Networks of European cities in worlds of global economic and environmental change

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Brunn, Stanley D., Lomme Devriendt, Andrew Boulton, Ben Derudder & Frank Witlox (2010). Networks of European cities in worlds of global economic and environmental change. *Fennia* 188: 1, pp. 37–49. Helsinki. ISSN 0015-0010.

Geographers use a variety of economic, social, and demographic data to measure the importance of global cities and the linkages between cities. We analyze the importance and connectedness of European cities using hyperlinks, or the electronic information provided by the Google Search engine. Hyperlinks are Web sites representing information that is produced; they are especially useful in measuring the impact of contemporary crises. We use the phrases economic slowdown and global financial crisis to derive a Global Financial Score (GFS) for 16 core, semiperiphery and peripheral European cities and global warming and climate change to derive a Global Environmental Score (GES). London and Paris are in the European core; Rome, Dublin, Madrid and Prague are in the semiperiphery; while Tallinn, Riga, and Belgrade are in the periphery. A strong positive relationship exists between the GES and GFS. We examine the linkages of the 16 cities to the 100 largest world cities and illustrate, with "clockgrams," the linkages London, Brussels and Athens have with other world cities. We calculated the number of linkages each of the 16 cities had with other world cities to identify Europe's urban cores, semiperipheries, peripheries, and deep peripheries. New York is in the core of both the economic and environmental maps. Some world cities are in the semiperiphery of one category and periphery of another. Milan, Istanbul, and Delhi are in the deep periphery for the GFS while Toronto and Athens are for the GES. Hyperlinks represent valuable databases to measure the impact of crises and regional and global urban linkages.

Keywords: Europe, world cities, urban networks, cyberspace, core-periphery relations, environmental change, financial crises, Google Search Engine, hyperlinks.

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Introduction

Study of the financial and environmental crises

"Global" and "world" are popular descriptors used by observers and analysts examining the dramatic financial and environmental changes occurring during the past year. Countless stories, reports, and editorials looked at the causes and consequences of these changes and how they affected the daily lives of cities, governments, residents, and businesses in large and small cities alike (see http://widerimage.reuters.com/timesofcrisis). Reports reflected on the widespread and pervasive impacts of the global economic recession and environmental catastrophes in major world cities (Kluger 2006). Headline items conveyed the sharp

URN:NBN:fi:tsv-oa2524

decline in New York, Tokyo and London stock markets, but also in many national and regional exchanges in South America, South and Southeast Asia, the Middle East and southern Africa (e.g. New York Times, 10 October 2008). Rising unemployment, declines in house sales and rising housing foreclosures, government bailout attempts, bank failures and acute professional and non-professional job losses were regular news items (ILO News 2008). At the same time, environmental scientists and government ministries were alerting their governments and citizens to continued temperature increases and rising sea levels, the shrinking of glaciers and ice fields in circumpolar areas, expanded desertification in semiarid areas, and anomalous weather patterns in many world regions (Torn & Harte 2006; Scheffer et al. 2006). On the world financial and environmental maps, few cities were spared unpleasant and gloomy reports about their economic status or environmental condition (Glantz 2006).

Scholars in various disciplines who are interested in the current state of economic and environmental affairs on global and national scales should be in the forefront of analyzing the impacts of aforementioned conditions. Geographers, economists, and political scientists should be among those social scientists examining these conditions, but also those in climatology, hydrology, and natural disasters (Amelung et al. 2007; Grimm et al. 2008; Fidrmuc & Korhonen 2009; Florida 2009).

A world cities perspective on the crises

A particularly useful perspective is gained by examining these current problems and changes in highly populated places. The world's largest cities would seem to provide a good starting point as most are connected with other cities both within their regions and at extraregional and global scales. Also since much headline news, data, and government decisions are city-based, it makes sense to consider the places where the intensity and magnitude of the problems are most manifest and visible. Thus we examine both the major cities themselves as major places of, and players in the economic and environmental crises, and how these cities are linked to one another. The unfolding of the global economic crisis or economic slowdown that began in 2007 and peaked around September 2008 was not centered on only one or two global population, financial, or government centers, but it became worldwide almost simultaneously. While New York, London and Tokyo seemed to generate the most press and news, banks and stock exchanges in South Asia, Latin America, Russia, and the Middle East were soon included in the spiralling economic recession or collapse. The networks of national and regional banks to creditors and lenders demonstrated the porosity of national borders and the globalization of financial markets. Also, the financial institutions demonstrated linkages that were both transnational and transregional.

Environmental scientists and ministries at the same time were also seeking solutions to acute problems that went beyond national boundaries. Global environmental changes, including the short term consequences of global warming, biodiversity loss and desertification required a different mindset than a compartmentalized domestic or national solution. International scientific cooperation and treaties were necessary to correct both impending crises and long term problems. In short, financial and environmental challenges faced rich industrialized countries or coastal megacities, but also small developing countries and developing world cities faced short term precarious environmental problems/crises in their agricultural, industrial or tourist economies.

An urban and knowledge basis to understanding current crises

We focus on major world cities and the amount, and content of Web information generated about their economic and environmental crises (see also Devriendt et al. 2009). Cities are an appropriate scale of inquiry because these are places where more than half of the world's population lives. These are also the places which directly or indirectly are and will be most heavily impacted by declining markets, job losses, housing foreclosures, bank failures, plant closures, unemployment increases, downturns in the construction industry and declines in public services (Hall 1966; Taylor 2004; Alderson & Beckfield 2007). Cities' economic problems cannot be addressed in isolation given the complex and various connections between cities throughout the world.

