GLASS NETWORKS: THE NETWORK STRUCTURE OF WOMEN DIRECTORS ON CORPORATE BOARDS

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Business and Administration

at Massey University, Palmerston North, New Zealand.

Rosanne Jane Hawarden

2010

A philosophical dedication:

"Whenever nonlinear elements are hooked together in gigantic webs, the wiring diagram has to matter. It's a basic principle. Structure always affects function." Steven Strogatz (2003:237) Sync: The Emerging Science of Spontaneous Order.

~~~~~~

Abstract

Boards of directors are overwhelmingly dominated by men. Globally, only 5-20% of directors of substantial corporations are women. Despite three decades of research and intervention this gender ratio has remained static except where affirmative action has forced change.

Using Carlile and Christensen's (2005) management theory building methodology, I develop a new theoretical approach to the study of women on corporate boards of directors called Glass Network Theory. Using concepts from small-world and scale-free network theory, I suggest that semi-permeable invisible barriers or glass nets, rather than glass ceilings, permit limited directors through to become connector directors with multiple board seats.

Resistance to change in gendered director networks is framed as a structural and normative characteristic of dynamic networks. Like other natural and social scale-free networks, gendered director networks display an emergent and self-perpetuating order. Low levels of diversity are incorporated as adaptive features of stable self-similar director networks responding to environmental pressures and economic fluctuations. Nested director networks at global, national or local levels show self-similarity at all scales, particularly where 'shoulder tapping' or preferential attachment underpins the network formation.

Probing gendered director networks with social network analysis tools shows that women directors in global and national networks are more likely to be found in the largest connected component than in the unconnected network components. Both male and female director networks show the characteristics of small-worlds, that is, high clustering coefficients and short path lengths. Both male and female directors also show 'positive assortativity' where directors of high degree associate with other
~~~~~~

directors of high degree. As the distribution of multiple directorships follows a power law, the model of the expected seat spreads is a useful tool to track the effectiveness of governance or affirmative action interventions such as quotas.

I conclude that female director networks are not inherently different from male director networks except in size.

Figure 1.
Image accompanying the Wall Street Journal article by Hymowitz and Schellhardt (1986) which introduced the term glass ceiling (Eagly & Carli, 2007a, p. 4).

Acknowledgement

I am particularly indebted to my two supervisors. A heartfelt thank you goes to Professor Ralph Stablein, Department of Management in the College of Business, for his encouragement to range far and wide in my exploration of social networks. I have come to greatly appreciate his analytical ability, collegiality and inclusiveness.

A special thank you must go to my second supervisor Dr Stephen Marsland, Associate Professor in the School of Engineering and Advanced Technology, for taking over the role of first supervisor at short notice. I am particularly grateful for his scholarly generosity and commitment. To have a mathematician, who participated in the legendary Santa Fe community, as my supervisor has been more than fortuitous.

Most beneficial too was Professor Stablein's introduction to the Academy of Management and the group of international academics who research Women on Boards of Directors. In particular Susan Vinnicombe, Diana Bilimoria and Mary Mattis, have been inspirational. Here in New Zealand my deep respect and gratitude for the stellar example she sets to academics and practitioners alike, has to go to Professor Judy McGregor.

My thanks also go to Professor Gerald Davis, University of Michigan, for making the iconic 1999 Fortune US 1000 data set available. It seems fitting that this should be used in the first women directors' network analysis.

I would like to acknowledge another act of scholarly generosity from the 1970s. Professor Matina Horner, President of Radcliffe College, now merged with Harvard University, took the time to send me, then an Honours student at the University of the Witwatersrand, information for my thesis on fear of success in women. I was delighted to find Professor Horner in the 1999 Fortune US 1000 dataset as a connector director.

I would also like to acknowledge the intellectual stimulus provided by the work of Duncan Watts, Albert-Lázsló Barabási, Mark Newman, Steve Borgatti and the UCINET community. I have been walking in the minds of giants and through them have known the thrill of discovering truly awesome ideas.

I would like to acknowledge the assistance of Rodney Dormer and Adrian Sparrow as well as Liam Fitzgerald and Michael Allan in the data analysis.

Finally my thanks go to my husband, Michael and children Bryan and Robyn for co-existing with the 'Big T' for so long. Thank you to Bryan for the research assistance and the ongoing challenge as to which of us would be the first doctor in the family.

Table of Contents

Index of Tables

Index of Figures

Glossary of Terms

*New terminology developed in Glass Network Theory

Assortativity	The tendency of network nodes to preferentially join others that are similar or like them.
Betweenness	The proportion of shortest paths from one node to another that pass through a central node.
Clustering coefficient	A measure of how close knit a group of directors are in relation to a director to whom they are all linked.
*Connector director	A director with two or more seats in substantive companies.
Degree	Average number of interlocks or links to a director.
Degree distribution	A frequency distribution that is constructed by counting the number of directors that have one link coming into them, the number that has two etc.
Geodesic distance	The length of the shortest path required to connect two nodes. For a network it is the average number of edges that must be traversed in the shortest path connecting any two nodes.
*Glass net	A transparent but semi-permeable barrier that permits predictable and limited numbers of men and women through to the boardroom.
*Glass network	The invisible or transparent network created when directors sit on common boards together as revealed through the tools of social network analysis.
*Glass Network Theory	A theory developed from an exploration of change-resistant gendered director networks where a glass network or invisible network blocks the path of women directors to the boardroom rather than a glass ceiling.
Homophily	Preference for the similar.
Edge, link or interlock	The relationship that a director has to his co-directors through sitting on a common board.

Power Law	Mathematical law of the 'vital few and the trivial many'.
Preferential attachment	A preference of network nodes to attach to nodes that already have edges.
Queen bee	A woman director with two or more seats, who by adopting the behaviour patterns of male directors is perceived as violating the norms of feminine behaviour.
Salience	Preference for notable and relevant characteristics.
Scale-free network	Networks characterised as having a degree distribution that conforms to a power law and is similar at all scales.
Seat	Alternative term for directorship to clearly distinguish individual directors from the many directorships they may hold.
Seat spread	Frequency distribution of multiple directorships.
Self-similarity	Repetitive smaller network segments which resemble the combined segments.
Shoulder tapping	A method of recruiting directors through personal invitations to known colleagues and acquaintances.
Small-world	A network with a low average geodesic distance between nodes and a high clustering coefficient.
Small-world Quotient	In a director network of *n* nodes with a mean of *k* edges or links per node, let *Lactual* equal the average geodesic or shortest path length between nodes in the largest connected component. Let *Lrandom* equal the average geodesic in which the edges between nodes are random (approximated by *ln(n)/ln(k)* where *ln* is the natural logarithm). Let *Cactual* equal the average degree of local clustering in the largest connected component. Let *Crandom* equal the average degree of local clustering in the randomized network (approximated by *k*/*n*). Then:

Small World Quotient (SW) = [Cactual/Lactual] * [Lrandom/Crandom]

Chapter One: Introduction

1.1 Thesis outline and intent

Globally boards of directors are overwhelmingly dominated by men. This thesis examines why women directors are still significantly underrepresented and whether the structure of director networks contributes to this gender imbalance.

On average only 5-20% of directors of substantial organizations are women (Vinnicombe, Singh, Burke, Bilimoria, & Huse, 2008). This gender imbalance is increasingly under challenge in Western countries, as notions of gender equity and equal employment opportunities become the norm. However, despite thirty years of affirmative action and efforts to increase board diversity, little has been achieved, with progress being described as glacially slow (Joy, 2008; McGregor & Fountaine, 2006) or glacial at best (Ross-Smith & Bridge, 2008). So pervasive is the exclusion of women from boardrooms that researchers have conjectured that barriers must exist (Vinnicombe et al., 2008). The term 'glass ceiling' is commonly used in the Women on Boards (WOB) literature and the popular press to describe the transparent and apparently impenetrable obstacles to women's progress onto boards of directors. Descriptive though this term is, it is difficult to encapsulate in theory, and indeed a lack of useful theory characterises WOB research. Since the 1990s the numbers of women on boards have been regularly monitored in many Western countries, but only one in ten papers addresses theory (Terjesen, Sealy & Singh, 2009). In asking for the first time in WOB research "are female directors' networks similar or different to those of male directors?" the intent of this research is to bring existing WOB theory into an inclusive framework based on this principle.

