Mapping ‘small things’ on the Web: Assessing the online presence of the nanotechnology industry*

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Paper prepared for the Annual Conference of the International Communication Association, San Francisco, May 24-28, 2007

Abstract

This paper uses a new approach to collection and analysis of data from the World Wide Web (WWW) to examine the online networks being built by the nanotechnology industry, the academia and other producers. In particular, we investigate the extent to which the nanotech sector as a whole is engaging with the wider social/public debate over the issue. This is a question of considerable significance, given the furore that greeted biotechnology companies’ introduction of ‘GM’ foods, and their apparent failure to anticipate the public backlash over perceived risks to human and environmental health. We approach the question in two stages: (1) we examine the hyperlinks of the major nanotechnology companies’ in terms of their social and technical orientation ; based on the structure of their inbound and outbound links, we map their position in the wider nanotechnology debate; (2) we examine the contents of the homepages of the online nanotechnology network identified in stage 1 to study more closely how nanotechnology issues are being presented and specifically the ‘space’ being given to its social implications. The results reveal that while certain segments of the scientific community may have accepted the case for more engagement with social aspects of nanotech, commercial developers as yet have not done so.

* We would like to thank Bruce Bimber from the Center for Nanotechnology in Society at the University of California, Santa Barbara, for helpful discussions and encouragement.

1. Introduction

A question asked with increasing frequency by academics, policymakers and industrial experts is whether nanotechnology will prove to be the "next GM". (Keller, 2007; Macoubrie, 2006; Waldron et al, 2006). Is this yet another new technology heralded for its potentially enormous economic and social gains that is then flatly rejected by consumers fearful of possible health and environmental effects? As to date, nanotech has largely remained a latent public issue with relatively limited media coverage and low levels of public knowledge and concern. Nonetheless, previous problems with respect to a range of technological developments has led to a greater rhetorical acknowledgement for the need for openness and transparency amongst policymakers and some scientists. Indeed, more commitment has been given to "upstream" public engagement over developments within the nanotech science (Wilsdon and Willis, 2004; Macnaghten et al, 2005). However, there are still concerns that this is not being matched out in practice by the nanotech industry.

In this paper, we seek to assess the extent to which the nanotech industry and its key proponents and developers are united and actively pursuing the drive toward public engagement. We do so using data from the World Wide Web (WWW) that focuses on the web linkages formed by the key investors and developers of nanotech within the business, corporate and academic spheres as well as the nature of the messages that are being transmitted from their home pages. Our goal is to describe how well the scientific and particularly business-oriented side of the nano-industry are engaging with the mission of engaging with the public and the wider social dimensions of nanotechnology explicitly via their home pages, and implicitly via their linking preferences. If they are not doing so, are there any advocates of the social side of the debate and how wide is the distance between them? In short, whilst the online world is only a partial representation of "real world activity", hyperlink analysis provides a rich source of data which yields a more complete picture of global nanotech industry networks, to highlight the prominence of certain organizations and networks, and to identify prominent discourses among an array of (possibly) diverse stakeholders.

This research is significant not only because it gauges the extent to which the nanotechnology industry actually practices what it preaches (at least in the online environment), but it also offers some preliminary insights into where the government may need to take a firmer hand in ensuring proponents are singing from the same hymn sheet. Nanotechnology, as Keller (2007) has noted, is not an area of research and development that is best suited to a tight regulatory regime. The very loose definition of the subject and broad range of disciplines it encompasses (including physics, materials science, mechanical and electrical engineering, genetics, cell biology) means that a more flexible, staged and iterative approach is probably the most appropriate way to proceed. However, such an approach as Keller (2007) notes arguably means that "a main task for those introducing new technology is building public trust the in safety of the technologies and the integrity of those introducing it" (5). Part of the process of ensuring that task is monitoring the communications of the key players in the debate – the task of this research.

2. Reaching Out: The Nanotech Industry, Government and the Public

So far it is "early days" in nanotechnology's development as a public issue. Consumer products featuring nanotecheither in name and/or content are only just beginning to being marketed in Europe; public awareness of nanotechnology is extremely low (Macoubrie, 2006; Cobb and Macoubrie, 2004; Scheufele and Lewenstein, 2005; Waldron et al, 2006; Dowling, 2004).[1] There

[1] Earlier work by Bainbridge (2002) had indicated higher levels of knowledge among respondents to a series of nanotech-related questions. However, the survey instrument, Survey2001 was a web-based survey run through National Geographics' website using self-selected respondents worldwide, and has been subsequently questioned in regard to how representative results are of the general publics of these nations (Waldron et al., 2006).

are signs, however, that the emergent issue cycle has some parallels to that of the 'GM' debate, namely that the public are forming views on the risks and benefits of nanotechnology in a range of areas including health and environment, despite professing very little knowledge (Macoubrie, 2006; Cobb and Macoubrie, 2004; Kearns et al, 2006). The common cognitive shortcuts used by individuals in forming these opinions include general orientations to science and technology, specific experiences with previous technological 'breakthroughs' and overall levels of trust and confidence in government to manage risks (Lee et al., 2005; Siegrist et al, 2007; Macoubrie, 2006; Cobb and Macoubrie, 2004). These factors imply a potential for instability and possible sudden change in the public's views, or lack thereof, on nanotechnologies. Mass media representations of emerging technologies are also relevant (Scheufele and Lewenstein, 2005).While coverage of the topic has been generally positive thus far (Anderson et al, 2006; Stephens, 2005), as the 'Frankenfoods' headlines that greeted the launch of GM crops in Europe attest to, such supportive headlines cannot necessarily be relied upon. Research showing a linking of genetic and biotechnology issues to wider ideological debates and international events in news reportage suggests public opinion (Hansen, 2006; Cook et al, 2004).

Given this starting point, tone may expect that government, science and business would be "doing things differently" in the nanotech realm, placing more emphasis on engaging with the public and talking about the social, ethical and environmental aspects of this new technology right from the start. The importance of early public engagement has been seen as crucial for a variety of reasons. Initially, public engagement was justified rather narrowly on the grounds of educating the public (the so called 'deficit model') so that they might become more accepting of the risks. The utility of the deficit model with its narrow focus on risk, however, has been subject to growing criticism and a rationale for engagement connected with wider objective of building trust between science, government and the public set forward.

Certainly there are signs that the scientific community, academic researchers and national and international government bodies are approaching the issue with an understanding of the public-as-key-stakeholder. Worldwide research and development (R&D) into nanotechnology has risen rapidly in recent years. Government organizations alone are reported to have increased their investment more than six-fold from $430 million to $3 billion across the period 1997 and 2003 with 35 nations having established a national nanotechnology initiative across this time frame (Roco, 2003). Under the European Commission's 7th Framework Funding Programme launched in 2007, a special stream for Science in Society was established in which nanotechnology figures prominently. In the US substantial funding for large-scale research into societal aspects of nanotechnology has been made available under the US National Nanotechnology Initiative (NNI) set aside a total of approximately $80 million to research with educational and societal implications and nanoscale research with relevance to the environment. From the start, the NNI 'considered societal implications…an integral part of the process.' (Roco, 2003: 185)). In 2006 one of the largest grant awards in social science for the establishment of Centers of Nanotechnology in Society at the University of California, Santa Barbara and Arizona State University, with the Centre's stated mission "to serve as a national research and education center, a network hub among researchers and educators concerned with nanotechnologies' societal impacts, and a resource base for studying these impacts in the US and abroad."(http://www.cns.ucsb.edu/about-cns-ucsb/). In the UK arguably there has been even greater rhetorical commitment around upstream public engagement that can be found in a variety of reports and documents including that issued by the Royal Society and Royal Academy of Engineering (Dowling, 2004). This stronger commitment, as Macnaghten et al (2005) argue, stems in part from the UK's particular historical context and the series of controversies that have emerged in recent years over GMOs and issues of food production, such as the BSE, crisis and the foot and mouth outbreak which contributed to public suspicion of the science and technology industry and further mistrust of government's handling of such issues.

