts for countries that do not have extensive facilities to develop Web pages or find it cheaper and legally easier to have the server located elsewhere.[5]

LINK/SIZE RATIOS

A useful indicator comparing a domain's number of hyperlinks and pages is the Link/Size Ratio or LSR. It is obtained by dividing the number of pages into the number of total hyperlinks. An LSR of 100 implies the numbers of links and pages are similar. A high LSR means there are many more links than pages, and a low LSR the reverse. For example, India has 16,620 IL and 802,500 pages for an LSR of 4828. The ratios for IL ranged from 387,043 for Nigeria and 300,805 for Niger, to 13.54 for Japan and 9.40 for the Republic of Korea. The highest ratios were for geographic domains with few pages. The lowest ratios were for the richest and most urbanized states in Europe and Asia, which produced many pages.

The rankings of LSR for OL were somewhat different. Most of the high ratios were for small island states as well as some countries in the developed world.

LEADING COUNTRIES IN MAJOR WORLD REGIONS

To obtain a global and regional perspective on hyperlink volumes and flows, we tabulated data on the leading countries in IL and OL in 10 major world regions. The countries within each region are familiar to regional geographers (De Blij & Muller, 1998; Lewis & Wigen, 1997) (Table 6). The pattern of OL is somewhat similar. The rankings sometimes shifted, as in the case of Europe, South America, sub-Saharan Africa, and Southeast Asia. The larger, richer, and more developed countries have the most OL.

CASE STUDY OF LINKAGES OF AFRICAN DOMAINS

To gain some insights into the linkage patterns of one continent, we selected nine African countries for detailed investigation. They were South Africa, Morocco, Côte d'Ivoire, Egypt, Kenya, Zimbabwe, Senegal, Zambia, and Ghana. There was great variation among these countries in the number of OL and IL and also in the number of countries that have hyperlinks. South Africa has almost 300,000 OL, whereas Kenya has about 10,000, Ghana 1,760, and Zambia 527. These nine countries had hyperlinks with 65 different country domains; they had OL with 53 and IL with 37 different geographic domains. Aside from the many linkages with Colombia (deleted for reasons explained in Note 3), most hyperlinks were with European states. South Africa was a leading link for five of these nine African states.

HYPERLINKS OF CENTRAL ASIAN STATES

What kinds of linkages exist for new states in an emerging political and economic region? We addressed this question by examining the five new Central Asia states of Kazakhstan, Kyrgystan, Tajikistan, Turkmenistan, and Uzbekistan. These countries were among those with the fewest IL. We also were interested in knowing whether these former Soviet republics retained their linkages with Russia following the end of the Cold War. Did they import information from Russia and export information to Russia? We learned that the largest number of OL from Kazakhstan, Kyrgystan, and Uzbekistan were with Russia. Indonesia is the leading link for Tajikistan, and Poland for Turkmenistan. The leading OL for these five states were a mix that includes several countries in Europe. In regard to IL, most OL are with Japan and Germany. Canada and the United States have very few linkages with these new states.

TABLE 6: Incoming and Outgoing Links, Leading Countries in Major World Regions

	First	*Second*	*Third*	*Fourth*
Incoming links				
North America	United States	Canada		
	1,767,935	1,576,719		
Europe	Poland	United Kingdom	Germany	Italy
	1,869,879	1,670,401	1,324,827	895,969
Australasia	Australia	Cocos Islands	Tonga	New Zealand
	928,793	842,490	779,241	160,507
South America	Colombia	Brazil	Argentina	Chile
	4,641,573	321,390	197,641	146,827
Central America and Caribbean	Puerto Rico	Panama	Antigua	Turks and Caicos
	275,487	242,888	179,047	165,344
North Africa/ Middle East	Niger	Israel	Morocco	South Africa
	1,004,691	254,596	221,966	195,752
Sub-Saharan Africa	Nigeria	São Tome	Seychelles	Côte d'Ivoire
	441,230	431,163	273,869	204,736
South Asia	India	Sri Lanka	Pakistan	Mauritius
	802,500	97,127	96,341	88,790
Southeast Asia	Indonesia	Papua New Guinea	Malaysia	Singapore
	1,136,287	272,038	247,694	213,786
East Asia	Japan	Macao	Mongolia	China
	581,029	219,528	171,421	155,312
Outgoing links				
North America	Canada	United States		
	1,821,720	1,743,581		
Europe	United Kingdom	Germany	Sweden	Italy
	2,983,282	2,518,701	1,315,997	836,793
Australasia	Australia	New Zealand	Tonga	Niue
	1,952,927	249,311	55,583	37,977
Central America and Caribbean	Mexico	Costa Rica	Nicaragua	Dominican Republic
	219,950	51,005	6,334	4,807
South America	Brazil	Argentina	Colombia	Peru
	711,757	118,841	44,337	29,824
North Africa/ Middle East	Israel	Lebanon	Morocco	Egypt
	225,436	8,632	6,280	3,788
Sub-Saharan Africa	South Africa	Kenya	Côte d'Ivoire	Zimbabwe
	299,018	10,665	6,539	5,567
South Asia	India	Pakistan	Mauritius	Sri Lanka
	11,584	6,539	3,903	3,744
Southeast Asia	Singapore	Malaysia	Thailand	Indonesia
	222,527	84,444	54,073	50,259
East Asia	Japan	Republic of Korea	Taiwan	Hong Kong
	5,104,154	1,054,273	725,694	176,015