I develop a new theoretical approach to the study of women on corporate boards of directors called Glass Network Theory. In building this new theory I use Carlile and Christensen's (2005) management theory building methodology. This cycles through repetitive phases of deductive and inductive theory building using observation, categorisation and association of concepts leading to predicable outcomes which are tested in management settings. Research results from initial phases feed into further theory building and further empirical testing.

The constructs developed in Glass Network Theory are derived from well established concepts in social network analysis, small-world and scale-free network theory (Barabási, 2003; Watts, 2004). These are used for the first time in the study of gendered director networks focussing on the networks and interlocks of women directors. Resistance to change in such networks is framed as a structural and normative characteristic of dynamic networks. Like other natural and social scale-free networks, gendered director networks display an emergent and self-perpetuating order. Low levels of diversity are incorporated as adaptive features of stable self-similar director networks responding to environmental pressures and economic fluctuations.

The relationship of diversity to board performance is not examined in this thesis which focuses on the structure of gendered director networks. Glass Network theory can be extended to incorporate this aspect by suggesting that in the largest connected component of a gendered director network the relationship is likely to be correlational not causal as board size and company ranking (as a proxy for company performance) moderate the relationship.

In undertaking the first social network analysis of gendered boards, I develop a comparative methodology that permits gendered networks to be visually presented so as to compare different networks in different countries at different times. New terms such as 'connector director' are developed to give precise and gender neutral definitions to popular concepts such as 'old boy networks' and 'queen bees'.

I also examine the 'seat spreads' or the distribution of the multiple directorships or interlocks of connector directors, and show how a mathematical generating function can account for the gendered patterns observed. Comparison between actual and expected seat spreads shows that governance and diversity interventions are changing the patterns of network linking between directors. This model can be used to demonstrate a theoretical world of perfect diversity, set realistic diversity goals and monitor changes in actual seat spreads following the imposition of quotas.

The director networks underpinning this research include the iconic 1999 Fortune US 1000 dataset used in numerous network studies as well as two longitudinal datasets, one from a global network, the Fortune Global 200 and the other a national network from the New Zealand stock exchange (NZX). I test some of the key concepts of Glass Network theory against matched directors in the longitudinal datasets as well as against random datasets.

Finally I explore the implications of Glass Network theory for diversity initiatives.

1.2 Relevance and Contribution

As the first network analysis of gendered director networks, this thesis has relevance for women on boards of directors (WOB) research and practical implications for management and governance. The assumption underlying most of the WOB literature is that the lack of women directors is undesirable and recommendations are given to mitigate this situation. For example, Hillman, Shropshire & Cannella (2007) found that firms linked to other firms with female directors are more likely to have female representation on their own board of directors as a way of managing external resource dependencies. Increasing board diversity is recommended as a strategy to improve the management of critical relationships.

Achieving equity on boards of directors drives much of the WOB research and this is the underlying raison d'etre of this thesis. In developing the new theoretical approach of Glass Network theory, new impetus may be given to researching the problem of increasing board diversity with a greater understanding of the structure and functioning of complex director networks. Despite significant research and many years of active effort, the gender balance on boards of directors globally remains stubbornly static (Goldin, 1990). I suggest that this resistance to change is a social phenomenon of interest in its own right and needs to be explained and understood before meaningful change can be achieved.

The social consequences of not changing gender ratios justify investigating gendered director networks. Firstly, if the number of women directors does not increase, particularly in times of skill shortages, large segments of the available human resources remain under-utilised and their potential wasted. Secondly, in times of economic downturn or crisis, when fresh and different ideas are required to stimulate change, monolithic boards of directors can act as a drag on the organization (Ragins, Townsend & Mattis, 1998). Thirdly, Mattis (2000, p. 44) finds it crucial that women are represented at the highest levels of a corporation as women directors act as role models and mentors for senior women, as advocates for the advancement of female employees and as "beacons of hope for other women climbing the corporate ladder". Likewise Milliken & Martins (1996) conclude that women directors signal that their organization offers opportunities for career growth to both current and prospective employees, attracting higher calibre individuals.

Glass Network theory may also be of value and assistance to practitioners who advise, counsel and coach women seeking board appointments or leadership positions. Many women are aspiring directors (Hawarden & Stablein, 2008) who approach chairmen and professionals recruiting and selecting directors with unrealistic expectations. This research hopes to assist them to set achievable goals for themselves.

Legislation to impose gender and racial quotas for boards of directors has been enacted in several countries, namely Norway and Spain with a racial and gender quota in South Africa (de Anca, 2008; Huse, 2007; April & Dreyer, 2007). France is introducing legislation and Australia is considering a diversity statement as part of listing requirements for public companies (Donner & Hymowitz, 2009). These quotas are being implemented for reasons of social equity but no mechanisms beyond traditional censuses exist to monitor the effectiveness of such legislation.

Successful change requires an understanding of what is being changed. Knowing whether male and female director networks are similar or different will focus and help justify the efforts of change agents. This thesis contributes to that understanding by drawing existing WOB theory together in a new taxonomy, developing a new theory of gendered director networks with two new methodologies to measure board diversity. By answering a set of research questions, I demonstrate that director networks follow specific patterns of organisation irrespective of scale or point of analysis, and conclude that the networks of male and female directors are fundamentally similar except in size.

1.3 Overview

As women increasingly entered the lower levels of the workforce, expectations were that they could and would be promoted on a par with their male colleagues (Branson, 2007a). This has not materialised, and the number of women declines rapidly up organizational hierarchies into management suites and boardrooms. Still (2006), in a study into female leadership, points out that despite considerable legislative, policy and social change in the equity area, women have not attained leadership positions in any significant numbers.

In the Southern hemisphere, Australian women in 2004 held 10.2% of executive management positions (compared to 8.4% in 2002) and 8.6% of board directorships (8.2 % in 2002) (Still, 2006). Total female representation in New Zealand management had increased to 27.1% in 2003 (from 15.7% in 1993) while the percentage of women on boards of directors had increased marginally to 5.4% (from 4.4% in 1997) (McGregor, 2004; McGregor, Thompson & Dewe, 1994; Pajo, McGregor & Cleland, 1997).

Similarly in the Northern hemisphere, a Catalyst 2005 census of USA corporate leadership found women holding 50.6% of all managerial and professional positions, 16.4% of all Fortune 500 corporate officer positions and 14.7% of all Fortune 500 board director positions (Catalyst 2006a; Catalyst 2006b). These percentages of women directorships decrease if smaller corporates are included, with Adams & Flynn (2005) reporting ranges from 7.1% to 12% in a regional USA analysis. Wilson (2004) reported that 75% of adult women in the United Kingdom were in or seeking work and in 2001 women held 24% of managerial positions, while Singh and Vinnicombe (2005) reported that in 2004 9.7% of the Financial Times Stock Exchange Top 100 companies (FTSE 100) directors were women (from 7.2% in 2002). The latest figures as reported by McGregor (2008) show marginal improvement, with Australian women directors at 8.7%, New Zealand at 8.65%, the USA at 14.8% and the UK at 11%. Terjesen and Singh (2008) also provide a breakdown across 43 countries.

In the first comprehensive review of WOB literature, Terjesen et al. (2009) found diverse schools of research with the predominant perspectives being human and social capital theories and gender schema at the individual level; social identity, token, and social network theories at board level; resource dependency, institution, and agency theories at the firm level; and institutional, critical, and political theories at the environmental level. Not included in this review are the advances in director research made in the newer schools of social network analysis, as they do not explicitly focus on women directors.