A major question that all this talk raises is how far the key proponents and developers of the technology are walking the walk. According to recent accounts, the message does not as yet appear to be strongly in evidence. In particular, commercial and business sponsors of the technology appear to have been somewhat less enthusiastic to talk about the social aspects of nanotechnology and advance public understanding of the issues. Indeed, one journal editorial recently accused the small to medium sized enterprises that dominate the nanotech industry of remaining 'largely silent of the risks of nanotechnology'. While it is accepted that this may result from resource constraints that such business face in undertaking public outreach efforts, the lack of attention is clearly a source of concern. One notable exception of good practice is identified within the sector - the Chemical Industry. The American Chemistry Council's Nanotechnology Panel has partnered with Environmental Defense (ED) to issue a Joint Statement of Principles on the potential risks that government should consider in relation to the manufacturers of the technology. (Editorial, Human and Ecological Risk Assessment, 2006).

Alongside these general calls for wider public engagement there have also been two more specific areas of concerns that have been highlighted in terms of networking, dialogue and engagement. Firstly, that within nation states there is often limited communication, dialogue and co-operation between government agencies, departments and professional bodies on developing potential nanotech regulatory standards. Secondly, that limited international co-operation is taking place around the potential need for the global harmonization of standards. This could become crucially important given the increasingly international nature of the nanotech industry, with growing international trade and also potential cross-border environmental hazards (IFAS, 2007)

3. Hyperlink Analysis

This paper draws extensively on hypertext analysis and data from websites in order to gain a picture of the developing nanotech industry. In this section we outline the value of such web data. The hyperlink is commonly seen as the essence of the web (Foot et al 2002). Patterns of hyperlinks represent communicative choices. A hyperlink from page A to page B have been interpreted in a number of ways. Kleinberg (1999) refers to web hyperlinks as "conferrers of authority" or endorsement whilst Davenport and Cronin (2000) argue that hyperlinks reflect trust. Hyperlinks have also been defined as representing the structure and value of the web (Bar-Ilan 2004, Ingwersen 1998), as producing associative relations (Burbules and Callister 2000), and as inscriptions of communicative and strategic choices on the part of site producers (Rogers and Marre 2000). Hyperlinks strongly suggest navigational patterns, that users largely follow (Hindman et al. 2004). Indeed, hyperlinks construct networks among people, organisations or nation- states. Thus we can interpret the social or communication structure among those social actors based on the hyperlink structure.

Building on the work of Park et al. (2005), Ackland and Gibson (2006) argue that hyperlinks are seen to promote a number of organisational functions:

- Information provision – hyperlinks can point visitors toward additional sources of information.
- Network building or strengthening – Hyperlinks allow organizations to create virtual organizational alliances and networks or maintain & strengthen offline ones through maintaining online ties.
- Identity building - The forging of indirect or implicit connections between groups can help to strengthen or reinforce their identity of those groups.
- Audience sharing - More efficient and immediate sharing of audiences and potential supporters particularly among like-minded groups.

- Message amplification or 'force multiplication' (particularly useful for marginal organizations/ groups with a low offline profile) whereby links convey a distorted sense of the extent of worldwide support for their message to users (Gerstenfeld et al. 2003; Whine, 2000).

3.1 Hyperlinks and nano networks

In the context of our study, therefore, link analysis should provide us with unique data on:

- How far the nanotech industry is networked and even whether nanotechnology really constitutes a sector in its own right given its diverse nature (Wood et al, 2004).
- How far nanotech industry is globalised and internationalized; the extent to which networks are being formed cross-nationally or whether they reflect and cluster around national governing structures.
- The extent to which nanotech industries and groups link to wider social or knowledge networks or are restricted to largely like minded organizations creating a "balkanization" effect.
- The prominence and visibility of organizations, networks and businesses in the online world. Hyperlink analysis should highlight which organizations are most networked and which sites are acting as hubs for network building and/or bridges to wider online communities.

3.2. Hyperlink data collection

To investigate these questions we used the web crawler which is part of the VOSON System[2] (Ackland, 2007) to construct a Web network dataset containing a "slice" of the Web that is relevant to nanotechnology.[3] A common problem when using web crawlers to construct web network datasets is where to start the data collection, i.e. what "seed sites" should be used as the starting point. For this paper, the starting point was corporations involved with nanotechnology development, in particular, the 25 corporations on the Merrill Lynch nanotechnology index (these are corporations that have a significant percentage of their future profits tied to nanotechnology) – see Table 1.[4]

The websites of these 25 companies were crawled using the VOSON web crawler (this identified pages that are *linked to by* these corporate websites) and the Google API was then used to find the pages that *link to* these corporate websites. After this data collection, the database contained 2772 web pages. It should be noted that while the unit of *data collection* is the web page, the *unit of analysis* is the web site; in other words, we aggregate the pages that are hosted on the same web site (the 2772 pages are hosted on 1135 web sites).

In the next stage of the data collection, we created a subset that contained the 25 seed sites plus those sites that are "important" in that they have a degree (indegree plus outdegree) greater than or equal to two i.e. they are connected to two or more of the seed sites. There were 202 seeds plus "important" sites. The 173 new sites identified by this process were then inspected to see whether they are specifically focused on nanotechnology and 22 new sites were identified. These 22 new

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[2] http://voson.anu.edu.au

[3] See Ackland and Gibson (2006) and Ackland and O'Neil (2007) for more details on the methods of data collection that are facilitated by the VOSON System.

[4] http://www.amex.com/?href=/othProd/prodInf/OpPiIndComp.jsp?Product_Symbol=NNZ

sites were added to the 25 original seeds and VOSON was then again used to find inbound hyperlinks to and outbound hyperlinks from the 22 new sites. The resulting database contained 11,431 pages (4,458 sites).

As before, a subset dataset that contains the 47 seed sites and 798 newly-identified "important" sites (degree >= 2) was created. It was not feasible to check the 798 new sites identified in this step to see whether they are focused on nanotechnology, and so instead we decided to simply identify the new sites that contained "nano" in their URL; 132 new sites were identified at this step (these additional sites were also crawled to find who they link to and the Google API was used to find who links to them). The final database therefore contains 179 seed sites; these sites were manually classified along several dimensions, and the frequency counts are presented in Table 2.

Where possible, country of origin of the site was determined from the country code top level domain (TLD). Since many of the sites do not have country TLD information (e.g. .com sites) we also used the WHOIS service to ascertain the country of origin of the person or company who registered the domain name. The vast majority (109) of the sites are from the US (for 4 of the sites, we could not determined country of origin). The majority (99) of the sites are ".com", while 29 are ".org", 12 are ".net" and 10 are ".edu".

