Subtheme	12 The Gender dimension in science and technology, innovation, technology transfer and entrepreneurship, venture capital
Title	**Gender and Innovation: Networks of Executive Women in Technology-Based Companies**

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Keywords women, gender, innovation, networks

Introduction

In this paper, we use a novel approach to look at the role of women in innovation. Based on socially constructed media and its analysis, we present network metrics and resulting visualizations that are intended to bring insights into networks of executive women with comparisons to networks of men as well as looking at sectoral differences.

State of the art

For the quest of innovation and subsequent wealth and growth, it has been stated that the role of women in the areas of innovation, entrepreneurship, patent creation, technology and ICT development needs to be enhanced and requires more in-depth analysis (for example by European Commission 2005). One reason behind this is that gender diversity in high-tech workforce has been called “driving force of technology” and it is seen to fuel problem solving and innovation (Simard et al 2008: 4). In addition, it has been said that “as society becomes more knowledge-intensive, ending any exclusion of women from science and technology becomes more pressing" (Etzkovitz et al 2000: 4). Still, engineering has been described as "a culture that celebrates hegemonic masculity" and recent articles describe how women are "out of loop in Silicon Valley"[1], and how start-ups are "alpha-male pissing contests"[2].

Gender, women and innovation

Looking into the issue of gender and women in innovation literature revealed a lack of literature related to women in/and innovation. This issue has been mainly addressed in two contexts: there is literature about (1) women in science, engineering and technology (SET) or women in science, technology, engineering and math (STEM)[3], and about (2) women in business and entrepreneurship (Bure, 2007).

Generally, innovation is reported and talked about as a gender-neutral activity while gender-studies in the context of SET and business/entrepreneurship basically mean studies about women. For example, the concepts of "leaky pipeline", which refers to women entering the fields but not staying there, as well as "glass-ceiling effect", referring to women not being represented at high-level positions as well as other gender barriers are oftentimes mentioned when talking about representation of women in the fields of science, technology and innovation (Lee et al 2007, Bure 2007, Simard et al 2008). However, few studies emphasize gender when talking about innovation: it has been stated that "statistical analysis of patents show that the low percentage of female researchers within the EU is accompanied by an even lower percentage of female inventors, leading to productivity loss for the economy to be expected" (Busolt et al 2009).There is another study that has shown that teams can be more innovative when they are made up of 50:50 even proportions of men and women (Gratton 2007). Studies that concentrate on men only and their role in innovation are even fewer (one exception being Tallberg 2004).

A comprehensive concept of "gendered occupational cultures" has been used to explain for gender inequality and segregation at work with the presence of subtle factors that can attract one gender more than another in particular occupation—beyond the obvious and widely acknowledged structural factors (Faulkner 2005, 2006). There have been some studies (mostly at regional or national levels) that have addressed the support and resistance of gender mainstreaming in innovation systems with the concepts of gender perspectives, doing gender and

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[1] http://www.nytimes.com/2010/04/18/technology/18women.html?src=me&ref=technology

[2] http://www.fastcompany.com/1623503/startups-an-alpha-male-pissing-contest?#

[3] For example in http://www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en

gender systems (for example Lindberg 2006, 2009; Danilta et al 2009) or the role of women in and their innovations in developing countries (Malhotra et al 2009).

Well into the 2010s, the gender diversity and equality remains an issue. This was acknowledged in the 2011 "Women in America" report by White House Council of Women and Girls: women's gains in educational attainment have significantly outpassed those of men over the last 40 years and a larger share of women now work in management, professional and related occupations; however, women still earn fewer degrees than men in science and technology, and, only a small percentage are employed in the relatively high-paying computer and engineering fields.

Women and business, or innovation, networks

Networking is about making connections or social links (Krackhardt and Hanson 1997), or "banding together of like-minded people for the purposes of contact, friendship and support" (Vinnecombe and Colwill 1995: 90), and corporate networking is seen to consist of individuals attempting to develop and maintain relationships with those deemed to have the potential to assist them in their work or career (Vinnecombe et al 2004: 8).

Successful networking is seen to offer positive outcomes such as increased job opportunities, job performance, income, promotions and career satisfaction, providing access to information, gaining visibility, career advice, social support, business leads, resources, collaboration, strategy making, and professional support (Green 1982). Furthermore, it has been found that a manager's ability to network was the strongest predictor of managerial success (Luthans 1988). Recently, it was reported that "both sexes rated their professional and business networks as very important to the success of their most recent startups, but women emphasized it more"[4].