In summary, Central Asian states are more closely linked with Europe than with Asia. Most OL are with Russia, Poland, and Germany. In regard to incoming links, Japan is the leader for Kazakhstan, Kyrgystan, and Tajikistan; France, for Turkmenistan; and Germany, for Uzbekistan. Other European countries, especially Russia and Poland, are among the leaders for those IL. Aside from Japan, the Republic of Korea, China, Indonesia, and to a lesser extent India are among the Asian states linking closely with these new states. Australia is far down on the list in importance.

TOTAL LINKAGES OF COUNTRY DOMAINS

In the data set, 53 states had OL to all 174 country domains. These were the richer and more urbanized European states, as well as the United States, Canada, and Australia. Brazil, Argentina, Malaysia, Singapore, Thailand, Taiwan, Japan, New Zealand, South Africa, Israel, and Mexico also had OL to all others. By contrast, 10 countries had 20 or fewer hyperlinks to other countries. Those with the fewest OL were Martinique (19), Nepal (18), Togo (15), and Northern Mariana Islands (4). Ecuador, Moldova, Turkmenistan, and Zimbabwe are examples of domains with median values. A ranking of the 174 countries on the basis of the total number of IL reveals a similar pattern but less variation. That is, more states export than import information.

RELATIONSHIPS BETWEEN COUNTRIES LINKED AND NUMBER OF HYPERLINKS

We were interested in discerning the relationship between the number of countries linked to and the total number of OL in the world regions mentioned above. A positive relationship would suggest that the larger the number of hyperlinks, the more countries to which a country would have connections. The Web connectivity scattergrams yielded mixed results. For all 174 country domains, $r = .508$. In some regions, for example, sub-Saharan Africa, Latin America, and Oceania, there was no apparent relationship (see Figure 1). In North Africa and Southwest and Central Asia, the relationship was positive, whereas in East and South Asia, there were too few observations to provide any meaningful results.

MAPPING A HYPERLINKED WORLD

We first calculated the total number of OL to other geographic domains. We divided the 174 domains into four categories, patterned after the core, semiperiphery, and periphery labels used by Wallerstein (1979) and Taylor (1993) in their analyses of world systems. The first group of 59 domains, labeled core, had 170 or more linkages. The second group, including 36 domains, was labeled