We then classified the sites according the main activity or purpose. We chose three broad categories: (1) production (2) dissemination (3) commercialisation. Production refers to companies/organisations that are either producing nanotechnology themselves (or services/equipment relating to this process) or are producing academic research relating to nanotechnology. Dissemination sites are non-commercial sites that are focused on making available research or information relating to nanotechnology that has been produced by others. Commercial sites are for organisations/groups who are not producers of nanotechnology, but are aiming to make a profit from it, for example by facilitating technology transfer or business consulting services. Each of these major categories had 2-3 sub-categories:

- *Production - technology company (63 sites).* These are companies that are involved in commercial activites pertaining to nanotechnology e.g. production of nanotechnology products, or equipment/services relating to nanotechnology.
- *Production – knowledge (31 sites).* These are organisations that are producing research relating to nanotechnology e.g. government/academic research labs, think tanks.
- *Dissemination - academic (17 sites).* Academic sites disseminating information relating to nanotechnology.
- *Dissemination - basic/blog (13 sites).* Blog sites focused on nanotechnology.
- *Dissemination - industry (16 sites).* This category includes industry groups.
- *Commercial - consortia (10 sites).* These are sites that involve partnerships between business, government and/or academia that are aimed at technology transfer.
- *Commercial - infosites (29 sites).* These are sites that provide information on nanotechnology and are primarily focused on making money e.g. by business services, consulting, job placement. These sites typically look like portals i.e. they have many links to other sites.

We also attempted to classify sites according to whether their main focus is on the "technology" side of nanotechnology (this also includes business), or whether they are focused on social issues (broadly defined e.g. including health, ethics, legal aspects). Of the 179 sites, only 13 were primarily concerned with social aspects of nanotechnology.

The final aspect of the data collection related to text content; we used the web crawler to automatically collected text data (meta keywords and text content) from the homepages of the 179 sites. We report on content analysis later in the paper.

3.3 Hyperlink Analysis Results

Our aim is to identify the roles that nanotechnology organisations are taking and in particular the extent to which social issues are being recognised and engaged with.[5] As a starting point, in Figures 1-3 we present force-directed graphs (FDG) drawn using the LinLogLayout layout algorithm of Noack (2005), where the node size reflects indegree to the site.[6] While these maps can only be used for descriptive rather than analytical work, they provide useful insights. For example, it is apparent from Figure 1 that social-oriented sites are reasonably well-connected with the rest of the technical-oriented sites; while they form a grouping to in the bottom left-hand corner of the map, are well connected to the other sites. It is apparent that commercial infosites (coloured orange) are quite prominent (based on indegree) and central (Figure 2), while commercial producers of nanotechnology (red) are not particularly prominent. Finally (Figure 3), there is no strong visual evidence of clustering by country of origin, although there may be a greater concentration of European-based sites in the upper part of the map.

Them we calculated the averages of various network measures are calculated for the different classifications of websites (Tables 3 and 4).[7] As only 13 sites were classified as "social", results in Table 3 need to be treated with caution. Social sites appear to be more prominent on indegree, the basic measure of network prominence,(indegree of 10.3 compared with the average of 7.5). However, we noted that www.foresight.org is a particularly prominent site and is possibly skewing the sample mean with n = 13. Excluding www.foresight.org, social sites have a mean indegree slightly lower than the average. A second measure of network prominence is provided by Kleinberg's (1999) Hyperlinked-Induced Topic Search (HITS) algorithm. This is based on the premise of the existence of hyperlinked communities that contain two distinct but inter-related, types of pages – authorities, which are highly referenced pages, and pages that point to the authority pages. The latter are referred to as hubs since they serve as central points from which authority is conferred on pages in the community. Thus, there is a mutually reinforcing relationship between authorities and hubs: a good hub points to many good authorities, and a good authority is pointed to by many good hubs.[8] In our dataset, social sites have higher authority scores than average (0.067 compared with 0.049), but again, this is largely due to the presence of www.foresight.org. When this is removed the average HITS authority score for social sites is close to average.

The final network measure in Table 3 is b*etweenness centrality* which gives an indication of the extent to which an individual node plays a "brokering" or "bridging" role in a network. This is calculated for a given node by summing up the proportion of all minimum paths within the network

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[5] Because some of the network measures we present below can only be constructed for a graph "component" (where every node is connected to at least one other node i.e. there are no isolates), we decided to drop the five sites that are isolates and hence the "final" dataset used for analysis contains 174 sites. The five sites that were dropped are all companies involved in nanotechnology production.

[6] Web sites are given initial random positions and modeled as electrostatic charges (repulsion forces that act to push nodes apart from one another). Hyperlinks between web sites are modeled as springs (attraction forces that act to pull together those sites that are connected to one another via hyperlinks). The algorithm shifts the position of nodes in an attempt to minimize the energy of the system (in general, the energy of the system will be smaller if two connected nodes are positioned near one another compared with if they are on separate sides of the map).

[7] All network measures were calculated using information on links in the seed corpus, N= 174. Hence indegree to any site refers to the number of hyperlinks pointing to that site that originate from other sites within the seed set.

[8] To calculate the HITS measures, each website *p* in the is associated with an authority weight x(p) and a hub weight y(p), which are initialised to 1. In a single iteration of HITS x(p) is replaced by the sum of the y's of all websites pointing to p, and y(p) is replaced by the sum of the x's that page p points to. After each iteration, the x's and y's are normalised and convergence is generally achieved after less than 10 iterations.

that "pass through" the node.[9] High betweenness centrality indicates a certain level of prominence of sites in the online networks formed by organisations involved in nanotechnology. The betweenness centrality for social sites is 272 compared with the average of 159, but again this is due to www.foresight.org; once this is removed social sites have much lower betweenness centrality than average.

In Table 4, the network measures are constructed in relation to the "type" of site. The striking finding is that commercial infosites are most prominent on indegree, HITS authority and betweenness centrality. Therefore, while commercial infosites are not actively engaged in nanotechnology and therefore are not "authoritative" in the sense of producing new products or research relating to nanotechnology, they appear to fulfill a useful and important function online. These sites serve to connect other sites together, thus improving the overall web presence of nanotechnology and enabling information to be found efficiently either via search engines or by users navigating the web. We then looked at individual websites ranked according to the various network measures (Table 5). Commerical infosites account for 6 of the top-10 sites and one socially-focused site (www.foresight.org) is in the top 5 of sites ranked by in degree. From the bottom half of Table 5, it is apparent that the sites that we have classified as "disseminators" are (understandably) prominent HITS hubs; half of the top-10 sites when ranked on this measure are disseminator sites. The Foresight website is again prominent, being ranked second on this measure. The composition of the top-10 sites when ranked according to HITS authority scores (Table 6) is broadly the same as what was found for indegree. From the bottom half of Table 6, we see that www.nsti.org (the Nano Science and Technology Institute) has the highest betweenness centrality score.