Lack of access to organizational and interorganizational networks is increasingly seen as a barrier for women to reach the top (Ragins and Sundstrom 1989, Ragins and Scandura 1999). It has been stated that networking opportunities and social capital (or relevant relationships) are key success factors for women's career progression in SET and business (Bure 2007), and that many women remain socially isolated from these networks—which are often informal—in turn negatively affecting womens' career opportunities at each step of the way (Etzkowitz et al 2007). Furthermore, women are not seen to be involved in the same informal networks as men (for instance, golf clubs and country clubs) where some of the very important decisions are made outside the traditional workspace[5]. It has been explained that networking, in the context of

[4] http://blogs.forbes.com/work-in-progress/2010/07/13/are-successful-women-entrepreneurs-different-from-men/

[5] http://english.people.com.cn/90001/90777/90852/6911846.html

women's networks, is "women's attempts to create for themselves the support generated for men by their informal same-sex grouping" (Vinnicombe and Colwill 1995: 90).

Setting up networks has been provided as one answer to combat the challenge. For example, women scientists and engineers at a recent conference were urged to build communication networks including electronic mailing lists and bulleting boards, as well as think of mentoring networks[6]. However, even though networks are seen to be part of the problem as well as the solution in the context of women in innovation, very little research has been published about formal corporate networks of women (Singh et al 2006).

Methodology

Our conceptual approach to innovation—and its participants—is relationship-based and network centric. Innovation takes place in the context of relationships that form a network via the linkages between firms and their human and financial resources (Russell et al. 2011). In this manner, we characterize the innovation network as social, as constructed from relationships between people and the organizations or institutions. Innovation networks are defined through connections or social links.

Our chosen method of network analysis is based on the premise that: (a) social structures can be represented as networks, that is, as sets of nodes (social system members), and (b) that sets of ties connecting the members (Wellman and Berkowitz, 1988). It has been used for several decades (with clearly defined network metrics) to study the sociological relationships of people and organization. This study focuses on networks of women in the context of technology-based companies. Using new visualization techniques allows for presenting the networks, graphic images present the statistical and personal relationships.

Data

We believe that the social media in its many forms, for example in Facebook, Wikipedia and Twitter as well as socially constructed databases, provides data that is available, timely and in unparalleled volumes. The approaches to open data accelerate this. Overall, social media has made social networks ubiquitous, and also given researchers access to massive quantities of data for empirical analysis (Lerman and Ghosh 2010).

Our dataset is continually build from web-crawling socially constructed data about press-worthy technology-based companies, their executives and board-level personnel, and investment organizations as well as transaction flows (Rubens et al 2010). Dataset emphasizes smaller

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[6] www.onlineethics.org/Topics/Diversity/DiverseEssays/Abstracts/abstractsindex/CENreport.aspx

companies and start-ups. In June 2011, the dataset included data about 66,000 companies, the people who are associated with them (over 76,000 records), investment organizations (over 5,300 records), and financial transactions totaling over US$410 billion. People included in the dataset are the press-worthy employees in their respective companies (e.g. founders, executives, lead engineers etc.), members of boards, members of advisory boards, or investors. Therefore, the women in this dataset can be called executive women.

Analysis

Our analysis method is visual network analysis, which provides a powerful way for enabling the investigator to gain insight into the structure of social network under study and to communicate the findings to others (cf. Freeman 2009). The visualizations are based on metrics computed from the network using social network analysis (SNA). Precise SNA metrics can be calculated both for the network as a whole and for its actors. Whereas generally simple metrics such as nodal degree representing the number of connections of a node are a good starting point to support visual network analysis, more complex metrics such as betweenness centrality (Wasserman and Faust 1994) can also be used in the analysis processs. All of these basically can be used to explain overall network structure, the different characteristics of the network, the roles of the network actors, and the nuances of their interactions.

Due to the availability of state-of-the-art network analysis tools and platforms, such as NodeXL and Gephi, social media can be turned into graphical images and even animations or movies representing various phenomena. For example, Rubens et al (2011) demonstrate that network analysis is a particularly suitable method for investigating phenomena that, essentially, are about networks.

Findings and interpretations

In this research, we think that there are visible knowledge gaps about the influence and impacts of gender in innovation systems and processes. We recognize that that women are present, though not equally represented, in technology based enterprises, but we know very little about how they influence (and are influenced by) innovation processes. Therefore, we wanted to explore gender in the context of innovation. However, the dataset that we used did not include information about the gender of the people. Toward gender-specific info, an analysis tool for gendering was therefore required. Traditional approaches of gender estimation were insufficient since many names are of foreign origin and are not in the standard name-gender dictionaries. For the purposes of this study, we estimated person's gender by applying Genderator method (Rubens et al 2011) to analysis of persons' bios based on gender-identifying pronouns e.g. "she", "her", "he", "his","him". Overall, 15 % (11,634) of the people had bios in the IEN dataset (as of June 2011), their gender was estimated by the Genderator method. In this resulting sample, there are 1135 (9.76 percent) females and 10499 (90.24%) males.