To incorporate the findings of social network research into WOB research a taxonomy is constructed that categorises WOB research along a dimension of similarity/difference with the responsibility for change in differing loci. Emphasizing the agent responsible for change is a central element in the taxonomy as most WOB research is about "improving corporate governance through better use of the whole talent pool's capital, as well as about building more inclusive and fairer business institutions that better reflect their present generation of stakeholders" (Terjesen et al. 2009, p.320). The taxonomy groups research schools into three categories, namely the mandatory quota school, the incremental change school and the value-in-diversity school. These are briefly discussed next.

1.3.1 Mandatory quota schools

These schools hold that women are similar in attributes and abilities to men, therefore the problem lies externally in businessmen who protect positions of power, privilege and prestige by refusing to appoint women to their boards. Men must be forced to change as they will not voluntarily increase the number of women on their boards. This also holds true for other forms of discrimination.

1.3.2 Incremental change schools

Contrarily these schools believe that women are different in attributes and abilities to men, therefore women must change themselves to be more similar to men to get board appointments. The problem lies in women directors who must change themselves through education, experience, and better networking, while businessmen must be cajoled to accept them onto their boards.

1.3.3 Value-in-diversity or business case for WOB school

This new school stresses the positive nature of the differences between men and women and exhorts businessmen to embrace the diversity women bring to their boards because early research has shown that board diversity results in better corporate performance and increases shareholder value (Erhardt, Werbel & Schrader, 2003; Joy, Carter, Wagner & Narayanan, 2007; Nguyen & Faff, 2007). The economic implications of this justify appointing more women to a board even though diversity brings its own demands with it, for example, decision making may take longer.

A sub-school, or the 'critical gender ratio' school, suggests that women behave differently in the boardroom depending on whether there is a single token woman or whether the gender balance approaches parity (Erkut, Kramer & Konrad, 2008). Token women suppress the creative qualities of diversity for conformity's sake or risk social isolation and marginalisation (Kantor, 1977). Only with a critical mass of other women can the productive elements of diversity of opinion and experience be safely expressed (Konrad, Kramer & Erkut, 2008).

1.3.4 New theoretical approach to WOB: Glass Network theory

New advances in network theory and computerised analysis techniques, some introduced from other sciences such as physics and mathematics, now permit a fresh approach to the problem of limited board diversity. Encapsulating and extending these advances, I propose a fourth approach, Glass Network theory. This considers similarities or differences between individual directors as irrelevant, as the rules of complex network formation and functioning override individual differences. I take the position that to change director networks effectively on any dimension it is necessary to understand how they are created, structured and function at different levels or scales.

My research moves away from the personal and psychological dimensions of women directors to a consideration of the place of both male and female directors in their social networks, through which the demands and pressures of the external business environment are conveyed. Contrary to current thinking, which finds women directors to be social anomalies and an ongoing source of speculation as to why some but not others succeed, I turn this thinking around and assume that a small percentage of women directors are to be expected in a complex director network. Built-in diversity allows a small group of directors who differ from the dominant group into boardrooms. Rather than a solid barrier or glass ceiling keeping women out of the boardroom, I suggest that the filtering mechanism is a glass net, a transparent but semi-permeable barrier that permits predictable and limited numbers of men and women through to the boardroom. Glass nets also function to filter out male aspiring directors. Glass Network theory takes a holistic approach that encompasses men and women directors, whereas most WOB research only considers women directors.

Sitting together around a boardroom table creates the invisible links or director interlocks that form the glass network for those permitted through a glass net. More links are created when directors invite co-directors to take up vacancies on other boards. It is these linking or connector directors who join one board to another through their multiple directorships or seats. The term 'connector director' is introduced to distinguish directors with two or more seats from the majority of directors who have only one. The term 'seats' is preferred to 'directorships' in order to clearly distinguish individual directors from the many directorships they may hold and to avoid interchangeable use of this term and double counting as Branson (2007a) finds occurring in some of the literature. Channels of power and influence are established through directors holding multiple seats, driving corporate performance and determining the shape of the business landscape (Davis, Yoo & Baker, 2003).

The metaphor of the glass network is a dynamic term, reflecting the incomplete and often fragmented nature of the director networks. These break into multiple components, often with a dominant large component, that wax and wane in changing political and economic climates. The presence of a large component indicates a tightly clustered director network where the co-directors of a specific individual also sit on other boards together and are known to each other. A fragmented network of many small components indicates the reverse: that directors do not sit on common boards together and cannot influence each other through their boardroom contacts. A measure of clustering from small-world theory, known as the clustering coefficient (Watts, 1999a), can be used as a proxy for an ‘old boy network’ or other social elites. What is not known is where women directors are in the network components and the extent to which female connector directors participate in these exclusive social networks.

Director networks exist at local, regional, national or global levels and are connected to each other through connector directors, whose business interests span communities and countries. Scale-free network theory suggests that director networks show self-similarity at all levels or scales (Barabási & Bonabeau, 2003). The structure of global director networks should therefore mirror national and local networks. What is also not known is whether women-only director networks show this property.

Like any other network, directors can be seen as points or nodes in a graph with links or edges, where they share common boards (Kogut & Walker, 2001; Newman, 2002; Battiston, Bonabeau, & Weisbuch, 2003; Conyon & Muldoon, 2006). The resulting graph strips away all other possible social interactions, allowing the extraction of the underlying structure. Notions of social networks or social webs derive from the 1930s, when initially anthropologists, followed by social scientists, searched for embedded social structures in the communities they studied (Scott, 2000). In a renewed search, natural and social networks have been successfully mined for a network architecture governed by shared organising principles (Barabási & Bonabeau, 2003; Buchanan, 2002). New understanding from small-world and scale-free network research into the role of power laws in the growth and functioning of complex adaptive networks is extended here to gendered director networks.

This same research has shown that once a stable state is reached the networks are robust and change-resistant, despite continually changing inputs and outputs (Newman, Barabási & Watts, 2006). This is a valuable attribute in power grids or the internet, but a problematical one when attempting social change. Pressure on the network in certain sectors may result in unexpected adaptations in the network as a whole. The social pressure to increase board gender diversity has resulted in certain groups of women directors benefitting while the desired goal of more women getting their first board appointment has not materialised. Terms like 'queen bee' are pejoratively used to describe such women, but there is no equivalent term for a successful male director (Mavin, 2006).

I suggest that, irrespective of personal attributes or behaviour, connector directors of either gender become the beneficiaries of preferential attachment and assortativity, normal mechanisms of complex social networks. In director networks these mechanisms are manifest in the outcomes of innumerable recruitment and selection decisions that operate within specific national legislative, social and economic constraints, and drive the formation and maintenance of director networks. The prevalent method of recruiting directors is through 'shoulder tapping' or personal invitations to known colleagues and acquaintances, usually by the chairperson (Conyon & Mallin, 1997). The rules of interaction or 'patterns of social mixing' (Newman, 2003a) in director networks are driven by 'homophily', that is a preference for the similar, and 'salience', or a preference for characteristics that are notable and relevant (Hillman, Cannella & Harris, 2002). These preferences limit the number of board appointments available to the pool of aspiring directors belonging to minority groups. In the boardroom context women are a minority group with access currently to only 5-20% of seats. These preferences reinforce the prevailing gender proportions observed.

Homophily and salience lead to the preference for male directors over female directors, and in network terminology are a form of 'preferential attachment' (Barabási & Albert, 1999). Complex network theory also suggests that preferential attachment leads to highly connected directors seeking out other highly connected directors to sit on the same boards, thus reinforcing existing elites (Conyon & Muldoon, 2006; Conyon & Muldoon, 2008; Newman, 2002). What is not known is whether this preference, called 'positive assortative mixing' or 'assortativity' is stronger or weaker than the preference for same sex board colleagues or preferential attachment.