4. Content analysis

In addition to the light hyperlink analysis sheds on the structure and distribution of the nanotechnology issue on the Web, we wanted to determine the extant content of social and technical –focused websites, and whether it bore any relation with either the type of producers and position in the network. Procedurally, clusters of keywords were identified from websites' meta-tags included in the websites. Meta-tags, embedded in HTML coding, allow website producers to identify the contents of the site for indexing in search engines. Thus, they are integral to the positioning of a given organization's website in relation to an issue, in this case nanotechnology. Meta-tags provide a pretty accurate reflection of the main aims, functions and contents of the website.[10] After this first identification, the resulting keywords, including, roots, variations on the root and plurals (Table 7) were mined from organizations' websites, to determine occurrence. Presence (0/1) was ascertained rather than frequency (n), as we are more interested in the distribution of certain contents and 'discourses' across websites rather than in their prominence per se. For the same reason, we only examined the front-page of each website, as a reflection of the main priorities of each organization. Meta-tags used in the first phase of keyword identification are usually common to entire websites, to highlight the organization core business. In other words, we examine here co-occurrence of

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[9] The betweenness centrality $C_B(v)$ for vertex v is: $C_B(v) = \sum_{s \neq v \neq t \in V(G)} \frac{\sigma_{st}(v)}{\sigma_{st}}$, where $\sigma_{st}(v)$ is the number of shortest paths from node s to t that pass through v, and σ_{st} is the total number of shortest paths from node s to t. Betweenness is sometimes normalised to sum to 1 over all nodes.

[10] The semantic structure of a website is determined both by the meta-identifiers and by the extant content of websites. Two different logics: producer-driven vs. user driven. The first is aimed at search engines, the second at website users.

keywords across websites and semantic clusters, as we are interested in cross-site rather than in digging deeper into specific websites.

Substantively, our content analysis sought to address four questions:

1. What 'keywords' are prevalent on nanotechnology websites?
2. Do 'keywords' depend on the type of producer of the website?
3. Are these 'keywords' structured in discourses about nanotechnology?
4. Do these discourses reflect the morphology of the network, specifically in relation to the position of different websites as hubs and authorities?

To answer the first question, the keywords *industry*, *science* and *business* top the chart, being reported on between a quarter and a fifth of all websites (Table 8). *Environment* and *health*, follow, being reported on one in six websites. Hence, it seems that industrial concerns precede social concerns in the framing of the nanotechnology issue. However, keywords such as *safety*, *future*, *society* and *education*, all present on about one in ten home pages, signal some limited engagement with limitedly controversial, wider consequences of the technology. The lack of open controversy is further confirmed by the low prominence of keywords such as *risk* (9%), *threat* (3%), *ethics* (6%) and *politics* (3%). In the same vein, *discussion* (15%), of a largely scientific nature, prevails on *debate* and *dialogue* (7% together).

In relation to the second question, there is an obvious relation between site producer and the 'slant' of their communication concerning nanotechnology. On the one hand, *industry* and *science* are prevalent on most websites, with peaks on basic divulgation websites and general commercial information sites. Surprisingly, producers of nanotechnologies are not particularly interested in *business* and *investment*, which are largely left to commercialization intermediaries. *Environment* and *health*, again, appear across the board as common concerns to all actors involved, including, albeit marginally, producers of nanotechnologies. Overall, whereas producers are extremely limited in their engagement with wider issues related to nanotechnology beyond its industrial / business side, websites aimed at dissemination provide the wider possible perspective on social and possibly political implication of nanotechnologies. Also surprisingly, producers of knowledge related to nanotech seem remarkably aware of the societal implication of the nano 'science', at least as well as academic divulgators, and definitely more so than any commercial intermediaries.

Regarding question three, we run a multi-dimensional scaling of the keywords, with the aim to identify underlying discourses to the production of nanotechnology websites (Table 9). The analysis yielded three main discursive dimensions, founded on different keywords. The first dimension, most prominent in the nanotech websphere, is an industrial / proactive discourse. It dwells on the prominence of *business*, *investment* and *opportunity*, largely disregarding *risk*, *safety*, *society*, *health*, and particularly, *discussion*. The second dimension corresponds to a science / education discourse, which strongly emphasizes nano science: *industry*, *science* and *education*. However, it equally ignores *investment* and *innovation* on the one hand, and *health*, *society* and nano-*threats* on the other. The third dimension identifies a social / critical discourse, where the risks associated with the technologies are stressed, along with the need of a political discussion. *Industry* is the main, critical focus, discussed along the lines of *safety*, *opportunity*, *environment* and *health*. *News* are prominent, whilst the *science* aspects and *innovation* aspects of the technology, along with *education*, are neglected.

The three dimensions are relatively independent, as demonstrated by low correlations between dimensional scales.[11] Also, they build on very different framing of the nanotechnology discourse.

[11] Dimensional scales values for discrete websites were obtained by multiplying keywords occurrence by dimensional coordinates. Scales thus obtained had no significant correlations (Table 11).

Conversely, such discourses are deeply tied, as could be expected, to the social / technical dimension identified by manual coding. The results on this front however are not straightforward, as Table 10 makes clear. As expected, the sites that were identified as 'technical' were remarkably more likely to be engaged in industrial / proactive discourse (η = .31 ***); however, socially oriented sites were not as strongly linked to the critical / social discourse. In addition, technical websites did not shy entirely away from the 'critical/social' discourse. Finally, 'technical' websites score higher on 'science' education, even though the distance between the two is barely significant ($p = 0.02$ for independent samples t-test). Overall, the results suggest that while industrial players engage, albeit to a limited extent, in discussions about the social side of technologies, and definitely engage in science / education, 'social' players are fully inscribed in the social / critical discourse.

Finally, we were interested in whether the semantics of the nano-sphere reflect its syntactics: in other words whether any of the discourses had a more central place in the networks than competing discourses. Results were to some extent unsurprising (Table 11). Overall websites contributing to the science / education discourse are in a more central, *authority* position than websites related to other discourse. That is, all websites link to sites including education / constructive keywords to a significantly greater degree than to other sites (industrial, critical). In other words, the science/education discourse is a bridging one regarding the issue of nanotechnology.

5. Discussion and conclusions

This analysis has focused on examining how well the science and technology world is addressing issues of wider public significance in their development of nanotechnology. Regarding the core producers of nanotechnology (companies listed by Merrill Lynch plus those we found through our first web crawl), it is clear that the social debate features only in a very limited way, and particularly so if one key site (Foresight) is removed. The overwhelming majority of sites that our analysis discovered, starting from this group of producers, was technical in orientation. Application of a more nuanced categorization scheme revealed that 'knowledge' producers and the commercialisers of the technology are the prevalent in the network in terms of raw numbers of sites. Disseminators – those passing on and knowledge and information about the nanotech research or products produced by others are the least well represented group. Given that this 'mediating' group is perhaps one that may be expected to include groups focused on interpreting the societal implications of the technology, their limited presence points again to the lesser significance of the social side of the debate within the network identified here.

When we probed more deeply, however, by exploring popularity and prominence based on authority, hub and betweeness centrality we found a slightly different picture. Socially-oriented sites appear to have as great a prominence as the technical sites in terms of inbound links and authority. Foresight, the think tank, occupies a central role in the network particularly in terms of acting as a brokering or bridging site. While most sites in the top-ten on these measures are technical, given the much lower numbers of socially oriented sites in the database as a whole, it is clear that at least one such site is a highly prominent player in nanotechnology production and commercialization world.