We can view the cities affected by environmental crises in a similar manner; seldom are environmental challenges confined to the territorial boundaries of one state. Problems of water short-

age or water quality, increasingly frequent coastal storms, rising sea levels inundating tourist beaches and hotels, and dependency on foreign fossil fuels, face cities and entire regions throughout the world. Large and small cities in hazard prone regions are affected both by unexpected short term environmental events and the unforeseen impacts of projected climate change.

A useful barometer to examine both the geography of economic and environmental crises is the content and distribution of Web information. Information is a core ingredient in a knowledge economy and society (Kellerman 2002). Identifying problems and resolving them may be considered primarily political and financial, but at their base we need to consider the information generated, reported, and analyzed. We can use a number of components to measure the impact of a knowledge economy. These could include employment in banking, financial, health, education, and communications (print and visual) as well as investments in information and communications technologies, science and technology, education, real estate, and financial institutions (Pred 1980; Kellerman 2002). Employment data on these and related categories can be obtained from government and industry reports and media reports about economic transactions and environmental events (Beaverstock et al. 2000).

While newspapers or government and industry reports are valuable information sources, we also have access to *unprecedented* volumes of relevant "crises" information via the Worldwide Web (WWW). The Web can be characterized as a vast informational archive; it represents a vast, valuable, and easily accessible information source for monitoring changes in urban economics. We also believe that the Web provides a very useful lens on the impacts of the current economic and environmental conditions in major world cities.

Below we present an empirical analysis of current economic and environmental changes based on the volume of Web information for major European cities. We use the Google, Yahoo, Bing, and AltaVista search engines which index billions of Web pages—numbers that increase by continuously creating, for all intents and purposes, seemingly inexhaustible databases. These electronic databases are both vast and timely, two characteristics which make critical and judicious analyses of their content an exciting and rich source of insights into the *impact of economic and environmental crises* on *global urban networks*. We use the volumes of hyperlink information provided by these search engines to derive real-time informational rankings of major European cities in regards to the global financial crisis, and global climate change. The Google database has been used previously to examine urban linkages by Brunn (2003), Williams and Brunn (2004), and Devriendt et al. (2008). We follow their procedure to not only identify the importance of these two crises in individual cities, but in measuring the amount or degree of paired linkages between cities (see also Devriendt et al. 2009; Boulton et al. 2010).[1]

Using google hyperlinks to measure the impact of the global economic and environmental changes at european cities in the global urban system

We discuss sixteen major European cities through a quantitative analysis of their individual topical cyberspaces (that is, the amount of Web information available about each city in relation to global environmental and economic crises), and the linkages between cities (that is, the volume of joint references to each city in relation to environmental and economic topics). We consider these sixteen to be representative of the variety of urban experiences within Europe. Some are major world cities, such as London, Paris and Rome; others are major regional centers in different regions such as Madrid in Iberia, Helsinki in Norden, Rotterdam in northwest Europe, Prague in eastern Europe, and Belgrade in the southeast. We also selected some from Europe's core, another set from the continent's semiperiphery and the final set in Europe's periphery. The cities are:

- **Core**: London, Paris, Rotterdam, Brussels, and Milan
- **Semiperiphery**: Dublin, Madrid, Helsinki, Prague, Vienna, and Rome
- **Periphery**: Lisbon, Athens, Belgrade, Tallinn, and Riga.

We specifically identified cities in each of Europe's core, semiperiphery, and periphery to observe whether there were any salient differences in the volume of information about the economic and environmental crises and if there were any significant or systematic differences in terms of linkages.

To obtain a reading of the relatives impacts of environmental and economic crises in each city,

we first recorded the absolute numbers of search results or hyperlinks for each of the European cities in combination with the two most frequently used keyword search terms describing the global financial crisis ('economic slowdown' and 'global financial crisis'). For example, "Rotterdam, Netherlands + economic slowdown" and "Rotterdam, Netherlands + global financial crisis". Similarly, to obtain data to measure the impact of environmental problems, we recorded the number of hits on 'global warming' and 'climate change' categories. For example, searching for the number of (Google) Web pages that jointly mention "Paris" and "global financial crisis" resulted in 283,000 entries.[2] Given that the correlation between the two financial and the two environmental search terms is high on the Web, we examined the two individual categories of the economic data and derived a Global Financial Score or GFS, which is the average of the two data entries for each city. We use the same procedure to derive a Global Environmental Score or GES.

The second part of our analysis looked at the relationships between each of the aforementioned sixteen cities to the world's largest 100 cities in terms of population (Demographia 2008). By combining two cities with one information term, we assembled four 16 x 100 city matrices on GFS and GES topics. Searching, for example, for the number of (Google) web pages that jointly mention "London", "Sydney", and GFS topics resulted in an average of 119,705 entries. As one would expect, the city results exhibited some variations. We look at the top ten links, or paired linkages, for each of the sixteen European cities. Again we would anticipate that there would be differences both in the volume, the ranking, and the location of London's (versus Prague's or Riga's) most linked cities in terms of economic and environmental information.

With these datasets in hand – that is, the hyperlink volume for each city and the hyperlink volume of the pairs of cities – we addressed several questions in this empirical analysis which we discuss below. We provide an analysis of the data and present a set of graphics to represent our findings visually. First, we have a look at the variations in the Global Economic Measures and Global Environmental Measures in Europe's core, semiperiphery, and periphery to discern whether there is a relationship between the Global Financial Scores and Global Environmental Scores for these sixteen European cities. Secondly, we look at their links to other world cities and in what parts of the world. Thirdly, are there any consistent patterns in the linkages of Europe's cities between cities in Europe's core, semiperiphery, and periphery? And finally, are there any discernible differences in the linkages of Europe's cities in regards to the economic crisis and the environmental crisis data? To aid in understanding these relationships, we constructed some "maps" of Europe's position vis-à-vis the world's current economic crisis and current environmental crisis.