Director networks are known to be highly clustered, and with the intermediate links between two directors being few in number (Newman & Park, 2003). This is also known as the geodesic distance or shortest path from one director to another. Both these characteristics are found in natural and social networks such as dolphin pods and protein chains or scientific citation and movie actor networks, giving rise to the notion of ‘six degrees of separation’ which has entered science as the ‘small-world’ concept (Watts, 2003). Small-worlds are characterised by a low average distance and a high clustering coefficient. In a small-world, another characteristic, the ‘degree’, or average number of interlocks or links to a director, is low. Director networks have been shown to be small-worlds (Davis et al, 2003; Stablein, Cleland, Mackie & Reid, 2005), but it is not known if female director networks, that is, the interlocks between women directors to other women directors, create small-worlds.

Preferential attachment gives rise to another form of complex network called a scale-free network (Barabási, 2003). Many forms of scale-free networks are found, for example in the brain, in chemical reactions, river systems, power grids or the Internet. Social networks such as movie actor networks or scientific citation networks are not only small worlds, but scale-free as well (Barabási & Bonabeau, 2003). Director networks have been shown to have some of the characteristics of scale-free networks, but limits to the number of directorships a director can hold restrict director networks to a truncated form (Battiston & Catanzaro, 2004; Davis et al., 2003; Newman, 2002; Newman, 2003a; Newman & Park, 2003; Newman, Strogatz & Watts, 2001).

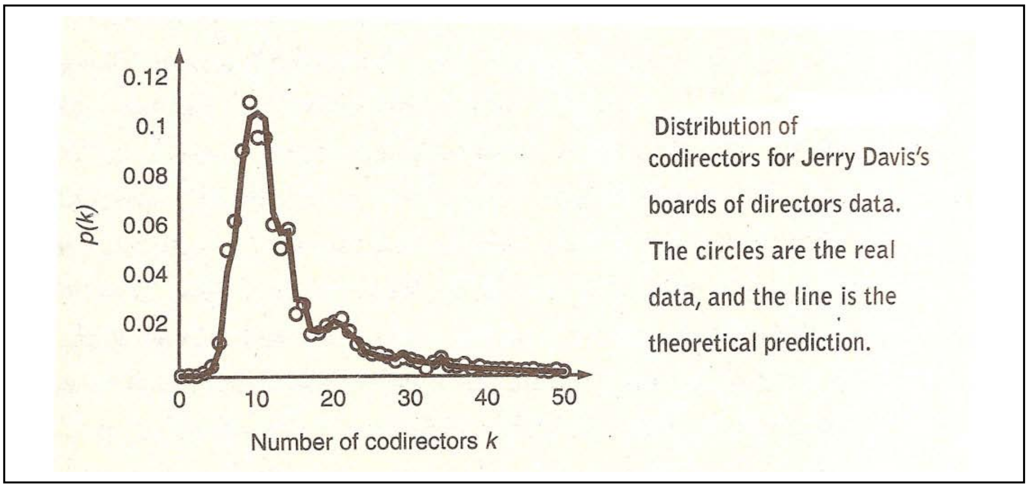
The characteristics of scale-free networks derive from the presence of a power law in the data, also known as the ‘law of the vital few and the trivial many’. Research into power laws has enjoyed a resurgence resulting in an increasing awareness of the prevalence of power laws in natural and social systems (Clauset, Shalizi & Newman, 2009; Newman, 2005b). Scale-free networks are characterised as having a ‘degree distribution’ that resembles a power law (Battiston & Catanzaro, 2004; Newman et al., 2001). Scale-free networks also exhibit a power law in a measure called ‘betweenness’, which measures the proportion of shortest paths from one node to another that pass through a central node (Goh, Oh, Hawoong, Kahng & Ki, 2002). Director networks have been shown to display power laws on both these measures (Battiston & Catanzaro, 2004; Newman et al., 2001). The implications of these observations have not been extended to gendered director networks.

A director degree distribution demonstrates a further property characteristic of scale-free networks. A degree distribution is a frequency distribution and is constructed by counting the number of directors that have one link coming into them, the number that has two, and so on. The term 'link' refers to the relationship that a director has to his co-directors, not the number of seats or directorships he or she has. In a scale-free network the number of nodes with each degree decreases at a constant rate. The majority of directors will have a low degree, but a few with multiple board seats, in a 'long right tail' will have a high degree (Watts, 2003 p.127), as illustrated in Figure 2. It is the highly connected directors who form the long right tail, creating the glass network. Complex network data consequently does not conform to a normal distribution. It is not known if highly connected women directors' degree distributions also follow suit.

To understand the role of the gendered glass network in proscribing the advancement of women directors, I examine the same director dataset used in Figure 2, the 1999 Fortune US 1000 dataset first used in Davis et al. (2003) as a gender benchmark and analyse it along dimensions relating to small-world and scale-free networks. I then extract and similarly analyse male and female director networks from publicly available databases of directors at a national and global level at two points in time to answer the questions posed in the research question set in Chapter Three. I test the derived measures against the continuing directors in the longitudinal datasets and the datasets created by allocating directors to network segments on the basis of random attributes.

I use a comparative methodology developed to compare the research datasets and to derive predictive ranges that can be used in future director network research. I also show that a non-symmetrical mathematical generating function will model expected seat spreads and can be used to track changes in actual seat spreads. This model can be used to monitor the impact of diversity and governance interventions.

Figure 2.
Illustration of a long right tail in a network of co-directors from 1999 Fortune US 1000 data from Watts (2003 p.127). This probability distribution depicts the same dataset used in this thesis.



Finally, I suggest that the 'one-size fits all approach' that has been followed to date in the business literature is ineffective. The same courses of action are proposed for aspiring directors in senior management roles, women directors in the Small-Medium Enterprise (SME) sector or women directors already in the corporate sector. Landmark points in a director's career based on their location in director networks can be identified and related to career opportunities. Only by understanding that many men and women start on the road to the boardroom, but network structures and dynamics determine that just a few succeed, will change to greater diversity be possible.

Chapter One Summary

This chapter begins by explaining the intent of the thesis, which is to explore gendered director networks and understand why aspiring women directors are excluded from boardrooms using the tools of social network analysis. The thesis contribution and relevance for management and governance practice as well as boards of directors' diversity interventions is considered.

An overview of a taxonomy of women on boards research is presented. An overview is also given of a new theory called Glass Network theory, which is based on concepts of small-world and scale-free networks.

Chapter Two: Literature Review

2.1 Introduction

This literature review is divided into three sections. The first section examines Women on Boards research as an emerging global research topic and the particular political and practical imperatives that are intertwined in this research in order to illustrate underlying value biases that drive WOB research. Several research strands that run through director, board and corporate governance research have been applied to WOB research. These schools are examined briefly in relation to WOB research and a number of findings considered from a network perspective. These are highlighted as there is sufficient data for some of these research findings to be re-worked in the following network section and re-interpreted. Rare longitudinal studies are noted. This review indicates that WOB research is still largely descriptive and empirical, with scope for new theorising within the current multi-theoretic approach.

In the second section, a new WOB theoretical framework grouping research along a dimension of similarity/difference with the responsibility for change in differing loci is expanded to encompass complex network theory and the antecedents to the proposed Glass Network theory. Previous research into director interlocks, glass ceilings and their variants, and the schools of director research known as 'Busyness Theory', 'Old Boy' networks and 'Queen Bee' theory are examined and their relationship to Glass Network theory highlighted.

In the third section, the development of the 'new' science of networks is briefly described (Barabási, 2003; Watts, 2004). Complex adaptive networks, small-world and scale-free networks and the mechanisms that create them, such as preferential attachment, are discussed and related to director networks. Extant research into director networks from these perspectives is described. Social network research that supports and underpins the network concepts used in Glass Network theory, such as the small-world quotient, betweenness and assortativity, are discussed.