Initial gender-based analysis and visualizations

The quantitative results the initial analysis are presented in Table 1. In addition to the results from gendering information, the number of nodes (referring to all entities present in the networks) as well as the number of edges (referring to number of relationships or ties). These results were achieved by expanding one degree out, and showing the person's associations with other entities (including companies, financial organizations and other organizations).

Table 1. Initial gender-based analysis of the dataset

	Males and Females	***Females***	***Males***
Individuals	11634	1135	10499
Nodes	27794	2734	23451
Edges	30497	2442	28123

From the dataset, the key metrics of network analysis were computed for both males and females of the sample with certain algorithms. Two key metrics of network analysis, connectedness and centrality, were computed for all vertices (people and companies) in this sample: (a) connectedness, also referred to as density, indicates the percent of edges that exist among vertices in a network out of all possible ties, (b) centrality refers to the location of the vertice in the network (Freeman 1979, Wasserman and Faust 1995).

In this study, connectedness was computed with clustering coefficient (describing how linked the network is), and centrality with average degree (describing the number of linkages) and with Eigenvector centrality sum change (reflecting a relative importance of a node within the graph). From the results (see table 2.), it is easy to see that those of females and males do differ: males' average degree is higher than that of females (2.398 vs. 1.786, being therefore 34% higher); males' average clustering coefficient is higher than that of females (0.012 vs. 0.005, being therefore 240% higher), and males' Eigenvector centrality sum change is higher than of females (0.33426 vs. 0.11427, being therefore 292% higher).

When looking at the metrics and rather drastic differences based on the gender, it should be noted that as males' representation was about 9 times higher than that of women within this data sample, certain caution should be used when comparing the results. Still, it looks like males (with their higher average degree) are more linked to more nodes in the network. Furthermore, (based on their higher average clustering coefficient and eigenvector centrality sum change) their networks are more linked, which means that the connections that men have are also connected to each other.

Table 2. Key network metrics of the sample

	Total	***Females***	***Males***
Average degree	2.416	1.786	2.398
Average clustering coefficient	0.011	0.005	0.012
Eigenvector Centrality sum change	0.33713	0.11427	0.33426

Further interpretation of the analyses was made on the basis of network metrics and the graphs produced from those metrics. For the network layout, the position of the nodes was determined first with cluster-based stage using OpenOrd layout algorithm (Martin 2011) as it allows to better distinguish clusters based on the interconnections between the nodes. Then ForceAtlans (Bastian et al 2009) was applied to lay out the subgraphs in which nodes repel each other, while edges pull nodes closer together. The network figure is embedded in the pdf document by using scalable vector graphics, so it is possible to zoom in to look at finer details of the network without the loss of resolution.

In the visualizations, gray indicates place of employment (company, financial organization, etc.), pink women (individuals) and blue men (individuals). Ties, which are marked by lines, between people and companies, called edges, indicate an existing relationship—founder, executive position, or investor. In our graphs, ties between a person and a company are represented by a non-directed edge (so not showing the direction between person and company). Edge's color is a blend of its nodes' colors.

As the number of nodes as well as of edges is high in our data sample, the picture of the networks of males and females (figure 1.) is not clear without zooming. However, it easily visualizes the differences in the quantity of nodes and edges of males and females: the end-result is predominantly blue. The "grey matter" in the middle indicates the connections that exist between companies or other organizational entities, also showing because their edge-numbers are higher, they are more connected to each other. There are some pink lines and dots, however, showing that women are present in the networks. Also, there are lines between pinks and blues that allow us to see that women and men are working together.