Empirical analysis

This analysis builds on and differs from earlier hyperlink-based publications (Brunn 2003; Devriendt et al. 2008) in that we limit the number of "unwanted"/irrelevant search results per city. In previous urban studies based purely on hyperlink/Web page volume, some ambiguities in data searches emerged. For example, quantifying the hyperlinks of "Paris" provides, in addition to "relevant" Web pages, substantial numbers of Web pages (blogs, "news" sites, forums, etc.) referencing celebrity Paris Hilton instead of the city "Paris". Our mining of the Google database relates to cities with information on specific topics. This procedure minimizes, but does not remove entirely, the "Paris Hilton effect". Adding the words "climate change" to "Paris" eradicates the ambiguity as to which Paris we are referring and thus removes (many) Hilton-related results. Thus, our rankings are based on their relationship with Global Economic Measures and Global Environmental Measures (Tables 1 and 2).

The volume of the *Global Financial Crisis* hyperlinks ranged from 662,000 for London, 283,000 for Paris, 144,000 for Vienna and 125,000 for Brussels to only 11,000 for Tallinn and 10,400 for Riga (Table 1). Rome and Madrid had between 89,000 and 100,000 and five other cities (Milan, Prague, Athens, Dublin, and Lisbon) had between 40,000-59,000. Belgrade, Helsinki, Tallinn, Rotterdam, and Riga had from 10,000-25,000. The numbers for the *Economic Slowdown* category also exhibited wide variance, from 710,000 for London to only 5220 for Riga. Paris and Brussels were the second and third leading cities in hyperlinks for this phrase, but they had only 137,000 and 109,000 respectively. Dublin was fourth, but it had only 71,000 followed by Rome, Madrid, and Vienna between 38,000-41,000. Four cities

Table 1. Global Economic Measures

Rank	City	Economic Slowdown	Global Financial Crisis	GFS
1	London	710000	662000	686000
2	Paris	137000	283000	210000
3	Brussels	109000	125000	117000
4	Vienna	38200	144000	91100
5	Madrid	39500	91600	65550
6	Rome	41700	89000	65350
7	Dublin	71100	41500	56300
8	Milan	38100	58500	48300
9	Prague	23800	53200	38500
10	Athens	23500	49700	36600
11	Lisbon	24900	40300	32600
12	Helsinki	15600	18700	17150
13	Belgrade	6810	25100	15955
14	Rotterdam	9250	11100	10175
15	Tallinn	5550	11200	8375
16	Riga	5220	10400	7810

(Source: Google.com, 29 July 2009)

Table 2. Global Environmental Measures

Rank	City	Climate Change	Global Warming	GES
1	Paris	13000000	3490000	8245000
2	London	9600000	5570000	7585000
3	Brussels	2130000	1050000	1590000
4	Rome	1550000	1450000	1500000
5	Vienna	1020000	793000	906500
6	Lisbon	1320000	370000	845000
7	Madrid	854000	799000	826500
8	Athens	694000	658000	676000
9	Dublin	609000	402000	505500
10	Prague	557000	423000	490000
11	Milan	423000	425000	424000
12	Rotterdam	478000	187000	332500
13	Helsinki	405000	181000	293000
14	Belgrade	122000	80100	101050
15	Tallinn	64500	64200	64350
16	Riga	77000	48100	62550

(Source: Google.com, 29 July 2009)

(Lisbon, Prague, Athens, and Helsinki) had between 15,000-24,000 hyperlinks. Belgrade, Rotterdam, Tallinn, and Riga were the lowest. In general these rankings were similar for cities in both categories. There were some discrepancies between the numbers and those in the three regions. London, Paris, and Brussels were considered core cities; all had large numbers of hyperlinks. Rotterdam and Milan, also in the core, did not. Cities we considered in Europe's periphery had the fewest hyperlinks.

The rankings for the sixteen cities were not that dissimilar when we looked at the number of hyperlinks on the two Environmental Measures (Table 2). In regards to *Climate Change* the top four cities were Paris with 13 million, London 9.6 million, Brussels 2.1 million and Rome 1.5 million. Lisbon and Vienna also had slightly more than 1 million each. Madrid, Dublin, Prague, Athens, and Milan had more than one-half million each. The fewest hyperlinks were in descending order: Belgrade with 122,000 followed by Riga and Tallinn at 77,000 and 65,000 each. There were fewer *Global Warming* hyperlinks for each city, but the ranks remained almost the same. London had the most with 5.5 million followed by Paris 3.5 and then Rome 1.4 and Brussels 1 million. Madrid and Vienna had about 700,000 each. Dublin, Prague, Milan, and Athens were in the middle. The bottom five were Rotterdam, Helsinki, Belgrade, Tallinn and Riga. Using this phrase the results were fairly similar to the core, semiperiphery, and periphery categories we established for the three sets of European cities.

Looking at the relationship between the Global Financial Scores (based on both financial search terms) and Global Environmental Scores (based on both environmental search terms) for Europe's cities, we observe that there is a strong positive relationship between the two scores: $r = 0.82$; $R^2 = 0.67$ (see Fig. 1). Not surprisingly, from what was stated above, London and Paris were the highest on both scores and Riga and Tallinn were the lowest. There was some consistency in the clustering of these cities in Europe's cores, semiperipheries, and peripheries. Rotterdam was the one of the exceptions; its place on the scattergram was distinctly different from other core cities. Athens and Lisbon on the other hand were more similar to other semiperiphery cities than the periphery city we classified them. The semiperiphery city category classified most of these cities correctly.