The content analysis provides further evidence of the lower prominence of the social debate within this network. Judging from homepages and meta-tags, the sites examined focus primarily on the scientific and industrial aspects of nanotechnology production. Social issues regarding the environment and health, however, feature relatively strongly, although not necessarily in relation to risks and threats. When examined in groupings – producer/disseminator/commercialiser – more interesting results emerge, with knowledge producers and disseminators showing a much greater tendency to feature the socially relevant terms, whereas the technology producers appear to be markedly silent on these matters.

Overall, this analysis revealed that despite the declarations of a greater need by the developers of nanotechnology to engage more broadly with public concerns and fears, such engagement does not appear to be taking place, at least among the core producers. By broadening the definition of producer, however, there is evidence of a more socially-oriented debate taking place, encompassing the academic research community as well as discussion and dissemination sites that the producers of the technology are linked into. The isolated but prominent position of Foresight in the online debate is interesting in that it clearly points out the heavy bias of the nanotech industry toward discussion of technical issues and avoidance of any of the more nagging social concerns. However, its centrality clearly indicates that it has a referential and authoritative role in the network, higher than that of many of the other technical sites. Thus, while the social side of the debate may not be very well represented by sheer numbers, where it exists it enjoys a position of some influence and significance.

Of course, our findings at this stage are preliminary. In particular, future analysis will need to expand the sample size. The number of sites focused on social issues in particular is small; while this may reflect the lack of attention devoted to this aspect of nanotechnology development among the scientific community, a larger sample generated via adaptive sampling techniques would provide us with a more robust empirical basis for our conclusions.

References

Ackland, R. (2007), “VOSON System User Guide,” mimeograph, The Australian National University.

Ackland, R. and Gibson, R. K. (2006) ‘Hyperlinks and horizontal political communication on the WWW: the untold story of parties online’. Under review. Available at <http://voson.anu.edu.au/papers/hyperlinks_polcomm.pdf>

Ackland, R and O’Neill, M. (2006) ‘Nanotechnology and Online Environmentalism.’ Under review. Available at <http://voson.anu.edu.au/papers/hyperlinks_polcomm.pdf>

Anderson A., Allan, S., Petersen, A. and C. Wilkinson (2005) ‘The Framing of Nanotechnologies in the British Newspaper Press’ *Science Communication* 27 (2), pp.200-220.

Bainbridge, William Sims (2002) ‘Public attitudes toward nanotechnology’ *Journal of Nanoparticle Research* 4: 561-570.

Barbules, N. C., & Callister, T.A. (2000). *Watch it: The risks and promises of information technologies for education.* Boulder, CO: Westview Press.

Bar-Ilan, J. (2004). ‘The use of web search engines in information science research.’ *Annual Review of Information Science and Technology* , 38, 231-288.

Borg, I., & Groenen, P. J. F. (2005). Modern multidimensional scaling: theory and applications (2nd ed.). London: Springer.

Brazill, T. J., & Grofman, B. (2002). Factor analysis versus multi-dimensional scaling: binary choice roll-call voting and the US Supreme Court. Social Networks, 24(3), 201-229.

Cobb, M. D and J. Macoubrie (2004) ‘Public perceptions about nanotechnology: Risks, benefits and trust.’ *Journal of Nanoparticle Research* 6(4): 395-405.

Cook , Guy, Robbins, Peter T. and Elisa Pieri (2006) ‘Words of mass destruction: British newspaper coverage of the genetically modified food debate, expert and non-expert reactions. *Public Understanding of Science* 15(5): 5-29.

Davenport, Elizabeth and Blaise Cronin (2000) ‘The Citation Network as a Prototype for Representing Trust in Virtual Environments.’ In B. Cronin and H.B. Atkins (eds.) *The Web of Knowledge: A Festschrift in Honor of Eugene Garfield.* Metford, NJ: Information Today.

Dowling, Ann (2004) ‘Nanoscience and nanotechnologies: opportunities and uncertainties’ Report issued by The Royal Society and Royal Academy of Engineering,: London. Available at <http://www.nanotec.org.uk/finalReport.htm>

Hansen, A. (2006) ‘Tampering with nature: ‘nature’ and the ‘natural’ in media coverage of genetics and biotechnology.’ *Media, Culture & Society* 28(6): 811-834.

Human and Ecological Risk Assessment, Editorial (2006) ‘Nanotechnology Nexus–Intersection of Research, Science, Technology and Regulation.’ *Human and Ecological Risk Assessment* 12: 811-818.

Ingwersen, P. (1998). ‘The calculation of Web Impact Factors’ *Journal ofDocumentation,*

54(2), 236-243.

Institute for Food and Agricultural Standards [IFAS] (2007) *An Issues Landscape for Nanotechnology Standards*, Michigan State University: East Lansing.

Kearnes, M., Grove-White, R., Macnaghten, P., Wilsdon, J., and B. Wynne, (2006)'From Bio to Nano: Learning Lessons from the UK Agricultural Biotechnology Controversy' *Science as Culture*, 15 (4) , pp.291-307.

Keller, Kenneth H. (2006) 'Nanotechnology and society' *Journal of Nanoparticle Research* 9:5-10

Kleinberg, Jon. (1999). 'Authoritative Sources in a Hyperlinked World.' *Journal of the ACM* 46(5) : 604-642.

Lee, Chul-Joo, Scheufele, Dietram A. and Bruce V. Lewenstein (2005) 'Public Attitudes toward Emerging Technologies: Examining the Interactive Effects of Cognitions and Affect on Public Attitudes toward Nanotechnology' *Science Communication* 27(2): 240-267.

Macnaghten, P., Kearns, M. and B. Wynne (2005) Nanotechnology, Governance and Public Deliberation: What Role Social Sciences', *Science Communication* 27 (2), pp.1-24

Macoubrie, J. (2006) 'Nanotechnology: public concerns, reasoning and trust in government.' *Public Understanding of Science* 15(2): 221-241.

Noack, A. (2005), "Energy-Based Clustering of Graphs with Nonuniform Degrees." In: Proceedings of the 13th International Symposium on Graph Drawing (GD 2005, Limerick, Ireland, Sep. 12-14).

Park, H. W., Thelwall, M and Kluver, R. (2005) Political Hyperlinking in South Korea: Technical Indicators of Ideology and Content. *Sociological Research Online* 10 (3) Available at http://www.socresonline.org.uk/103/park.html

Roco, M. C. (2003) 'Broader societal issues of nanotechnology' *Journal of Nanoparticle Research* 5: 181-189.

Rogers, R., & Marres, N. (2000). Landscaping climate change: A mapping technique for understanding science and technology debates on the world wide web. Public Understanding of Science, 9, 141-163.

Scheufele, D. A. and Lewenstein, B. V (2005) 'The public and nanotechnology: How citizens make sense of emerging technologies' *Journal of Nanoparticle Research* 7(6): 659-667.

Siegrest, M. Keller, C., Kastenholz, H. Frey, S. and A. Wiek (2007) 'Laypeople and experts' perceptions of nanotechnology hazards.' *Risk Analysis* 27(1): 59-69.