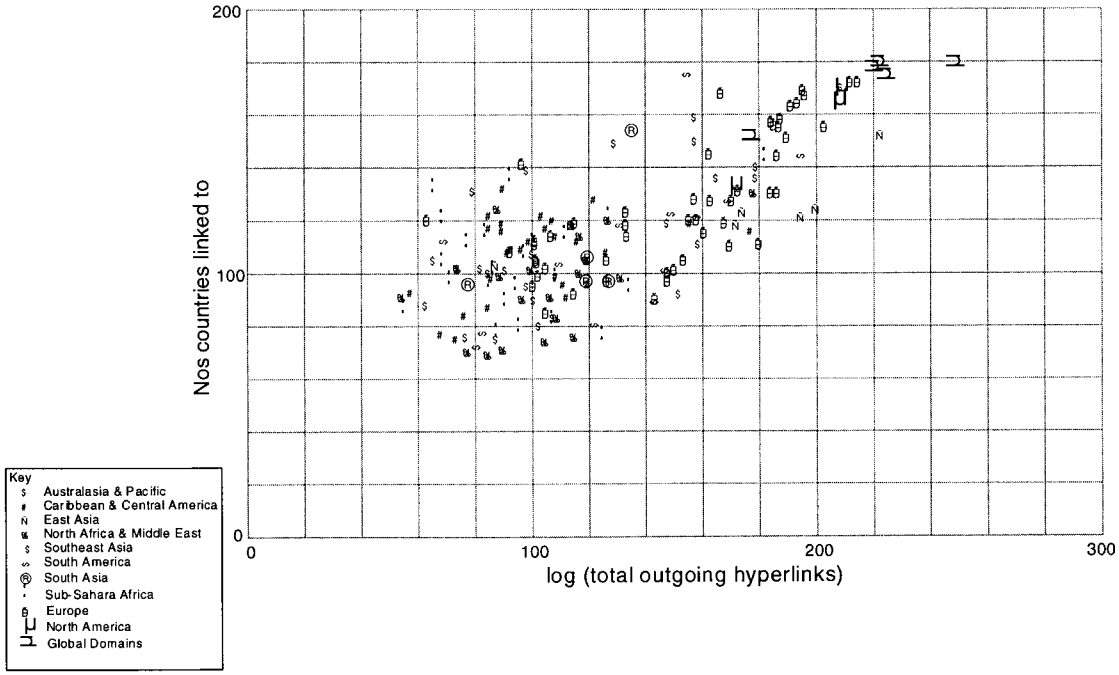

Figure 1: Scattergram of Number of Countries Linked to Against Total Outgoing Links
NOTE: Nations are classified into ten regions.

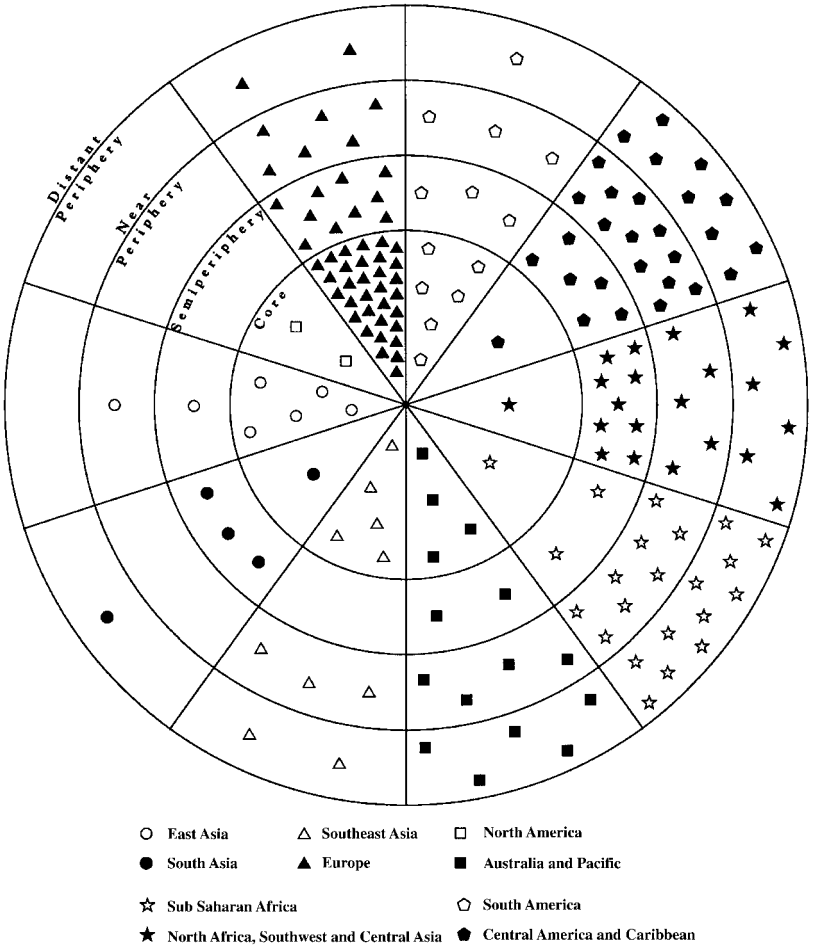

Figure 2: Concentric Map of Hyperlink Linkages of World Domains

semiperiphery; the third, with 42 domains, near periphery; and the final group, with 37 domains, distant periphery. The map in Figure 2 illustrates clearly the uneven geographical distribution of hyperlinks.