Section 2.2 Women on boards of directors (WOB) research

2.2.1 Women on Boards as an emerging global research area

As a research topic, women on boards of directors (WOB) has only been addressed in the last thirty years, which is when it became apparent that women were not progressing in any great numbers into executive roles and directorships despite the 'mass arrival' in the late twentieth century of women in the workplace (Wittenberg-Cox & Maitland, 2008). Articles in scholarly journals are still few and far between, but one or two researchers in most Western countries now contribute to a growing pool of knowledge. The recent comprehensive review by Terjesen, Sealy and Singh (2009) confirms the descriptive nature of much of the research and the absence of substantial WOB theory,

In terms of publications, Burke and Mattis (2000) set the initial benchmark with the "first volume, to our knowledge, devoted exclusively to the subject of women on corporate boards of directors" (p.10). This was followed by Thomson and Graham (2005) with a practically orientated handbook based on qualitative research in the UK and US, arguing that more women on boards of directors will create shareholder value.

2007 saw two WOB books published. Huse (2007) continued the focus on creating share holder value and reported on the implications and consequences of the Norwegian legislated affirmative action requiring public bodies to comply with the gender requirements of 40% of each gender. Huse (2007) introduced the ABC board typology (aunt, barbarian and clan) derived from board task expectations. 'Barbarian' refers to boards composed of influential outsiders, including those with paternalistic orientations, who impose their will on board outcomes. 'Clan' boards describe institutional or insider theories of board operation and includes social networking approaches. 'Aunt' boards invariably consist of women directors who are appointed to rubber stamp executive decisions and to meet legal requirements. The gendered nature of boards is an integral part of this typology.

Branson (2007a) in the second book took a view from corporate governance models and having mined Title VII discrimination cases in the US, focused on the biases of board nomination committees and executive officer selection procedures, recommending that women seek different paths to men in order to gain Chief Executive Officer (CEO) status, while frequently shifting professional behaviour and work ethics as they climb the corporate ladder. Late 2009 saw the publication of a further book by the same author examining the exclusion of women from the route to the boardroom through executive suite appointments and the 'side stepping' of women onto boards from other occupations. Branson (2009) highlights the need for an enabler or initial advantage that leads to the serial appointment of a 'trophy' or celebrity woman director on US corporate boards.

A fifth book, (Vinnicombe, Singh, Burke, Bilimoria, & Huse, 2008), is a comprehensive report on international progress (or the lack thereof) towards board gender diversity and a thematic review of current research. It includes countries that have not previously featured in the literature. Research into women directors is actively taking place on a global basis in Western countries that is, USA, UK, Canada, Norway, Spain, France, Israel, Jordan, Tunisia, Iceland, Australia, New Zealand and South Africa.

A number of academic or non-profit organizations, such as Catalyst Inc, Corporate Women Directors International, the Cranfield Centre for Developing Women Business Leaders and Korn/Ferry International have been collecting data on boards of directors, including the numbers of women, since the late 1980s and initially led the corporate efforts to see more women in the boardroom. This has been continued through regular national censuses monitoring progress (or the lack of it) and as a way of drawing attention to intervention attempts. New Zealand, for example, conducts a biannual census of women's participation (McGregor 2004, McGregor & Fountaine, 2006; McGregor, 2008). Since 2002, the Australian Equal Opportunity for Women in the Workplace Agency (EOWA), www.eowa.gov.au, conducts a now biannual census of Australian women in leadership. Similarly, in collaboration with Catalyst Inc, the South African Business Women's Association (www.bwasa.co.za) has conducted an annual census of women in leadership since 2004. Methodological limitations make comparisons prior to the mid 1990s difficult, and inter-country comparisons need to be considered in the light of differing business norms and institutional structures.

Scholarly organizations such as the Academy of Management have held WOB sessions annually since 2003, where the community of WOB researchers gather to support research and follow progress. WOB gets regular coverage in the popular business press, particularly where countries or regions are actively pursuing initiatives and interventions or have active women directors' organizations (Devlin, 1999). A few executive search organizations supplement their recruiting role with WOB research, For example the Women on Board™ mentoring scheme was established in 2006 by Patrick O'Callaghan and Associates and the Richard Ivey School of Business to promote the nomination of women to corporate boards in Canada (www.poca.net).

Also, a South African executive search company Memela, Pratt & Associates who specialize in diversity and Black Economic Empowerment candidates, conduct women on boards research (www.mp-a.co.za). Their qualitative research reflects a difficult business environment responding to changing political circumstances where sufficiently experienced Black male and female directors are not readily available.

2.2.2 Intertwined practical and political imperatives in WOB research

Lack of adequate data was a concern of WOB researchers in the late 1990's (Burgess & Tharenou, 2002) and stimulated much of the early research. Women on boards of directors research is of considerable interest in the popular business press as it drives practical and political equity imperatives. Conversely, scholarly articles refer to surveys and studies undertaken by the business media, particularly those in their country of origin. Advice is frequently given in academic articles as to how women should direct successfully or position themselves for future appointment to boards (Burgess & Tharenou, 2002; Branson 2007b).

There is a blurring of boundaries between academic research and business consultation that provides well–intentioned, but value driven advice. The term diversity has a multiplicity of meanings and can provoke intense emotional reactions with the politically charged ideas of affirmative action and quotas. Herring (2009) sees these reactions as stemming, in part, from a narrow focus on protecting and favouring certain groups over others.

To some extent academic interest is playing catch-up, in observing an emerging feminist phenomenon and speculating as to why equity is not being achieved as fast as those with vested interests wish it to happen. Biographies of successful women continue to be presented to encourage aspiring women directors (McGregor, 2008). A benchmark of progress will be the cessation of the practice of quoting and naming individual directors once the presence of many women directors makes this impractical.

Burke and Mattis (2000) question the validity of these business-orientated statistics and the methodologies employed to collect this data. Even if less rigorously collected, this data does have some usefulness in viewing progress, particularly when it is the first time such data is reported. It also has historic interest indicating sufficient concern and interest in women's groups to generate research activity. For example, the 1985 Zonta report from a business women's organization, and the first New Zealand study of women directors, analysed all 221 publically listed companies (involving 1057 directorships), finding only 1.42% or 13 women holding 15 directorships. The known pattern of one woman replacing another commenced at this early date (Farrell & Hersch, 2005). By 1996, Pajo et al. (1997) reported that this number had increased to 4.4% or 56 women directors in 166 New Zealand corporations with a total of 1,282 directors.

Unusually in the WOB literature, high profile nomination failures were commented on in early New Zealand research, giving an indication of the level of shareholder activism at this time. Shilton, McGregor and Tremaine (1996) reported on two unsuccessful board challenges by aspiring women directors. A search of the literature failed to find similar reports from other countries. It is not known if direct shareholder activism is either non-existent or ignored. An analysis of the language used by organizations such as Women on Boards (www.womenonboards.org.au) who claim to be "the leading advocate for improving gender diversity on Australian boards", suggests that confrontational approaches are not favoured. The legal challenges pursued by Israeli women directors to enforce quotas (Izraeli, 2003) appears to be unique, with board affirmative action not extending to such measures in other countries.

WOB research is usually treated as a separate research area to women in management, except where pipeline issues are concerned (Davidson & Burke, 2004; Helfat, Harris & Wolfson, 2006). Researchers contrast the low levels of women on boards of directors, and the equally low levels of women CEOs and managers, with the rising numbers of women in the general work force, which approaches parity with male workers or exceeds them (Arfken, Bellar & Helms, 2004; Ragins et al., 1998). The numbers of women directors may be related to the number of women in management, and researchers have explored these relationships.

Adler (2001) suggests that the number of women on boards in the USA is related to the number of women Master of Business and Administration (MBA) graduates with 25 years of experience at a particular point in time. Adler (2001) suspects that women on boards is a numbers game and that by increasing women in management, giving them the experiences and education of male senior managers, board appointments will inevitably flow. Other research is indicating that this is an unlikely scenario. Following fears in the media that highly educated women were opting out of the work force to raise children, the so-called 'opt out revolution', Herr and Wolfram (2008) conducted a follow up study of Harvard women graduates. The preliminary results suggest that more women MBAs exit the workforce than women doctors or lawyers. They conclude that the American business environment is less family-friendly and more demanding in terms of time commitments than professional environments. This supports the findings of Branson (2007; 2009) that American women directors are not drawn from the pool of CEOs and MBA graduates, although an MBA can serve as an indicator of financial literacy - an essential board skill.