When we examine the economic and environmental linkages between the 16 European cities

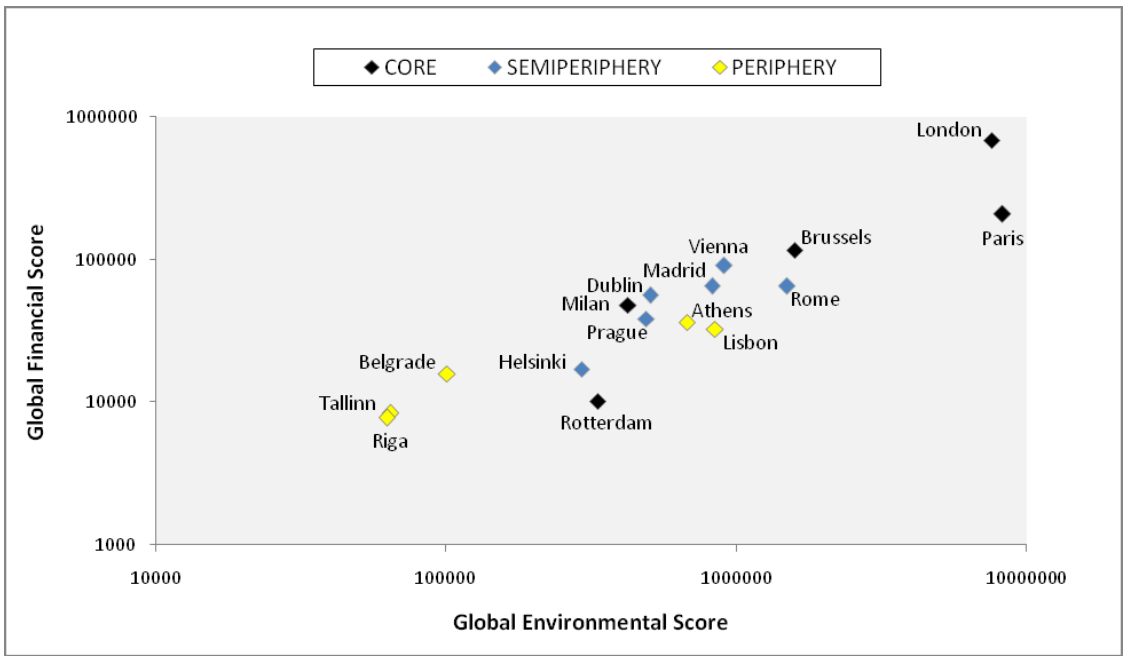

Fig. 1. Relationship between GES and GFS

and other cities we discover the extent of their international and transnational dimensions. As noted above, for each of the sixteen, we will look at their top ten links to other world cities. We would anticipate that some of the sixteen would be linked with large European cities, some with North American cities and some with cities in Asia and elsewhere. What we did not know in advance in this empirical analysis was what patterns we would uncover.

In our examination of the *Global Financial Scores* for our sixteen European cities, we discover that their top ten connections are accounted for by a total of 35 world cities. All are connected to New York, which is not surprising considering the U.S. and especially Wall Street Stock Exchange were identified early as major actors/contributors to the global economic slowdown and financial crises. New York was the most linked city to London, Rome, Vienna, and Milan – all major knowledge and industrial cities – but also Dublin, Prague, and Athens, and the second most linked city for Brussels, Paris, Rotterdam, Tallinn, Helsinki and Belgrade. London had the most links with Paris, Rotterdam, Brussels, Belgrade, Helsinki and Tallinn. What were noteworthy in these rankings were the strong ties with Asian (especially Chinese) cities as well as Singapore and also Moscow. Singapore was the third most linked city with Milan and Rotterdam, the fourth most linked with Paris, and fifth most linked with Madrid. Beijing was the second most linked city with Dublin, the third for Brussels, and the fourth for Rome. The Chinese capital's rankings were ahead of Hong Kong (fourth for Dublin and fifth for Paris) and Tokyo (ranked second for Milan). Moscow, like Singapore and Beijing, was linked to many European cities, perhaps not surprising considering its close proximity to some of our selected cities in Eastern Europe. It was the third most ranked city with Tallinn, fourth with Brussels, Belgrade, and Prague, and fifth with Athens, Helsinki, and Riga. Berlin also emerged as a major city with links to other European cities. It was the third most linked city with Paris, the fourth with Athens, and the fifth with Brussels, Tallinn and Belgrade.

There were also some unexpected and unusual linkages that defy easy explanation; these include Teheran as Athens's third most linked city, Delhi as Milan's fourth, Sydney as London's second, Cairo

as Vienna's second, Teheran as Rotterdam's fifth. When we consider the sixth through tenth rankings for our sixteen European cities, we also have some new cities, some with only links to only one or two cities. Examples include Atlanta (with London), Shanghai (with Dublin), Seoul (with Brussels), Baghdad and Mumbai (with Paris), Karachi (with Rome), Shanghai (with Rotterdam), Delhi (with Helsinki and Lisbon), Phoenix (with Riga), Mumbai (with Rome), and Miami (with Lisbon).

Another perspective on these variations illustrates the vast differences in the volumes of hyperlinks between pairs of cities. For example, there are more linkages between London and New York (217,000) than between London and other nine cities it is most connected (Prague, Lisbon, Vienna, Dublin, Belfast, Helsinki, Tallinn, Rotterdam, and Riga). This discrepancy illustrates the importance of these two north Atlantic anchor cities, London and New York, in the world's financial markets. The London-New York linkages exceed those of London-Paris. Brussels links with London (70,000) exceed those of Vienna with New York and Madrid with Mumbai being most linked to Madrid. Athens in our calculations had more links with Teheran than with Berlin or Moscow and Milan had more with Tokyo than with Paris or Brussels. Helsinki's links were with a variety of cities, including London, New York, Paris, Delhi, and Moscow.