A HYPERLINK INDEX

We developed a Hyperlink Index (HI), patterned after the Export-Import Index used by economic geographers and economists, to measure the balance in

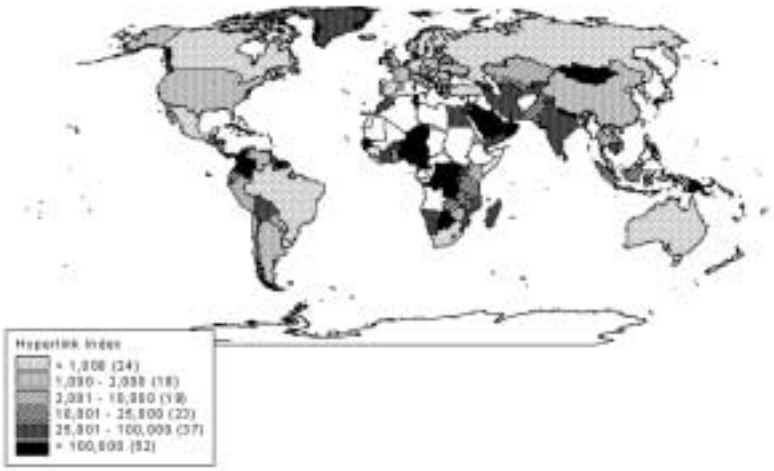

Figure 3: Map of Hyperlink Index for 174 Countries

international hyperlink traffic. The HI for each country was calculated as follows:

$$\text{HI} = \frac{\text{Number of Outgoing Links}}{\text{Number of Incoming Links}} \times 1{,}000.$$

A large HI would mean there were many more OL (exports) than IL (imports). A small HI would mean the numbers of OL and IL were almost equal. In many regions, there were wide variations in the HI, not surprising considering the imbalances between OL and IL cited above. Such variations suggest that regional medians or means would have little meaning. The indexes for those with the very highest HI were so large as to be virtually meaningless in any global analysis, except to note the wide imbalances that exist. More meaningful results are provided for Europe, North America, East and South Asia, and Australia and New Zealand (see Table 7).

A choropleth world map showing the HIs for states and domains is similar to the concentric circle map above (see Figure 3). Of the 43 countries with an HI less than 2,000, 24 are in Europe. Not unexpectedly, Canada and the United States also have low values, as do Japan, the Republic of Korea, China, Australia, New Zealand, Mexico, Brazil, Venezuela, Singapore, and Israel. At the other end of the spectrum are some of the poorest states, in sub-Saharan Africa, Central Asia, the Caribbean, and Pacific Basin. Small isolated and island states tend to have the highest HIs.

TABLE 7: Examples of Countries With Low, Middle, and High Hyperlink Indexes (HI)

Low		*Middle*		*High*	
Japan	(114)	Thailand	(2,135)	Guatemala	(12,049)
Russia	(353)	Estonia	(3,087)	Jamaica	(12,989)
Brazil	(427)	Kazakhstan	(3,356)	Pakistan	(14,8733)
South Africa	(446)	Peru	(3,658)	Ecuador	(16,982)
Australia	(520)	Lebanon	(4,273)	Vietnam	(17,114)
Germany	(526)	Paraguay	(4,663)	Ghana	(19,469)
Hungary	(822)	Poland	(4,828)	Indonesia	(22,608)
Singapore	(959)	Iceland	(5,002)	Sri Lanka	(25,942)
United Sates	(1,014)	Slovenia	(5,148)	Jordan	(26,143)
China	(1,017)	Ireland	(6,947)	Dominican Republic	(33,154)
Switzerland	(1,019)	Bulgaria	(9,211)	Morocco	(35,345)
Israel	(1,129)	Nicaragua	(10,202)	India	(69,276)

NOTE: A low Hyperlink Index means more export (outgoing) links than importing (incoming) links. A high Hyperlink Index implies the reverse.

CORRELATIONS BETWEEN HYPERLINK INDEX AND GNP PER CAPITA AND PERCENTAGE URBAN POPULATION

We wanted to observe if there was any relationship between the HI for the world's states and GNP per capita and the percentage living in urban areas. We hypothesized that there would be an inverse relationship, that is, a low correlation between HI for the rich and urban states. The correlation between HI and GNP per capita was $r = -.16$ and that between HI and percentage urban was $r = -.235$. These correlations, although not completely unexpected considering the bimodal nature of the HI for 174 countries, supported our hypothesis: that the lower an HI, the more balanced or even the numbers of OL and IL.