From a research perspective directing is seen as a black box, in that very few boards have permitted outsiders to study them in action (Huse, 2008; Le Blanc & Gillies, 2005). Not knowing what directors do or how boards function makes understanding how male and female directors function as individuals around a boardroom table very difficult. Zelanchowski and Bilimoria (2003), in a rare study, interviewed American women executive directors, also known as 'inside' directors, finding that there must be a convergence of influence with inclusion, for women to be fully effective at the top of the organization. Evidence of male resistance and backlash reported by interviewees is interpreted by the authors in terms of tokenism theory (Kantor, 1977).

2.2.3 Limited theoretical perspectives in WOB research

In the limited WOB literature where a theoretical framework is utilised and developed, the topic of women on boards of directors stands at the nexus of several disciplines or theoretical perspectives (Terjesen et al., 2009). WOB research can be viewed as a particular case or exemplar for a discipline or as a research topic in its own right (Burke, 1997a: Burke, 1997b). Disciplines and theoretical orientations encountered in WOB research are feminist studies, the value in diversity perspective, human and social capital theory, agency and resource dependency theory, career development theory, and a multi-theoretic approach utilising elements of several theories.

2.2.3.1 Feminist studies

Feminist researchers have taken an interest in women on boards, utilising the post-modern tradition of deconstructing dominant themes in the work place (Pringle & Olsson, 2002). Feminist theorizing is always critical and politically orientated toward social change and a just society by reducing the domination of one group over another. Liberal feminist theorizing in its concerns with feminine 'sameness' or 'difference' and with how knowledge is constructed to further the interests of some over others, underpins most WOB research. Feminist research considers knowledge and responsive action intertwined. Calás, Smircich and Bourne (2007; 2009), for example, consider whether research addressing glass ceilings in corporations has stimulated female entrepreneurship and the exodus of women from corporate life to a more flexible work environment.

By deconstructing work in the upper echelons of an organization and masculinity as virtually inseparable, Halford and Leonard (2001) see women placed in an antithetical position in relation to sources of power and influence. There are numerous barriers to surmount to get promotion to management and as many difficulties in performing successfully once in the executive suite. The stress of battling in an ongoing hostile environment finally forces many women to leave. Branson (2007:25) describes such tactics as 'fragging and sandbagging' which are ploys to sabotage the careers of women promoted into management, resulting in unfair dismissal claims and consequent court cases.

There has also been an attempt to determine whether directing, as an extension of management, is a male gendered occupation. In an empirical study set in Israel, based on a survey of all women directors and a male control group of directors of public corporations, Talmud and Izraeli (1999) tested two contrasting hypotheses. Firstly, gender may be an individual level property, correlated with job and occupational variables and associated behavioural differences. If these variables are controlled, the differences should disappear. Alternatively, gender may be an institutionalized characteristic of the workplace and embedded in roles and responsibilities. As a consequence, gender influences are not easily eliminated. Their findings lend partial support to the latter view of directing as a gendered occupation.

2.2.3.2 The value-in-diversity perspective or business case for women on boards

Academics currently involved in the value-in-diversity debate are engaged in an intense effort to establish that the presence of women on boards improves firm performance. The value-in-diversity perspective argues that a diverse workforce, relative to a homogeneous one, is generally beneficial for business, resulting in higher corporate profits and earnings (Herring, 2009). The board diversity school argues that boards' processes are similar to those of other groups, and by raising board diversity, governance processes will improve, resulting in better board and firm performance, thus increasing shareholder value. The 'value-in-diversity' perspective stands in contrast to the 'diversity-as-process loss' perspective, which is sceptical of the benefits of diversity and argues that diversity can be counter-productive (Hambrick, Cho & Chen, 1996; Kilduff, Angelmar & Mehra, 2000; Knight, Pearce, Smith, Olian, Sims et al., 1999; Miller, Burke & Glick, 1998; Pelled, Eisenhardt & Xin, 1999; Polzer, Milton, & Swann, 2002).

Although the ambit of diversity scholars is across society and organizations (with a burgeoning subsection researching women in management), the impact of board diversity on performance is increasingly under scrutiny, especially in countries actively engaged in legislated or informal affirmative action at board level (Burke & Mathis, 2005; Catalyst, 2004). In this research the feminist bias and rhetoric needs to be distinguished from the substance. The subtext of this research is that an economic imperative for diversity will sweeten the pill of social change and persuade those who control the director networks to admit the formerly disadvantaged to their ranks. In New Zealand, for example, the Ministry of Women's Affairs (www.mwa.govt.nz) actively promotes board diversity on the basis that it is 'good for business', relying on reports from organizations like Catalyst and the McKinsey Company to make their case (Desvaux, Devillard-Hoellinger & Baumgarten, 2007; Joy et al., 2007).

Two influential studies have found significant positive relationships between the fraction of women or minorities on the board and firm value (Carter, Simkins & Simpson, 2003; Erhardt et al., 2003). However this relationship is moderated by increasing firm and board size and decreasing numbers of inside directors (Carter et al., 2003). A causal relationship between women directors on a board and the company's performance, as well as market perceptions of performance, cannot be assumed. In a study investigating Australian Stock Exchange directors using Tobin's Q as a measure of shareholder value, a proxy for performance, Nguyen and Faff (2007) show that "encouragingly" (this phrase indicating their unarticulated bias) the presence of women directors is associated with higher market value and consequently higher share prices. Again, this result appears to be moderated by board size, with more profitable firms with bigger boards being more likely to appoint a female director. Female directors are also more likely to be appointed to boards of more industrially diversified companies. The common factor in both these studies is board size which points to a relationship with diversity that is not explained.

The correlation of diversity, performance and profitability may be a function of a diverse workforce being a cheaper and younger workforce (Herring, 2009). Women executives, like women employees globally, are paid less than their male equivalents in salaries, bonuses and incentives directly linked to company performance (Kulich et al., 2008). A recent director compensation survey in the US (McGregor, 2007) indicates that female directors tend to receive higher cash compensation than male directors but when aggregated with non-cash compensation such as stock options, male directors are paid more. Scarce women directors earn more as they are appointed to more committees in order to balance committee diversity and meet governance criteria. Age was not a control variable in this study and it is not known if older women directors received higher fees. Experience and seniority lead to bigger salaries and as female directors are on average younger than male board members, they are also likely to receive lower compensation, suffering 'double jeopardy' as representatives of two or more minority groups (McGregor, 2003).

Erhard et al. (2003) comment that diversity research typically follows two general distinctions: the observable or demographic and the non-observable or cognitive/behavioural. Carter et al. (2003) see this issue of board diversity and performance as an empirical one as no theoretical framework gives a clear prediction as to the nature of relationship. Glass Network theory, which is presented in Chapter Three, can give new direction to this debate through the observable mechanisms of connected components and connector directors holding multiple seats. The links between diversity and board/firm performance are not explicitly examined in this thesis which is concerned with the preliminary step of describing gendered director glass networks. The link to performance can be derived from Glass Network theory and is already supported by extant research from the 'busyness' theorists looking at whether directors with multiple seats shirk their responsibilities.