Stephens, L.F. (2005) 'News Narratives about Nano S&T in Major U.S. and Non-U.S. Newspapers'. *Science Communication,* 27 (2), pp.175-199.

Waldron, A. M., Spencer, D. and C. A. Batt (2006) 'The current state of public understanding of nanotechnology' *Journal of Nanoparticle Research* 8(5): 569-575.

Wilsdon, J. and R. Willis (2004) *See through Science: why public engagement needs to move upstream*, Demos: London.

Wood, S., Jones, R. and A. Geldhert (2004) *Nanotechnology from the science to the social*. ESRC: Swindon.

Table 1: Companies comprising the Merrill Lynch Nanotechnology Index

Company Name	Symbol	URL	% Weighting	Speciality
Biosante Pharmaceuticals	BPA	http://www.biosantepharma.com/	5.09%	Nanobio
Kopin Corp	KOPN	http://www.kopin.com/	4.89%	Semis
Skyepharma Plc Ads	SKYE	http://www.skyepharma.com/	4.88%	Nanobio
Cabot Corp	CBT	http://www.cabot-corp.com/	4.66%	Materials
Amcol Intl	ACO	http://www.amcolinc.com/	4.62%	Materials
MTS Systems	MTSC	http://www.mts.com/	4.56%	Instrumentation
Veeco Instruments	VECO	http://www.veeco.com/	4.46%	Instrumentation
Accelrys Inc	ACCL	http://www.accelrys.com/	4.43%	Instrumentation
Flamel Technologies Ads	FLML	http://www.flamel.com/	4.38%	Nanobio
FEI Co	FEIC	http://www.fei.com/	4.28%	Instrumentation
Immunicon Corp	IMMC	http://www.immunicon.com/	4.18%	Nanobio
Headwaters Inc.	HW	http://www.headwaters.com/	4.10%	Energy
Nanophase Technologies	NANX	http://www.nanophase.com/	3.85%	Materials
Altair Nanotechnologies	ALTI	http://www.altairnano.com/	3.83%	Materials
Ultratech Inc	UTEK	http://www.ultratech.com/	3.83%	Instrumentation
Symyx Technologies	SMMX	http://www.symyx.com/	3.81%	Instrumentation
Arrowhead Research	ARWR	http://www.arrowres.com/	3.80%	Multi
Westaim Corp	WEDX	http://www.westaim.com/	3.77%	Nanobio
Novavax Inc	NVAX	http://www.novavax.com/	3.53%	Nanobio
Harris & Harris Group Inc	TINY	http://www.tinytechvc.com/	3.51%	Venture Capital
pSivida Ltd. (ADS)	PSDV	http://www.psivida.com/	3.50%	Nanobio
Nanogen Inc	NGEN	http://www.nanogen.com/	3.47%	Nanobio
Acacia Research-Combimatrix	CBMX	http://www.acaciaresearch.com/	3.38%	Multi
NVE Corp	NVEC	http://www.nve.com/	2.61%	Semis
Lumera Corp	LMRA	http://www.lumera.com/	2.60%	Semis

Table 2: Classification of nanotechnology-related web sites

Country	***count***
Australia	3
Austria	1
Belgium	1
Canada	5
China	2
Denmark	1
Egypt	1
Europe	1
Finland	1
France	6
Germany	11
India	1
Israel	1
Italy	3
Japan	4
Netherlands	1
New Zealand	1
Romania	1
Russian Federation	3
Spain	1
Switzerland	3
Taiwan	1
United Kingdom	13
United States	109
unknown	4
total	179

generic TLD	***count***
biz	1
com	99
edu	10
gov	7
mil	1
net	12
org	29
unknown	20
total	179

Type	***count***
producer - tech co	63
producer - knowledge	31
dissem. - academic	17
dissem. - basic/blog	13
dissem. - industry	16
commerc. - consortia	10
commerc. - infosites	29
Total	179

Focus	***count***
Social	13
Technical	166
Total	179

Table 3: Network measures by social/technical orientation of site

	N	***indegree***	***outdegree***	***hits authority***	***hits hub***	***betweenness***
Social	13	10.3	14.6	0.067	0.089	272.0
Technical	161	7.3	7.0	0.048	0.043	166.9
total	164	7.5	7.5	0.049	0.047	174.7
(www.foresight.org ommitted)						
Social	12	6.8	10.6	0.051	0.076	55.5
Technical	161	7.0	6.7	0.049	0.045	166.9
total	163	7.0	7.0	0.049	0.047	159.1

Table 4: Network measures by site type

	N	*indegree*	*outdegree*	*hits authority*	*hits hub*	*Betweenness*
producer - tech co	31	3.7	1.3	0.024	0.014	27.7
producer - knowledge	58	8.5	7.9	0.057	0.052	218.2
dissem. - academic	17	8.6	8.3	0.054	0.055	131.1
dissem. - basic/blog	13	5.3	17.0	0.038	0.120	92.7
dissem. - industry	16	9.9	8.4	0.065	0.045	257.7
commerc. - consortia	10	3.9	21.2	0.027	0.115	240.2
commerc. - infosites	29	14.5	9.7	0.090	0.047	416.2
total	164	7.5	7.5	0.049	0.047	174.7

Table 5: Top-10 sites (sorted on indegree, and HITS hub score)

Sorted on indegree

URL	***Country***	***Type***	***Focus***	***Indeg***	***outdeg***	***hits_hub***	***hits_auth***	***betweenness***
http://www.smalltimes.com/	US	commerc. - infosites	technical	64	8	0.011	0.311	1808.5
http://www.nanovip.com/	US	commerc. - infosites	technical	52	46	0.205	0.288	3635.4
http://www.foresight.org/	US	producer - knowledge	social	48	56	0.245	0.261	2869.2
http://www.nano.gov/	US	producer - knowledge	technical	48	33	0.156	0.254	2400.2
http://www.nanotechweb.org/	UK	commerc. - infosites	technical	45	0	0.000	0.244	0.0
http://www.nsti.org/	US	dissem. - industry	technical	44	51	0.196	0.231	3784.7
http://www.nano.org.uk/	UK	commerc. - infosites	technical	42	19	0.084	0.246	2342.8
http://www.azonano.com/	Australia	commerc. - infosites	technical	32	11	0.027	0.214	510.8
http://www.nanoforum.org/	Germany	dissem. - academic	technical	32	6	0.022	0.152	716.2
http://www.nanotechnology.com/	US	commerc. - infosites	technical	32	2	0.007	0.207	314.4

Sorted on HITS hub score

URL	***Country***	***Type***	***Focus***	***indeg***	***outdeg***	***hits_hub***	***hits_auth***	***betweenness***
http://www.nstc.in/	India	commerc. - consortia	technical	3	75	0.266	0.017	1582.5
http://www.foresight.org/	US	producer - knowledge	social	48	56	0.245	0.261	2869.2
http://www.nanotec.it/	Italy	commerc. - consortia	technical	3	38	0.212	0.023	212.6
http://www.nanobot.blogspot.com/	US	dissem. - basic/blog	technical	19	34	0.207	0.131	627.9
http://www.nanovip.com/	US	commerc. - infosites	technical	52	46	0.205	0.288	3635.4
http://www.thenanotechnologygroup.org/	US	dissem. - academic	technical	11	35	0.203	0.093	245.3
http://www.nsti.org/	US	dissem. - industry	technical	44	51	0.196	0.231	3784.7
http://www.nanotechbuzz.com/	US	dissem. - basic/blog	technical	6	28	0.193	0.040	54.8
http://nanotechnologie.startpagina.nl/	Netherlands	dissem. - industry	technical	0	30	0.180	0.000	0.0
http://www.venetonanotech.it/	Italy	commerc. - consortia	technical	1	23	0.176	0.010	3.2