SUMMARY AND CONCLUSIONS

Using data derived from the AltaVista search engine, an exploratory analysis of Web hyperlink volume and flows discovered much unevenness in the 77 million hyperlinks among the 6 nonstate domains and 174 country domains. The six nongeographic domains account for 60% of the global hyperlink connections, especially the .com domain. The remaining 40% (geographic domains) are dominated by wealthy states in Europe, the United States, Canada, and Japan. Of the top 15 states in IL 8 are in Europe, the same number as the leaders in OL. There is a greater concentration of hyperlinked trade that is exported among the world's states. The top 5 country domains in OL account for 47% of all information exports, the top 5 domains in IL, for only 20% of all imports. The unevenness is further illustrated by the other end of the spectrum. One hundred fifty-five states accounted for only 23% of all OL, but those same states had 60% of all IL. States and most regions are heavier importers of pages than exporters.

The main hyperlink trade tends to be concentrated in a few states, and especially in the most economically developed regions.

Our analyses reveal that most of the trade is among wealthy states in rich regions. There also are tremendous imbalances between OL and IL among the geographic domains. There are many more strong exporting than importing countries. The OL tend to be the rich and urban states in Europe and North America, plus Japan and Australia, but also some cyber-information islands in the Caribbean and Pacific Ocean. The fewest OL are from poor states in sub-Saharan Africa and the Caribbean. The least-linked parts of the world are the Pacific Islands, sub-Saharan Africa, Central Asia, and the poorer states of South America. The hyperlinked world is not quite akin to the colonial linkages or global trade in raw materials or finished products, but it is similar in that it is dominated by Europe and other wealthy Europeanized parts of the world, such as the United States, Canada, and Australia. An HI, which we suggest is similar to the Export/Import Balance of Trade measure, revealed gross imbalances between hyperlink exports and imports, especially between European states, which tended to have similar OL and IL, and poorer states in Africa, Europe, and Asia, where the imbalances were substantial.

We suggest five projects that are worthy of further study. The first is to examine the flows between those major world regions we have described. Are these information flows similar to world trade in raw materials and finished products? Or does the ease in transmitting information among and between regions mean that distance is not a barrier to the transactions? Second, although the volume of hyperlinks will increase during the next two decades, will the imbalances in flows change with the diffusion of Web technology, more Web users, and more use of Web resources? Third, how did the hyperlink map we prepared come to be the way it is? What countries and regions were linked first? Were they the most wealthy and urbanized in Europe and North America, or were they small island states, such as Tonga, Seychelles, Macao, and Anguilla? What are the attributes of those states with the fewest hyperlinks, for example, those in Central Asia? What are the inside or outside forces that contribute to the paucity of linkages? Fourth, what are the dominant categories of hyperlinked information? That is, what is sent from Country X to others globally or in its world region and what is received? If we consider major information categories such as tourism, finance, sports, politics, and current events, where is this information sent and received in greatest volume? Fifth, and finally, it would be worth studying the history behind major countries or global hyperlink islands that have an extraordinary number of export messages, for example, Tonga, Cayman Islands, Cocos Islands, and Niger. How were these set up and by whom, and what are the major categories of information sent and received? We note that these islands can be both senders and receivers. Answers to these and other intriguing questions that arise from our research suggest that social, policy, and behavioral scientists from different disciplines and countries will find much to discover and explore in the fascinating hyperlinked worlds of the present and future. These investigations

will be enriched further by scholars coming from multiple traditions using different paradigms and traditions.

NOTES

1. An Organization for Economic Cooperation and Development (OECD) survey in May 1999 revealed that 78 percent of Web content was written in English (OECD, 1999b). See Paltridge, 1999, and Hargittai, 1999, for discussion of the importance of the English language on the Web.

2. The first measure is simply whether a country possesses a connection to the Internet. The best known examples of this measure are the international connectivity maps created by Larry Landweber (ftp://ftp.cs.wisc.edu/connectivity_table/). In the 1980s and early 1990s, this measure was useful, but now, virtually all countries have some degree of Internet connectivity. Internet access in many developing countries often remains only available for the wealthy, usually located in the principal cities. The second measure, wired-ness, usually refers to teledensities (telephone lines per capita) or PC penetration at the national level. This type of measure is widely produced in high-profile reports by the OECD (1999c) and the International Telecommunication Union (ITU) (1998).