The top ten linkages in terms of *Global Environmental Scores* for our sixteen cities are with 34 world cities. All are linked to New York. But New York was not the most linked for all cities; it was the leader for London, Paris, Rome, Dublin, and Madrid, and, but not for Rotterdam, Helsinki, and Tallinn, all with more links to London. Brussels was most linked to Paris. There were also some unexpected patterns, including Prague and Sydney, Belgrade and Houston, Athens and Istanbul, Lisbon with Hong Kong, and Vienna with Moscow. The pattern of second most linked cities exhibited nearly as much variety as the leading cities. Again, some unexplained patterns emerged: Berlin was second for Vienna and Riga; New York for Brussels, Prague, Helsinki, and Lisbon; Chicago for Rome and Dublin; and Paris for Rotterdam and Tallinn. Other rather surprising linkages were Athens and Mexico City, Milan with Bangkok, and Madrid with Istanbul. In regards to the variation in hyperlink pairs, there are vast differences. There are more linkages between London and New York (4.1 million) than for all of the ten most linked cities to Dublin, Helsinki, Rotterdam, Belgrade, Tallinn, and Riga combined. Another way of looking at the London-New York volume is that it exceeds all of the cities most linked to Rome. The Brussels-Paris links (685,000) exceed the London-Houston (650,000) links; Athens-Istanbul (421,000) is more than Madrid–New York (436,000), Rome-Los Angeles (402,000) and Vienna-New York (487,000). Helsinki is most linked to London, New York, and Paris (each from 100,000-130,000 links) followed by Moscow, Berlin, Chicago, Tokyo, Boston, Washington, and Beijing (each above 60,000 links).

To illustrate the linkages that European cities have with other world cities in regards to the current economic and environmental crises, we developed a series of innovative so-called "clockgrams." Each illustrates both the volume and name of each of the ten most linked cities on the GES (see Figs 2a, 3a, 4a) and GSF (see Figs 2b, 3b, 4b). We illustrate these variations with two cities in Europe's core, London and Brussels, and one in the semiperiphery, Athens.

One reads each graphic by starting at the top, that is, twelve o'clock. By going clockwise one can identify the ten leading cities with which that city is connected and also the volume of hyperlinks (web pages jointly mentioning the two cities in relation to financial topics). When comparing the three GES graphics, it is easy to identify London as having the most total hyperlinks; Brussels has only about one-quarter of London's total and Athens has only about one-tenth. The top ten linkages also exhibit some variation. London's linkages are global: New York, Sydney, Moscow, Hong Kong, and São Paulo. Five of London's top ten linkages are with U. S. cities. Brussels on the other hand has many more linkages with Asia: Beijing, Hong Kong, Istanbul, Singapore, Seoul, and Tokyo. New York is its only North American linkage. Noteworthy also are the ties with Moscow. Athens, a much smaller city, and much less important on the European and global economic scene, illustrates an expansive network not that dissimilar from New York. Its top ten linkages include some in East Asia (Tokyo and Hong Kong), South Asia (Mumbai), Southeast Asia (Singapore), Middle East (Teheran), Australia (Sydney), and Russia (Moscow). Its only major European link is with Berlin.

The clockgrams for the Global Environmental Scores also exhibit some distinct variations. London has far and away more linkages than Brussels and Athens combined. In regards to the global warming and climate change variables, London