Table 6: Top-10 sites (sorted on HITS authority score, beweenness centrality)

Sorted on HITS authority score

URL	*Country*	*Type*	*Focus*	*indeg*	*outdeg*	*hits_hub*	*hits_auth*	*betweenness*
http://www.smalltimes.com/	US	commerc. - infosites	technical	64	8	0.011	0.311	1808.5
http://www.nanovip.com/	US	commerc. - infosites	technical	52	46	0.205	0.288	3635.4
http://www.foresight.org/	US	producer - knowledge	social	48	56	0.245	0.261	2869.2
http://www.nano.gov/	US	producer - knowledge	technical	48	33	0.156	0.254	2400.2
http://www.nano.org.uk/	UK	commerc. - infosites	technical	42	19	0.084	0.246	2342.8
http://www.nanotechweb.org/	UK	commerc. - infosites	technical	45	0	0.000	0.244	0.0
http://www.nsti.org/	US	dissem. - industry	technical	44	51	0.196	0.231	3784.7
http://www.azonano.com/	Australia	commerc. - infosites	technical	32	11	0.027	0.214	510.8
http://www.nanotechnology.com/	US	commerc. - infosites	technical	32	2	0.007	0.207	314.4
http://www.crnano.org/	US	dissem. - academic	social	24	25	0.164	0.173	234.5

Sorted on betweenness centrality

URL	*Country*	*Type*	*Focus*	*indeg*	*outdeg*	*hits_hub*	*hits_auth*	*betweenness*
http://www.nsti.org/	US	dissem. - industry	technical	44	51	0.196	0.231	3784.7
http://www.nanovip.com/	US	commerc. - infosites	technical	52	46	0.205	0.288	3635.4
http://www.foresight.org/	US	producer - knowledge	social	48	56	0.245	0.261	2869.2
http://www.nano.gov/	US	producer - knowledge	technical	48	33	0.156	0.254	2400.2
http://www.nano.org.uk/	UK	commerc. - infosites	technical	42	19	0.084	0.246	2342.8
http://www.nanowerk.com/	US	commerc. - infosites	technical	22	42	0.151	0.139	2183.8
http://www.smalltimes.com/	US	commerc. - infosites	technical	64	8	0.011	0.311	1808.5
http://www.nstc.in/	India	commerc. - consortia	technical	3	75	0.266	0.017	1582.5
http://www.fei.com/	US	producer - tech co	technical	4	12	0.099	0.013	1163.0
http://www.nanoforum.org/	Germany	dissem. - academic	technical	32	6	0.022	0.152	716.2

Table 7. Keywords identified

Business	Innovation [innovate, innovation, innovator, innovative]
Capital	Investing [invest, investing, investment, investor]
Citizen	Opportunity
Collaborate	Policy [policy, policymakers]
Debate	Politics
Dialogue	Public
Discussion	Responsibility [responsible, responsibility, responsibly]
Education	Risk
Environment	Science
Ethics	Society [social, societal, society]
Health	Threat

Table 8. Keywords by type of website producers

	Overall	**Production**		**Commercialisation**		**Dissemination**		
		Technology	*Knowledge*	*Consortia*	*Infosites*	*Basic*	*Academic*	*Industry*
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Industry	27	16	26	10	38	54	35	38
Science	25	17	32	10	38	38	29	12
Business	18	11	13		31	23	18	44
Environment	17	6	23	10	21	38	29	19
Health	16	5	23	10	17	46	29	13
Invest	16	3	3	30	31	46	12	38
Innovation	15	13	13		17	31	18	13
Discussion	15	2	16	10	14	46	29	31
News	13	3	16	10	28	38	12	6
Opportunity	13	8	6	10	17	8	29	31
Safety	12	3	16	10	17	31	24	6
Future	11	2	13		14	38	24	6
Society	11		23	10	3	38	24	13
Education	10		13	10	14	31	12	19
Risk	9		13		14	54	12	
Collaboration	9	3	3	20	17	15	6	19
Policy	7		10		7	23	24	6
Ethics	6		19			23	6	
Responsibility	5	2	3		14	8	12	
Debate	5		6			31	6	13
Politics	3		6			15	6	
Capital	3				7	15		13
Threat	3		3			23	12	
Dialogue	2		6			8	6	
N = 179		*63*	*31*	*10*	*29*	*13*	*17*	*16*

Table 9. Dimensions of nanotechnology discourse

	Dimension of discourse		
	1 – industrial / proactive	2 – science / education	3 – social / critical
Industry	.408	**1.109**	**.673**
Science	**-.435**	**1.019**	**-.644**
Education	.022	**.324**	**-.318**
Environment	**-.697**	.240	**.392**
Business	**.972**	.222	-.299
Policy	-.121	.162	.141
Discussion	**-.715**	.095	-.228
Future	-.235	.068	**-.406**
Responsibility	.026	.034	.087
Capital	.250	.022	.010
Opportunity	**.636**	-.019	**.490**
Safety	**-.345**	-.048	**.454**
Dialogue	.011	-.101	-.063
Collaboration	.421	-.107	**-.300**
Debate	.113	-.138	.134
Risk	**-.360**	-.184	.069
Politics	.063	-.209	-.013
Innovation	.162	-.210	**-.789**
News	.016	-.223	**.660**
Threat	-.004	**-.262**	.043
Ethics	-.055	**-.380**	-.134
Society	**-.345**	**-.446**	-.262
Invest	**.746**	**-.483**	-.051
Health	**-.536**	**-.486**	**.354**

Notes
Multi-dimensional scaling space coordinates.
Proxscal algorithm with squared Euclidean distances.
Bold denoted most significant keywords.
Three dimensions chosen, Stress = 0.027.
Table ordered by the Dimension 2, decreasing values.

Table 10. Relation between producers and discourses

Scales	*Scale min, max, mean, SD*	*Focus*	*N*	*Mean*	*SD*	*Sig.*
Proactive / industry	-3.02 3.01 .003 1.00	Technical	166	.09	.94	***
		Social	13	-1.10	1.20	
Constructive / education	-1.89 2.46 .362 .79	Technical	166	.40	.77	*
		Social	13	-.14	.95	
Critical / social	-2.19 3.09 .034 .70	Technical	166	.02	.66	
		Social	13	.26	1.12	

Notes
Results of independent samples t-test
Test variables: three dimensional scales
Groping variable: website focus

Table 11. Correlations between dimensions and producers

	Hits authority	Proactive / industry	Constructive / education	Critical / social
Hits hub	.248 (**)	-.096	-.004	.004
Hits authority		-.033	.214 (**)	.068
Proactive / industry			.059	-.017
Constructive / education				-.051

Notes
N = 179
Pearson's correlation coefficients
** = correlation is significant at the 0.01 level (2-tailed).