Measurements of hosts per capita as a third metric have also been used. A host is a computer connected to the Internet. In many ways, this is a more technically refined version of the wired-ness measure. Probably the best known geographic application of the hosts-per-capita measure is the basic analysis and maps produced by the Internet consultancy, Matrix Internet and Directory Services, Inc. (http://www.mids.org/). Measurements of potential Internet bandwidth capacity and prices between countries and cities have also been used (Cukier, 1999; OECD, 1999a; Townsend, 2001, this issue). Bandwidth is used as a proxy for traffic flows, as data flows are virtually impossible to obtain for the Internet in a representative form. Finally, domain names have been used as a metric in the analysis of Internet globalizations (Zook, 2001). A domain name is a globally unique identifier for a company or organization on the Internet.

3. A simple program was written to submit queries to AltaVista and gather the reports on the number of matching Web pages. Not all states are represented on the Web or covered by the AltaVista search engine. North Korea, Eritria, Bhutan, Laos, Somalia, Sudan, Iraq, Libya, Rwanda, Burundi, Central African Republic, Haiti, St. Vincent, Grenada, St. Helena, Ascension, Tristan da Cunha, and Nauru are missing, as are the Falklands/Malvinas, Pitcairn, Kiribati, Seychelles, Maldives, British Virgin Islands, Reunion, and the French Southern Antarctic Territory. But data are provided for East Timor, Niue, Brunei, Faroe Islands, Greenland, Anguilla, St. Kitts, and Nevis. Taiwan is included, but there are no entries for Nunavit, Palestine/Gaza Strip, and Tibet.

Initially, 245 separate queries, one for each domain, were submitted to AltaVista on December 18, 1998, to determine the number of Web pages in the index for these domains. The resulting page counts ranged from 0 (for 22 domains) to more than 48 million for the .com domain. From the 245 domains, 180 were selected, which had more than 100 pages. Queries were then submitted to AltaVista to gather counts on the number of links among the 180 domains.

To obtain a complete matrix of links from all domains to every other domain required 32,400 separate queries, which ran for 2 days, December 19 to 20, 1998. The resulting counts were stored as a 180×180 matrix in a spreadsheet, from which a variety of descriptive statistics and summary tables were created.

A particularly serious caveat should be raised concerning the reliability of the data in terms of incoming links. This is because in the selection of the destination domain in the queries, AltaVista does not always return correct and consistent results. In certain cases, AltaVista returns spurious matches for the destination domain; for example, for Colombia, whose domain is .co, AltaVista will also return some matches from .com, .co.uk, co.kr (the commercial domains for the United Kingdom and the Republic of Korea, respectively). This problem was identified for certain domains that

exhibited an unusually high number of incoming links in relation to the total number of pages for that domain. There is no way to circumvent this problem with AltaVista, but we do not feel that this problem invalidates the general patterns revealed in the results presented. Issues of reliability of the number of matches search engines return have been raised by other researchers (e.g., Notess, 2000), but at the moment, there is no viable alternative data source.

4. Also, we eliminated from the analysis the data for Colombia, whose domain address, .co, is undoubtedly widely used by companies and corporations; also, data were inconsistently reported by queries to AltaVista. The Colombia (.co) entry for Incoming Linkages (IL) was 4.6 million, which exceeded that of any country. That total was surpassed only by Network.net (13.3 million) and Commercial.com (10.7 million for IL). We, thus, have no accurate value for the total IL for this South American country. By contrast, the Colombia Outgoing Linkages (OL) total was 44,387, not markedly different from that of Chile (55,000) and Peru (nearly 30,000). Flaws in using data from AltaVista and other search engines have been noted by Norris (1998a, 1998b, 1999a, 1999b). He noted that whether because of whimsical reasons (friendly Web page developers) or data-entry errors, inaccuracies occur. Also, search engines are far from complete in their indexing of the Web, and the problems appear to be getting worse (Lawrence & Giles, 1998, 1999). Many domain-name operators, especially for small English-speaking island states such as Niue, Tonga, Anguilla, and Cayman Islands, are companies outside the countries themselves, primarily in the United States and Britain. Who operates the domains for all different countries is provided in a useful Web site developed by the ITU: http://www.itu.int/net/cctlds/.

5. For example, Andorra, the number one domain in IL, has 1.9 million IL, but only 2,793 pages. For Niger, there are 1 million IL but only 334 pages; for Cocos Islands, 842,000 IL and 6,241 pages; and for India, 803,000 IL and 17,000 pages. It should be noted that some of the discrepancies between the number of pages and large IL are undoubtedly due to data problems with AltaVista.

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