2.2.3.3 Human capital theory: profiling the women director

The current concern with diversity and performance was preceded by demographic research into the human capital (personal characteristics, skills, education and business experience) possessed by women directors (Terjesen et al., 2009). This research focused on benchmarking and profiling women directors in order to quantify and explain the gendered nature of boards of directors. At the core is an attempt to understand why some women and not others have succeeded in getting board appointments (Burke, 1997a; Burke, 1997b; Joy, 2008; Pajo, et al., 1997; Shilton et al., 1996; Singh, Vinnicombe & Johnson, 2001). Much of the early research profiling women directors attempted to rebut popular explanations for the failure of women to be appointed to boards, focusing on 'supply' issues as opposed to 'demand' issues (Farrell and Hersch, 2005; Huse, 2000). Some of the more pervasive relate to the lack of women with suitable experience and qualifications, lack of directing experience, the invisibility of suitably qualified women, and the lack of aggressiveness in putting themselves forward as well as male discomfort in female company.

Singh, Terjesen, and Vinnicombe (2008), in a human capital profile of the United Kingdom FTSE 100 women directors, dispelled these notions and found that most women directors possessed or exceeded the human capital of male directors. Terjesen et al. (2009) commented on the "somewhat unexpected finding in Singh et al.'s study was almost 25% of women appointed in 2001 to 2004 already had FTSE 100 board experience" (p.325). An examination of the 2007 FTSE 100 report similarly shows a large swing, with 80% of the thirty new female board appointments already having FTSE 100 board appointments (Sealy, Singh & Vinnicombe, 2007). This evidence is important for this thesis as an indication of the adaption of UK director networks to demands to appoint more women directors by preferring those women who already had proven track records.

As monitoring by WOB researchers has clearly established the percentages of women directors at a national level, interest is extending to other sectors particularly in countries where there is evidence of legislated affirmative action, such as South Africa, Israel, Spain, Norway/Scandinavia, or informal affirmative action as in the Australian and New Zealand state sectors. The ratios may range from 35% to 42% and are considerably higher than the commercial sectors (BWA Census 2008; Izraeli, 2003; McGregor & Olsson, 2004; McGregor & Fountaine, 2006; McGregor, 2008; Ross-Smith & Bridge, 2008). Both the Israeli and Norwegian experiences with legislated quotas show that voluntary compliance to legislated changes is likely to be tardy, and enforcement measures need to be implemented (Izraeli, 2000; Hoel, 2008).

It has been firmly established that larger boards tend to have more women directors and there are fewer larger companies that do not have a token woman on their boards

(Nguyen & Faff, 2007; Farrell & Hirsch, 2005; Carter et al., 2003). Evidence also suggests that women are more favoured as directors in some industries, often those employing high numbers of women, for example, retail or insurance (Arfken et al., 2004). Burke (2000) concluded that in Canadian boards the number of women on boards was moderated by board size, which was in turn influenced by industry sector and company size.

Regional studies are now being undertaken as the need for action devolves downward. McCormick, Hyland and Marcellino (2002) analysed the board composition of companies head-quartered in New York and found support for the presence of women on the board in larger companies with higher revenue. Adams and Flynn (2005) co-ordinated a regional comparison across the top 100 companies (by revenue) in nine US states and reported low percentages of 7.1% in Georgia to highs of 12.4% in Chicago. They found evidence that a higher proportion of women directors, who were significantly younger on average, were 'outside' or non-executive directors and that coming from academia or consulting was the way for women directors to overcome the lack of direct line experience.

Arfken et al. (2004) examined publicly-held companies in Tennessee over two time periods and despite strong economic growth resulting in a doubling of the numbers of directors (461 to 891) and women directors (25 to 52), the percentage of women remained at just over 5%. In a further analysis, Bellar, Helms and Arfken (2004) reported that other states, for example Georgia, had the similar low percentage of women directors (4.6%). In addition, they reported that in the 2002 data only one company had three women board members, twelve had two women members and twenty-five had one woman member. These studies are highlighted as few studies report on boards with more than one woman director, essential information for WOB research analysing network patterns. This regional data supports the theoretical perspective of this thesis that corporate director networks, whether regional or national, will follow the same network patterns despite growing or contracting local economies.

In a study looking at the global characteristics of women directors, Burgess and Tharenou (2002) conclude that the median age was 45-50 (50-59 in the USA), two thirds have an undergraduate degree and one third a postgraduate degree, 60-70% are married and have on average 2.5 children. This is one of the few studies to report on marital status and numbers of children. The need to care for family members is seen as one of the barriers to women's progress and has received some attention in WOB research. Family commitments are never considered when male directors are under the research spotlight: gender bias is a thread running through much of the early WOB research.

In an earlier study, Burgess and Tharenou (2000) attempted to distinguish inside or executive directors from independent or non-executive directors. Not surprisingly many of the female executive directors had family connections or were business owners. One of their surprise findings was that non-executive directors reported less mentoring and need of career support, while reporting that networking played a greater role in successful board appointments than those of inside women directors. The authors felt that the independent women directors must be "exceptionally robust and hardy women" (Burgess & Tharenou, 2000, p.123). Although the authors did record multiple board seats, these were grouped into bands of two and were not included in their regression analysis. Glass Network theory may account for the hardiness of non-executive directors as these are connector directors above the glass net and are benefitting from the forces of preferential attachment.

Given that boards of large corporates generally operate through committees, such as nomination, financial or remuneration committees, some committees are considered more important than others. Testing the hypothesis that women were not on highly valued committees because of lack of experience, known as the 'experience-based bias argument', Bilimoria and Piderot (1994) found support for 'sex-based bias' where women are assigned to committees such as public affairs while men were assigned to finance or remuneration committees irrespective of experience. The proponents of the 'sex-based bias' school hold that "the highest cadres of corporations function as 'old boys clubs' with "glass ceilings" limiting the accession of women to the topmost leadership ranks" (Bilimoria & Piderot, 1994, p. 1457).

2.2.3.4 Social Capital Theory

Complementary to the human capital school are the social capital theorists. Terjesen et al. (2009) see these two schools of thought as predominant at the individual director level, with social capital theory influential at board level. Burt (2000) views social capital theory as a core theory across several disciplines and as a metaphor for social advantage. Notions of social capital are tied to those of social connectedness or networking as they generate benefits such as trust, reciprocity, information and co-operation. In a classic case study exploring gender and social capital, Burt (1998) found a puzzle. Men and women managers utilized different forms of social capital. Women managers, as outsiders or individuals lacking in organizational legitimacy, needed to borrow the social capital of others in order to achieve early promotion. Although Ronald Burt is a major contributor to social network theory, no studies apply his concepts to the study of gender on boards. He acknowledges "the influence of the 'small-world schools' of thought" and sees similarities to his work, but does not explore these any further (Burt, 2005, p.13). The Burt approach and the Watts/ Barabási research may ultimately be different social networking paradigms and it should be noted at this point that this thesis is placed in the 'small-world and scale-free' theoretical school.

In a reflexive paper on New Zealand directors, Van der Walt and Ingley (2003) see director networks as linking into pools of social capital. Through their mix of competencies and connections directors add value to the board's governance processes. A diverse board therefore has potentially more social capital than a homogenous one. Van der Walt and Ingley (2003) develop a taxonomy describing what is meant by diversity on boards and the implications of social capital for board dynamics and decision making. They suggest that board appointments are beset by a mythology about who should serve on board, and that diversity per se is insufficient for building an effective board. Highlighting board selection practices, they comment that "boards need to focus foremost on merit criteria for director selection and, ideally, to comprise qualified individuals reflecting in the mix – gender, and a range of experience and ethnicity" (Van der Walt & Ingley, 2003, p.232). The implication being that merit, whether acquired through the possession of human or social capital, should be the final selection criterion in a board appointment once a diversified pool of qualified candidates has been considered. Van der Walt and Ingley (2003) see merit not as an alternative to diversity but as a way of ranking similarly well qualified candidates once diversity issues have been accommodated. A discourse relating to the merit appointment of directors does not exist in the governance literature. Where the term is encountered, it is used in relation to selection procedures to rebut tokenism and quotas (Pajo et al., 1997).