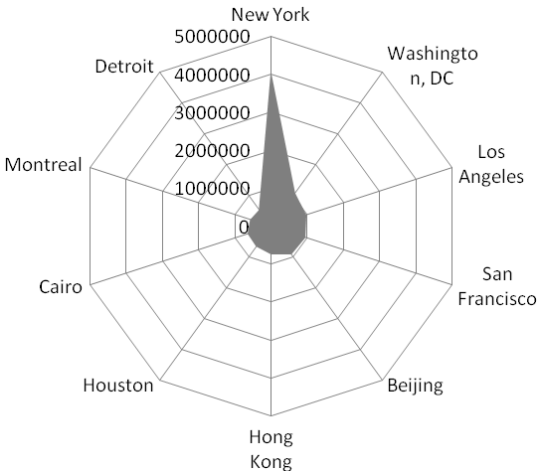

Fig. 2a. GES clockgram London

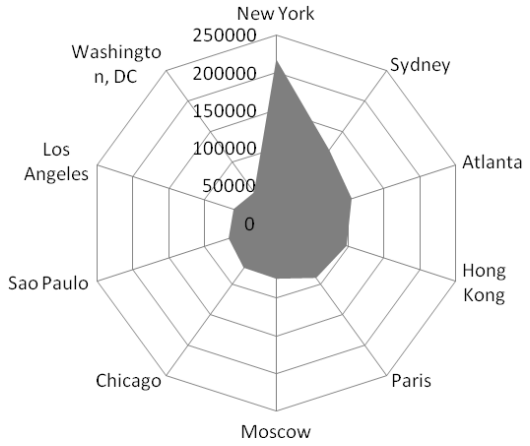

Fig. 2b. GFS clockgram London

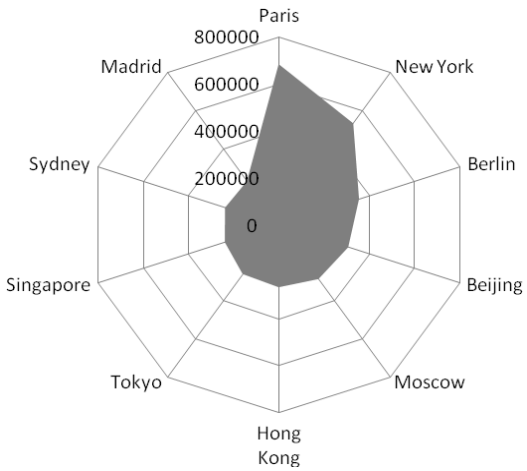

Fig. 3a. GES clockgram Brussels

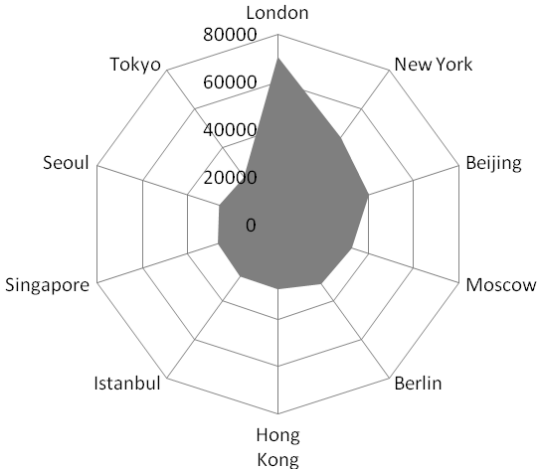

Fig. 3b. GFS clockgram Brussels

has a huge volume of linkages especially with one city, New York. This linkage dwarfs all other linkages combined. The other cities on this city's list of top ten links are mostly a cross section of cities in the U.S. (four), Asia (two), and Middle East (one); none in Europe. Brussels has linkages, as it did with the economic graphics shown above, with major cities outside Europe; these include cities in Europe (Berlin and Madrid), Asia (Beijing, Hong Kong, Tokyo and Singapore), Russia (Moscow), Australia (Sydney), and one in the U.S. (New York). Athens, like Brussels, also exhibits an international mix, but is dominated by a half dozen cities in the Middle East (Istanbul), Latin America (Mexico), U.

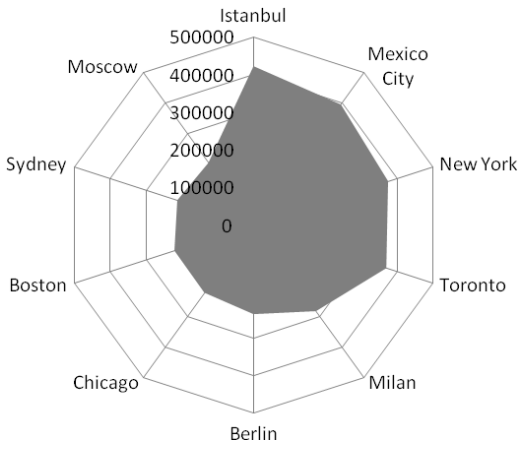

Fig. 4a. GES clockgram Athens

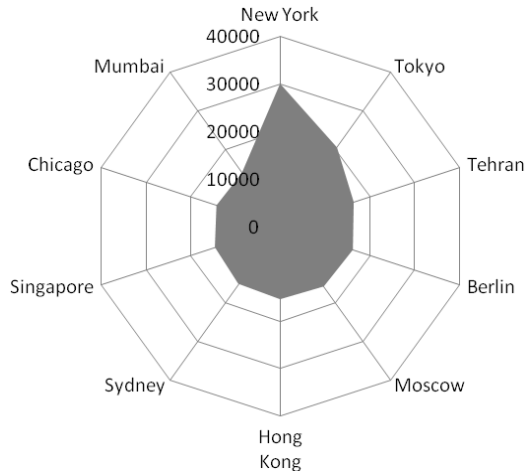

Fig. 4b. GFS clockgram Athens

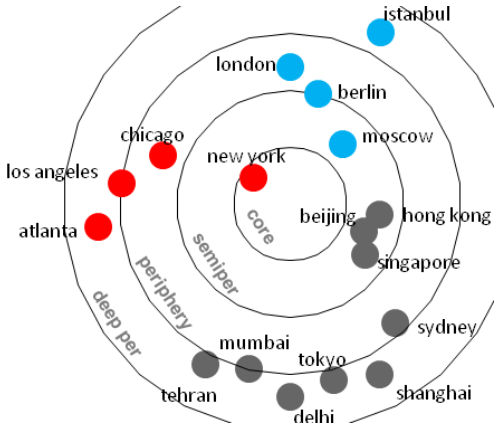

Fig. 5. Global Financial cores, semi peripheries, peripheries, and deep peripheries

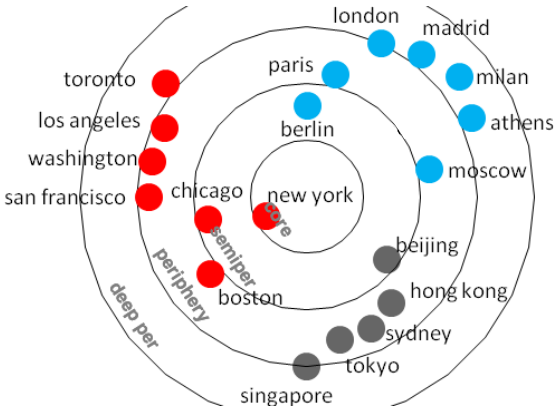

Fig. 6. Global Environmental cores, semi peripheries, peripheries, and deep peripheries

S. (New York), Canada (Toronto), and Europe (Milan and Berlin). Moscow and Sydney are also included in this city's mix.

We next wanted to observe if there are any distinct patterns in the cities listed most frequently in regards to the economic and environmental crises. The central query was whether there were core, semiperiphery and periphery cities that might be easily identified. We totaled the number of times a given city appeared in the top ten lists of all sixteen cities. The highest possible score was 16, which would represent a core city, that is, a city that was ranked in the top ten for each of the sixteen cities. The lowest score would be one, which would mean it was important for only one of the sixteen cities. The two diagrams we constructed are Fig. 5 for the Global Financial Score and Fig. 6 for the Global Environmental Score. On each we identify and map these knowledge regions: *core*, *semiperiphery*, *periphery*, and *deep periphery*.