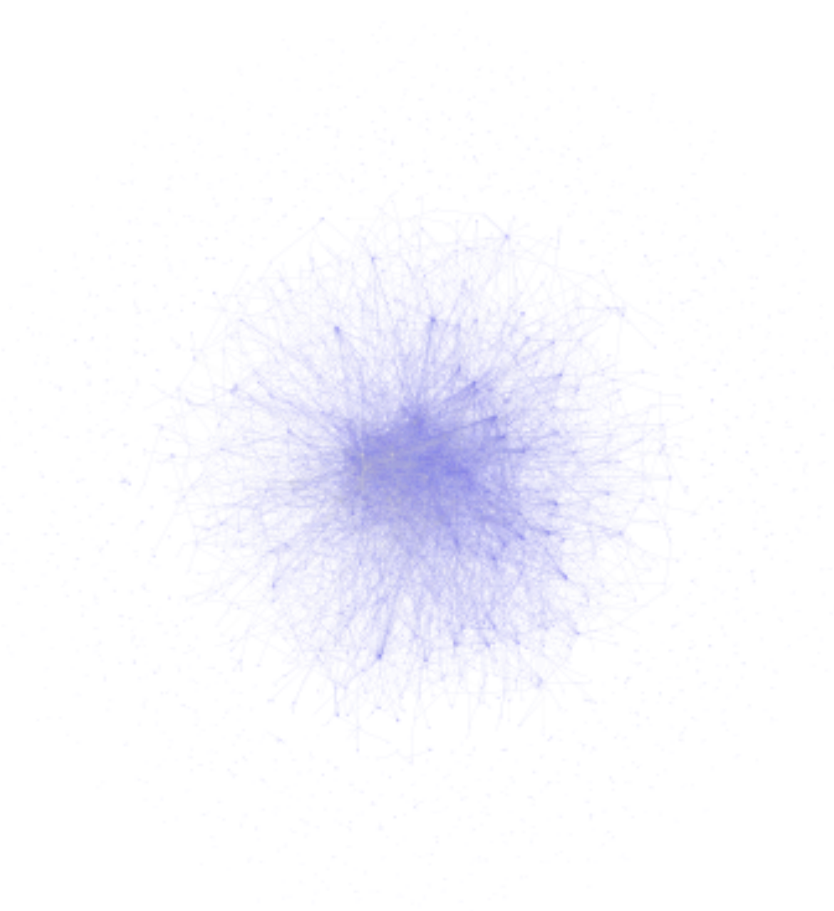


Figure 1. Network that contains males and females and their directly contained entities.

Sectoral gender-based analysis

Moving forward with the analysis, individuals' relationships with companies were current employment, board position or investors were looked at. Current employment was inferred from the most recent listing in the employment history data associated with each individual. Since this network analysis visualization was not designed to work highlight duplicate edges (in essence, to show the separate connections between two entities), duplicates were removed, leaving only the most recent position within a company but allowing for multiple ties with different companies. The companies with which these individuals were associated were identified and characterized by sector.

Overall, these individuals were associated with companies in their defined sectors. The percentages show the percentages of people in the sample in the different sectors (table 3.) This sectoral analysis shows that web sector is the biggest sector, as from the gendered dataset 27 percent of the people were seen to belong to web sector. About 16 percent of the people were in software sector, over 7 percent in mobile sector as well as in games-video sector. Some small differences can be seen between males and females: for example, almost 30 percent of women in the sample were in web sector corresponding to 27 percent of males, 15 percent of men in the sample were in software sector corresponding to 13 percent of females.

Table 3. Sectoral analysis of the dataset (numbers indicate percentages)

Sector	***Overall dataset***	***Females***	***Males***
web	27,066759	29,80519	26,94345
software	15,738499	12,5974	15,73552
mobile	7,2985126	8,100649	7,397916
Games-video	7,0217918	7,353896	7,039125
Other	6,5894154	5,487013	6,509482
Advertising	6,3818748	5,487013	6,3728
Ecommerce	5,1366309	4,87013	5,142662
Enterprise	4,7388447	4,366883	4,749701
Consulting	4,0989277	4,237013	3,861268
Public relations	3,4244206	4,237013	3,365795
Network hosting	2,8363888	4,107143	2,887408
Biotech	2,4040125	2,743506	2,374851
Search	2,1445866	2,37013	2,135657
Cleantech	1,625735	1,363636	1,65727
Hardware	1,625735	1,25	1,640185
Semiconductor	0,8820477	0,746753	0,888433
Security	0,6918021	0,503247	0,68341
Legal	0,328606	0,373377	0,307535

The gender-based sectoral analysis allows us to see how the differences between males and females play out within the different sectors. First of all, the numbers of nodes within each visualization is an indicator of how many people in our sample belonged to that sample. For the purposes of this research, which are more descriptive, introductory and explanatory, we present the resulting network visualizations for the following six sectors: web, software, mobile, advertising, biotech, and cleantech. The first three of these were chosen because they are the sectors in which most of the people in the sample are; advertising was chosen because it is seen to represent traditionally more female-inclusive environment (though in our sample 5.5 percent of women were in advertising compared to 6.4 percent of men); and biotech and cleantech were chosen because they are new sectors that are expected to be lacking some of the more traditional gender-issues.