Figure 1: 174 seed sites – nanotechnology focus

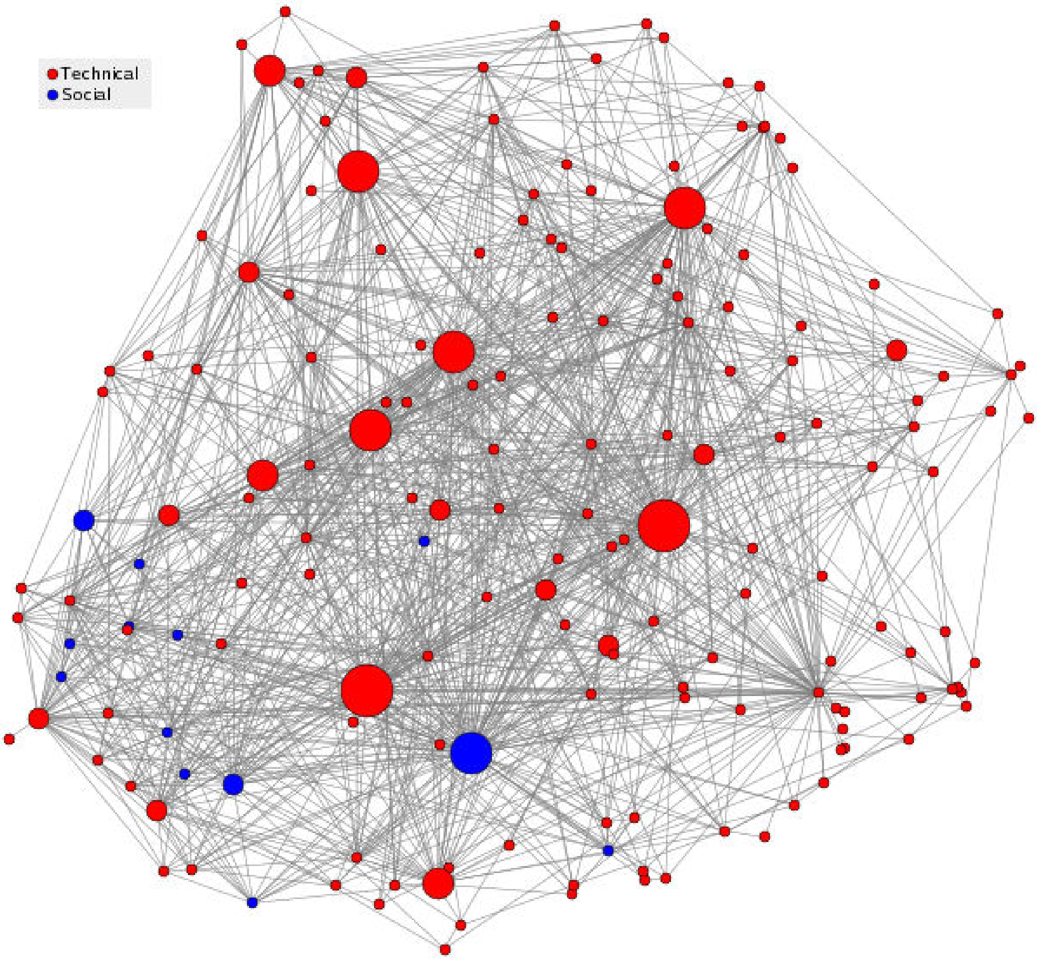

Figure 2: 174 seed sites – site "type"

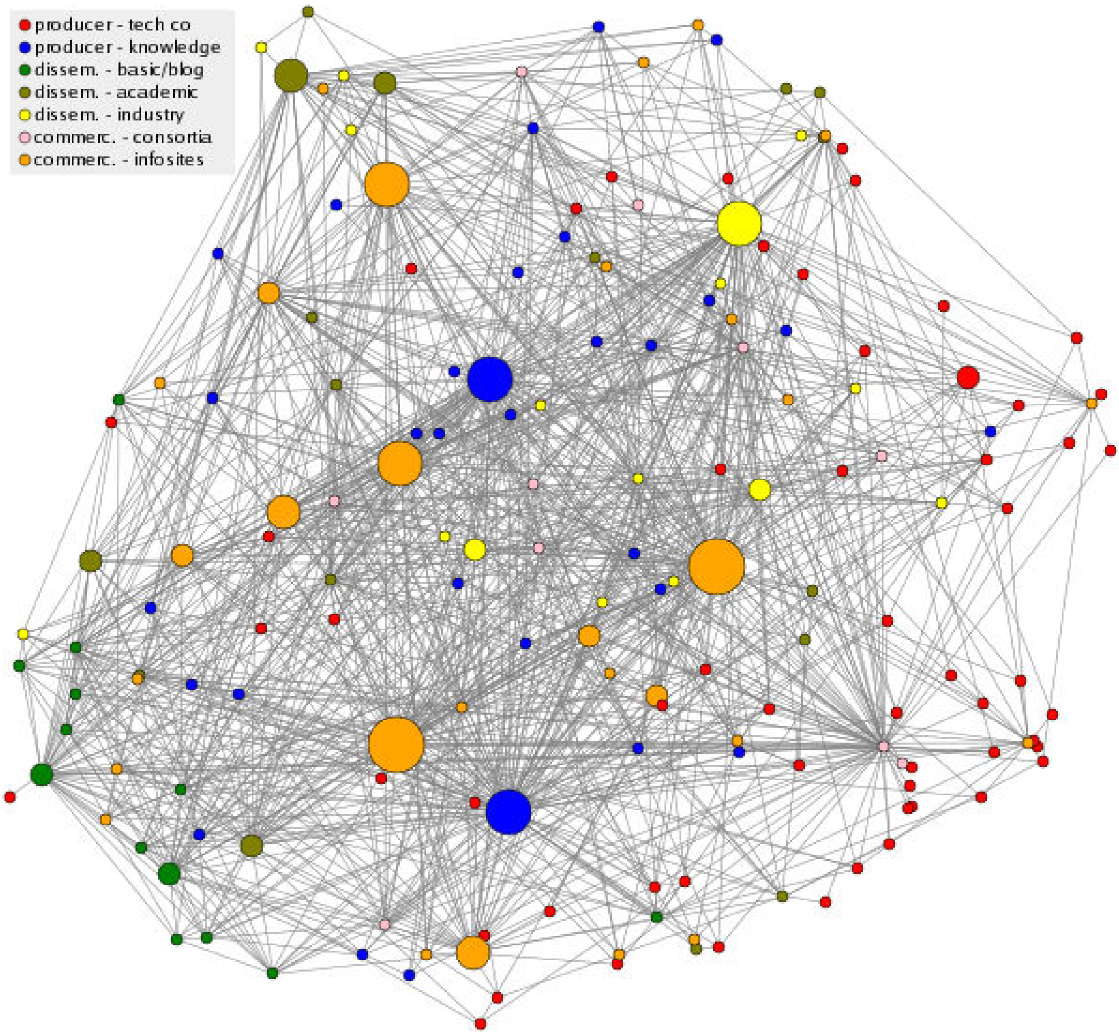

Figure 3: 174 seed sites – country of origin