In regards to the *Global Financial Score*, New York was clearly identified as the *core*. No other city was ranked by all European cities, thus this global metropolis becomes the core or center for an understanding of the linkages these cities have to the global financial crises. In the second region are cities mentioned 12–13 times: three of the four cities are in Asia: Beijing, Hong Kong, and Singapore. Moscow is also in the second or *semiperiphery* category. In the *periphery* region are five cities with 5–9 linkages; two of these are in Europe (Berlin and London) and two in North America (Los Angeles and Chicago); the remaining city is Sydney. In the *deep periphery* category are seven cities mentioned only 3–4 times. These are mostly cities in Asia: Istanbul, Shanghai, Mumbai, Teheran, and Delhi; Atlanta is the non-Asian city in this mix. Seventeen other cities had linkages with one or two of the sixteen cities; these are also deep periphery cities. Examples of single linkages were Brussels with Seoul, Lisbon with Montreal, Phoenix with Riga, and Vienna with Cairo.

We also identified the same four regions for the *Global Environmental Score*. New York is the sole *core* city appearing somewhere in the rankings of all sixteen cities, hence it is our knowledge core. The second zone, or *semiperiphery*, has three cities: Berlin, Chicago, and Beijing, three major cities in three different economic world regions. The *periphery* category includes six cities, also in different regions; Hong Kong and Tokyo in Asia, Boston in the U.S., Paris in Europe, Moscow in Russia and Sydney in Australia. The outer ring, the *deep periphery*, includes nine cities mentioned 3–4 times. Most (four) are in Europe and three in North America. There were 15 other cities that had a single or two linkages with the sixteen. Examples of single linkages were Paris with Miami, Milan with Osaka, Prague with São Paulo, and Rome with Rio de Janeiro.

Discussion

From our analysis, we identify five major findings. First, the current economic and environmental worlds, as measured in information or knowledge contexts, are very complex. That is, there are no easily discernible or predictable patterns characterizing the linkages between cities. Beneath the volume of information/knowledge linkages for any individual city, or within any given pair of cities, captured in terms of search engine data there are many complex interactions between businesses (financial, advertising, ICTs, real estate, etc.), industries (heavy and light), services (tourism, health care, environmental, and education) and NGOs. From our "one day time slice" of data looking at the linkages of the world's 100 largest cities, the financial worlds and environmental networks are shown to be complex indeed. While one might have expected that New York, London, Paris, and Tokyo would lead the way in being linked with major cities in Europe, this generalization has not been shown to be the case. Rather Beijing, Berlin, Sydney, Moscow, and even Mumbai, Cairo, and Istanbul enter the picture as being linked prominently to one or more of the sixteen European cities we investigated. Tokyo, surprisingly, is eclipsed in this analysis by Beijing.

Second, explaining the results or attempting to provide some authoritative insight into the significance of these results is problematic. Whereas New York and London are leaders in terms of linkages in measuring the financial slowdown and crises, Beijing, Moscow, Chicago, Sydney and Singapore also enter the picture. This complex picture also emerges when looking at cities most linked in regards to information generated about environmental problems, including climate change. In short, it is not simply the case that the world's largest cities are those most linked with the sixteen European cities. Rather, large regional cities in South, Southeast, and East Asia emerge as important, as do large cities in the Middle East and Latin America. What we do not know based on this analysis of European cities are the kinds of specific economic and environmental information generated about each city, or the complex business, governmental, and other linkages underpinning these "information" connections (we examined these relationships previous for selected world cities in Devriendt et al. (2009)). Perhaps these European cities are leaders in the linkages related to service and industrial economies, or to distributions of investments by national and regional banks and other financial institutions. Further, it is possible that the volume of linkages is related to diaspora populations investing in major cities, these cities having strong and active tourism economies, or vibrant "Sister City" relationships between pairs of cities.

A third major finding is that there is a strong and positive relationship between the GFS and GES. While this relationship might be a surprise, on reflection it makes some sense that the many cities

reporting economic problems and financial crises would likely be the same ones where their governments, industrial and service economies, research universities and think tanks would be concerned about the impacts of global warming and climate change. Many of the European coastal cities examined here facing potentially serious environmental problems, including rising sea levels, and dependency on imported fossil fuels are the same ones facing financial problems of one sort or another. Environmental and economic problems are information-based and most of those reports from any country would emanate from, and relate to, the largest cities and the capital cities.

A fourth major finding from our analysis is that the traditional consideration of core-semiperiphery-periphery categories for European cities does not appear to make much sense in a knowledge/information world where distance is no barrier to communication of economic transactions. That it does not make sense should also not be surprising as the economic recession or depression gripped the continent's large, medium and small cities, regardless of location. To be sure the largest cities had the most information/knowledge hyperlinks about the economic and environmental categories, but some other large cities had fewer than expected, for example, Rotterdam and Vienna. The smaller cities, not unexpectedly, had fewer information hyperlinks in part probably because of their population size; this would be the case for Riga, Tallinn, and Belgrade. In short, the small number of hyperlinks simply meant there was less information generated.