In the resulting visualizations, we can see that web sector (Figure 2.) is the most "dense" network with most nodes as well as edges, corresponding to the above presented metrics that show that almost it has almost twice the people in the next sector, which is software. Also we can see that compared to software sector (figure 3.) and mobile sector (figure 4.), web sector has a more dense core, as software and mobile sectors are more fragmented. Moving to sectors with fewer nodes, we can see that the number of nodes becomes less, making it easier to see the individual nodes as well as the connections between them. Surprisingly, advertising network visualization (figure 5.) does not highlight the role of women and the highly connected individuals, whose vast networks are clearly visible, are men. The "newness" of biotech (figure 6.) and cleantech sectors (figure 7.) becomes evident from the fact that the network is more fragmented, and the connections more limited. For the purposes of this research, we do not explore the factors that may contribute to these differences between sectors in more detail.

From all of the sectoral visualizations, we can see that the presence of women in all of the networks (when looking at nodes as well as for edges) is not dominant, as men's blue still is the main color (corresponding to the higher representation of men) and the splashes of red are rare. We can see some evidence of the networks of executive women, but also note that the majority of well-connected nodes are men (also noting that the grays in the visualizations refer to organizational entities, which can be linked for example through financing).

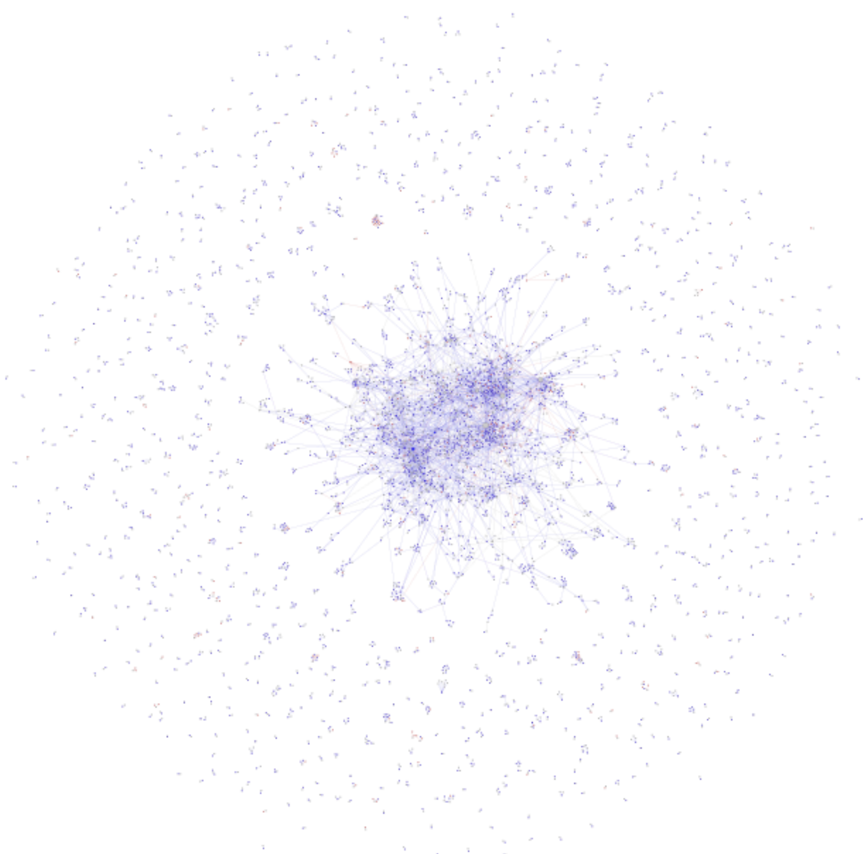


Figure 2. Gender-based analysis of web sector network

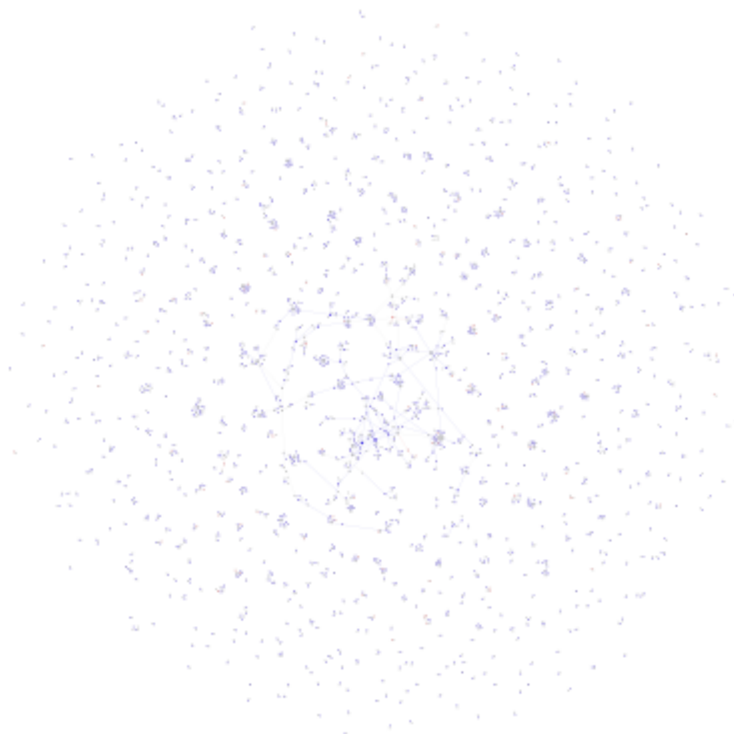


Figure 3. Gender-based analysis of software sector network

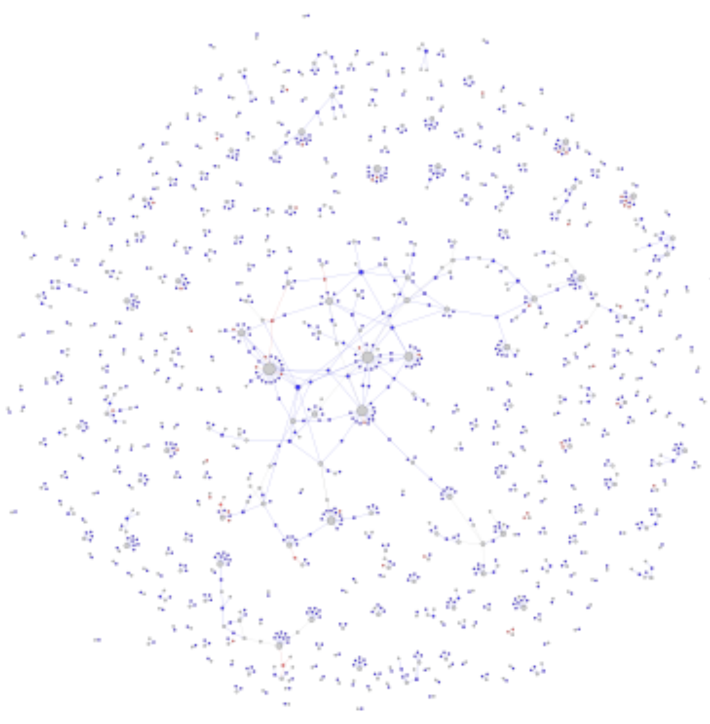


Figure 4. Gender-based analysis of mobile sector network

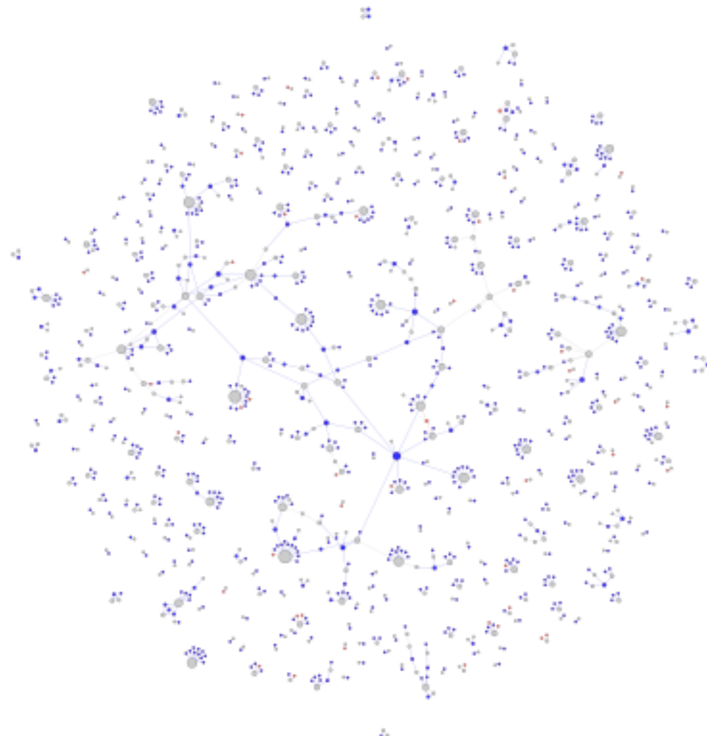


Figure 5. Gender-based analysis of advertising network

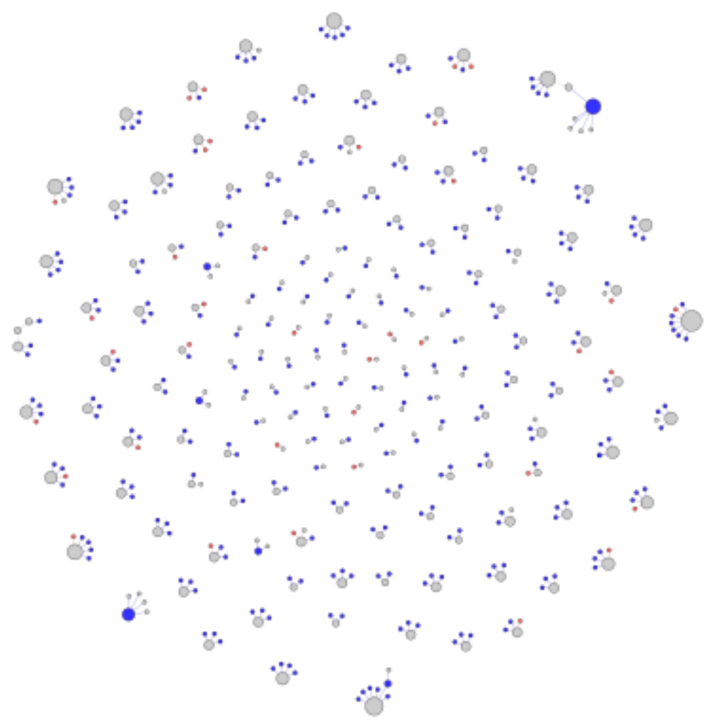


Figure 6. Gender-based analysis of biotech network

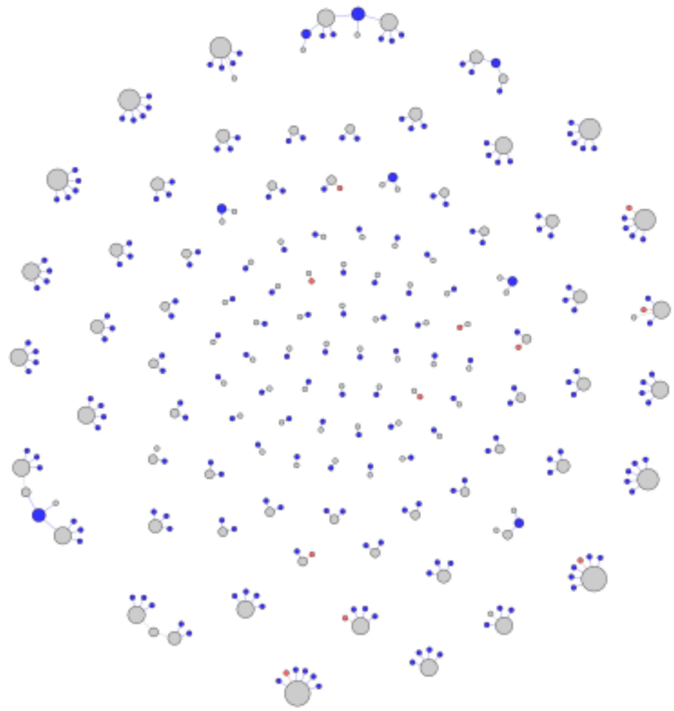


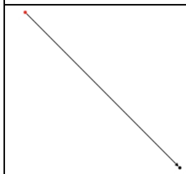
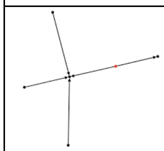
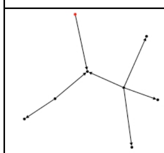
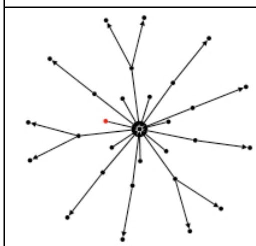
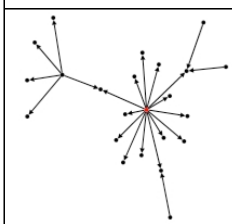
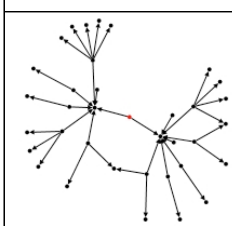
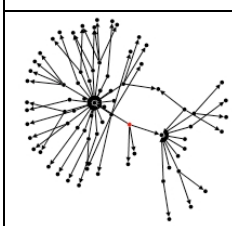
Figure 7. Gender-based analysis of cleantech network

Egocentric networks of women

Our initial results show that women are founders of technology-based companies, that there are women in the executive level, and that these women have networks. We may assume that these women have achieved their position with the benefits from their strong, personal networks that for example have not stopped them from penetrating the glass-ceiling and have not leaked from the pipelines. For example, there are certain females that demonstrate high levels of betweenness, and whose network patterns reveal how they are strategically positioned to link different networks.