The fifth pattern is that a different kind of core-periphery pattern emerges from these results, and it is a pattern that has some unexpected surprises. New York becomes the knowledge/information core around which European cities revolve. That New York is at the center is not that surprising, but what is surprising are the next leading cities which are most linked to European cities. Beijing, Berlin, Moscow, Singapore, and Hong Kong are leaders rather than London and Paris. This finding illustrates that the global economic and environmental linkages of many European cities are indeed trans-European, that is, they are in large, important, and emerging financial and decision making centers in South, Southeast and East Asia. The multitude of major city linkages, even for those ranked, third through tenth, is also a global pattern, not one of highly concentrated linkages amongst European cities. This may be one of the most important and interesting findings of this research.

Following the above interpretations, the point about the diversity of economic and environmental linkages for these cities needs to be amplified. Some of the linkages are surprising as they do not seem to follow any obvious logic. One example is that European cities link with others in Europe but also with former colonies. Another example is that Beijing emerges as a stronger and more dominant linkage of European cities than Tokyo. This finding may reflect the dynamic growth of China's aggressive production and trading climate while the rest of the world was experiencing a slowdown. London comes across as a more important European lynchpin than does Paris. That Moscow is strongly linked with Riga, Tallinn, and Helsinki should come as no surprise, since it is closer to these cities than to large central and west European cities. What is interesting is that these three northern European cities have stronger linkages with London and New York than with Moscow. And there are some unexplained linkages that emerge, for example, Milan and Barcelona with Prague in the financial sphere, Mumbai with Madrid also on financial crises, and Bangkok with Milan, also on financial issues. In regards to the environmental crises, there are also some puzzling results, for example, Istanbul linked most with Cairo (perhaps not unexpected if one considers they are two major players in the Middle East information production), Mexico City linked with Athens, and São Paulo linked with Prague. What is noteworthy in our analysis is that the only Latin American cities that ranked in the top ten with the sixteen European cities were Mexico City, São Paulo, and Rio de Janeiro. No major city in Sub Saharan Africa linked as among the top ten linkages with any European city in our study.

Conclusions and future studies

This study represents a first attempt to provide a detailed description and analysis of the linkages of European and world cities in regards to current web information generated about economic and environmental crises. Our reading is based on the volume of electronic information pieces, viz., search engine results, based on the linkages of sixteen European cities with the world's one hundred largest cities. Specifically, we looked at the volume of information linkages between cities with respect to two economic crisis related keyword

phrases: "global financial crisis" and "economic slowdown". We also examined two categories of information about the state of the world's environment: "global warming" and "climate change". We calculated the number of Google search results for each of the four phrases in conjunction with our sixteen cities into combined Global Financial Score (GFS) and Global Environmental Score (GES). Our sample deliberately included cities in Europe's core as well as semiperiphery and periphery.

The results revealed a much more complex pattern of relationships regarding knowledge generated than what we anticipated. The linkages of these cities seem to follow little regularity with respect to city size or city location, that is, location within Europe's core, semiperiphery and periphery, or with their most linked cities. New York emerges as the dominant city that most European cities are linked; London and Paris are not always in the top five and neither is Tokyo. The global linkages place Berlin, Beijing, Hong Kong and also Sydney, Singapore, and Moscow as strongly linked with Europe's cities in regards to the economic and environmental crises. We also discovered that there was a strong and positive relationship between the GFS for the cities and the GES. Since both scores are information-based, it is not unreasonable to assume in knowledge economies that cities that generate the most news about economic crises would also generate much information about their environmental conditions.

The findings reported and the approach we adopt offer many additional opportunities for investigation into the current economic and environmental crises where information generated or produced is the framework for linkages in a global network of cities. We would identify four studies that are worthy of investigation. First, how similar would be the results if we investigated the information hyperlinks for sixteen or twenty cities in another region, such as South Asia or East Asia or Latin America? Would there be as many or more global linkages? What city or cities would dominate? Second, what would be the results of a hyperlink analysis that looked at information generated for European or other cities in Chinese or Spanish or French? Third, what are the specific crisis categories of the linkages between these cities? One could examine the content or subject matter of the top ten search result items for each pair. Are they about real estate investments, business closures, bank collapses, unemployment, quality of life, or anomalous weather? Fourth, and last, it would be useful to investigate the linkages with smaller populated centers in Europe and elsewhere. Would these cities have more national and regional ties than the largest ones or would they also be linked globally to places in Asia and North America? The results to these and other research questions regarding knowledge economies and societies await further study by economic and urban geographers, and others, interested in the spatial *and* temporal patterns of the current economic and environmental crises. Both human and environmental geographers have much to contribute to our understanding of the regional and global worlds of crisis facing urban humankind.

ACKNOWLEDGEMENTS

All authors contributed equally to the research and writing of this article and take responsibility for any errors or omissions. The research work is funded by the Research Foundation–Flanders.

NOTES

[1] One shortcoming of previous hyperlink analyses is that there is not any critical reflection or discussion on the merits of using search engine data. While there are clear advantages to using the Google Search Engine – especially size (over one trillion unique URLs trawled), and timeliness (the index is continuously updated by its distributed network of "spiders") – some cautions should be noted. For example, when searching via Google.com (the US/international version of Google), the spelling of search terms and city names in English limits our analysis to the English language Web. This and other "problems" regarding these methods are discussed, and how these are addressed in the subsequent analysis, in Devriendt et al. (2009).

[2] This real-time information analysis was run on 29 July 2009. As the Google database is updated on a continuous basis and second by second, as spiders trawl for new, updated and defunct content. We utilize, in order to obtain real "snapshot" data, a script that ran our queries and extracted search results synchronously (see Devriendt et al. 2009).

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