For this purpose, several types of egocentric (personal networks) were indentified and labeled, drawing upon the historic graph theory of Radcliffe-Brown (1940). Each of these is described with an example of a female innovator (see table 4.). The examples show that networks of executive women demonstrate several types of personal egocentric networks.

Table 4. Examples of egocentric networks of women.

	Explanation	***Example***
	Point-to-point network: a single edge connects an individual to a company,	Co-founder and head or R&D is connected to her biotechnology company
	A tree network: a person is connected to more than one company	A female founder and chief executive officer (CEO) of an executive search and career management firm service technology-based businesses
	A complex tree network showing multiple connections	A female chief technology officer (CTO) or a large multinational enterprise in the network and hosting sector
	A star-network, where more than one person is connected to a company or in which a person is connected to more than one company	A female key executive, in charge of product development for a large multinational company in the web sector, she is one of several key executives and some of her peers also have relationships with other companies
	A complex star-network, where one person is even more connected to a company or vice versa	A female who has founded several companies and also is an investor is shown, this female is at the center of cone star of companies in which she invests in, and is connected as a ray to three others which she funded
	A mesh-network, in which redundant connections exist between a portion of nodes	A female chief technology officer of a biotechnology company is one of three people (the other two are males) who have relationships with three similar companies, thereby creating a mesh of tree and start networks that characterize those companies.
	A complex mesh-network, in which redundancy is even higher	A female founder and chief executive officer (CEO) for a company in the web sector; she is one of two nodes with high centrality linking several tree and start networks into a mesh network.

The visualizations of egocentric networks can provide valuable information. For example, the female who has a mesh network holds relationships with two companies creating a network of relationships that links 21 companies. In a similar manner, the female who is shown to have a complex mesh network, holds a strategic network position as she can link several tree and star networks into a mesh network. These executive women can be called “superconnectors”—people who have an exceedingly large and diverse number of contacts, who as “brokers” of social capital have the power to amplify one’s message exponentially[7]. Much can be learned from studying the women who have succeeded despite “the specific challenges for gender equality are the exclusionary male networks embedded in many intermediary organisations” (Vehviläinen and Ylijoki 2007), This study therefore can be seen as one method for recognizing these superconnectors.

Conclusions

It has been said that data is a vital prerequisite for “making the case” for gender equality and diversity policies, and that the lack of relevant evidence has created a barrier for promoting and increasing gender awareness (Lee et al 2007: 9) as well as hindered measuring and tracing of innovation (Wynarczyk 2007). In this paper, we provided data and metrics as we looked at gender in the context of innovation with the support of network analysis, concentrating on executive women’s networks in technology-based companies. Therefore, our research contributes to the utilizing of the method of network analysis in the context of women and innovation studies, as well as to the understanding of the role of women in the context of innovation.

Our findings including both gender-based network metrics and network visualizations, indicating that there are differences between males and females participating in the innovation networks, and that the networks differ by sector, as well as by the role of the participants. The results (and their visualizations) can support fruitful discussions and recommendations about the development of executive women’s networks toward stronger, bigger and more dense networks, possibly taking the sectoral differences into account.

Policy implications

Networking is key to fostering innovation in ecosystems. Through flows of know-how and financial resources, novels areas are identified and introduced to the markets. Programs and policies that promote networks help accelerate the flows of resource to build, grow and sustain business. The role of women will be facilitated by people, programs and policies that promote networking. and our approach can provide support for the identification of these females.

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[7] http://www.kellogg.northwestern.edu/News_Articles/2008/uzzi-kewn.aspx

Cities, regions and countries want to encourage innovation and want women to join the call-to-action for innovation and entrepreneurial activity. What can be learned about the power structure of innovation by studying relationship networks among people, companies and investment organizations that can advise new programs and initiatives to leverage the capacity of female innovators and entrepreneurs for technology-based regional growth? The visualization of executives' networks provides a new lens on the relationship basis for innovation. The character of networks differs across sectors, company size, and role (founders, investors, and key executives), as well as by gender. Insights from results of this study can inform program and policy initiatives to cultivate greater involvement of women in starting, running and investing in new businesses.

Though the results of this study are seen to contribute toward novel insights about networks of executive women, many questions still remain about the role of women in innovation. Future research, with equal random samples of males and females, is suggested to combat some of the limitations that come from samples of unequal representations.

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