2.2.3.5 Agency theory and resource dependency theory

The director literature has been dominated by two theories; agency theory, or the role and abilities of directors to effectively monitor management on behalf of shareholders (Johnson, Daily & Elstrand, 1996), and resource dependency theory, which suggests that directors are appointed to boards because they can provide or secure access to essential resources for the company (Terjesen et al., 2009; Le Blanc & Gillies, 2005; Van der Walt and Ingley, 2003). Resource dependency theory is essentially a form of social networking theory, with directors linking boards and firms to resources. Pfeffer and Salanick (1978) saw four key benefits arising from these inter-board links, namely, expertise and advice, channels of information, commitment from essential suppliers and legitimacy.

Empirical results linking board composition and performance in agency roles have been mixed with Hillman, Cannella and Paetzold (2000) neatly encapsulating these two aspects of director roles into a four way categorisation, namely, insider, business expert, support specialist or community influential. They demonstrated that boards responded to different environmental conditions of regulation and deregulation by selecting directors with differing strengths in specific areas.

Extending the resource dependency perspective to women and racial minorities, Hillman, Cannella, and Harris (2002) examine how differences in race and gender intersect with the 'diversity of expertise', or differences in occupation, education and experience. Using various demographic characteristics and interlocking seats as proxies for resources, they find support for "predicted differences in occupation — most racial minority and female directors come from non-business careers as opposed to white male directors; education — a greater percentage of female and racial minority directors hold advanced degrees than white male directors" (Hillman, Cannella, & Harris, 2002, p. 758).

Hillman et al. (2002) view multiple board seats as a resource representing an increase in the number of external linkages directors provide to their boards. These linkages may act to "reduce uncertainty by linking the firm with environmental contingencies and further reducing transaction costs when dealing with these external elements" (p. 751). Their prediction that women and racial minorities holding multiple seats will show differences in joining patterns was supported, as women and minorities with two seats join subsequent boards at a faster rate than do white males. However, the number of boards on which they already sit is an important factor in their rate of joining subsequent boards.

Their prediction that female and African-American directors will more likely serve on multiple boards than white male directors was not supported. As is shown in section 3.2.3.2 the Hillman et al. (2002) data, when re-worked from the view point of Glass Network theory, does provide support for their hypothesis, as well as providing supporting evidence that the director network adapts to the pressure to add more female and minority directors by adding them faster than white males once they already have substantive board experience.

2.2.3.6 Career Development Theory

Career development theory argues that a board appointment is just another job and the role of the professional director, usually a non-executive or outside director, is a career, often the pinnacle of a management career (Burgess & Tharenou, 2002). Women's careers have been conceptualized as different to men's, since a linear progression on a career trajectory cannot be assumed (Vinnicombe, Singh & Sturges, 2000). Powell and Maniero (1992) see women's careers as complicated and difficult to conceptualise as different or similar to those of men. They see women alternating between focusing on their career and focusing on relationships as they move along with the river of time, with some women, such as single mothers, having to fight against the stream harder than others.

Moen (2005), in dissecting the concept of a career as a full time continuous path leading in an orderly fashion to retirement, finds it to be a mystique underpinned in the case of women by the feminine mystique. For her the career mystique is a false myth, and a form of 'glass corridor' that corrals individuals along certain paths as they move through their lives. Moen (2005, p.203) finds that "most contemporary Americans don't want retirement to be a permanent time out, effectively a second childhood of boundless leisure. Rather, many would like to retire from one job, possibly have a bit of a vacation from any obligations, and then move into something less taxing but more enjoyable or meaningful, a second act".

Although she does not specifically extend her argument, the career of a professional director fits the classification of a 'second act'. Moen (2005) raises the idea that it is possible to have a career that includes avocational activities, that is, activities that are additional to regular work and are undertaken for enjoyment and stimulation. Directing non-profit organizations is recommended as one way of preparing for a directing career and can be defined as an avocation.

A search of the literature revealed only one study of the career path to the boardroom, in this instance, personnel or human resource directors (Kelly & Gennard, 2000). The authors identified three career pathways and determined that the zigzag path was predominant over a vertical or parachute path, explaining their results as due to the rapidly changing corporate environment of the 1990s, which precipitated changes in organizational mission, structure and culture. Others have described the path to the boardroom as a 'glass cliff' with women being overrepresented in precarious leadership positions (Haslam & Ryan, 2008).

The road to the boardroom in the United States is more complex, with junior executives being appointed as inside directors, at the behest of CEOs, before being appointed as chief executive officers themselves (Westphal & Zajac, 1995). Dalton, Dalton, and Trevis Certo (2004) suggest that women who have not enjoyed service as inside directors are very unlikely to become CEOs, thus effectively taking themselves out of the pipeline for later outside directorships. Very little is known about aspiring director groups, although increasingly these can be identified from the many databases being established (Hawarden & Stablein, 2008).

2.2.3.7 The multitheoretic approach to WOB research

A review of the boards of director literature reveals multiple theoretical approaches and a complaint that empirical support is inconclusive, particularly in relation to firm performance (Lynall, Golden & Hillman, 2003). In a paper developing a multitheoretic approach to board research, Lynall et al. (2003) find it to be a question of when each is helpful, provided the predictions each theoretical approach makes do not contradict each other. They point out that there are few longitudinal studies of board development in new firms that track board composition from adolescence to maturity. They suggest that the relative power of the CEO and/or external financiers as key stakeholders is critical in the founding stages, and the point in the firm's life cycle when the board was formed will greatly influence its ongoing composition.

Lynall et al. (2003) are alone in suggesting that board composition is relatively persistent with the initial board composition enduring, despite a changing environment and company requirements. From the point of view of complex network theory, Lynall et al.'s (2003) proposition is the equivalent to Lorenz's 'butterfly effect', or 'sensitive dependency to initial conditions' resulting in small initial variations producing large long term dynamic effects (Strogatz, 2003). As a result of inertia and institutionalization, organizations develop coherent systems of shared understandings that support continuation of the established patterns (Romanelli & Tushman, 1994). Lynall et al. (2003) see board composition over time as path dependent and once a particular course of action is committed to, only incremental changes from that path are likely to result. They did not extend these concepts to the gender composition of boards of directors.

Section 2.3 Unifying and extending Women on Boards theory and the antecedents to Glass Network theory

2.3.1 Unifying Disparate Theoretical Schools

While WOB research has taken place within a variety of frameworks, there is no unified approach pulling it into a cohesive whole. Diversity researchers such as Powell (1999) grouped research into three categories, namely person-centred, situation-centred and social-system-centred. Terjesen et al. (2009) broke WOB research into four major overlapping themes: micro, meso, macro and industry/environment or individual, board, firm, and industry/environment. Underlying both these frameworks is a categorisation that moves from the individual and local out to larger groups, whether social or geographical. While convenient, these frameworks do not reveal an underlying theoretical approach. The only specific director taxonomy to do this is that of Huse (2007) with the ABC board typology he devised to describe Norwegian boards. It has applicability only in the specific situation of legislated affirmative action and cannot be used as a general taxonomy.

I suggest that a productive approach to thinking about the gender imbalance of boards of directors is to categorise current schools of thought along a dimension of gender similarity/difference, placing the responsibility for change in differing loci of action. The similarity/difference dimension underpins what is meant by diversity. In a comprehensive dissection of the concept of diversity Harrison and Klein (2007) find three distinctive types of diversity: separation, variety, and disparity. Ambiguous research results, they suggest, are the result of failure to recognize the meaning, maximum shape, and assumptions underlying each type with the consequence that theory development is being held back.

Their approach stresses that diversity occurs within a social unit and that the unit per se is not diverse except with respect to one or more specific features of its members. Diversity, they propose, is three things: substance, pattern, and operationalisation. Their theoretical constructs focus on the substance of diversity and they criticise the operationalisation of the concept. For example, combining racial or ethnic characteristics into one measure is not recommended, as the underlying constructs differ. In their brief discussion of social network theory the authors conclude that "network analysis may allow researchers to enrich their understanding of the relational processes associated with each diversity type, even allowing a single demographic variable to be associated with more than one diversity type and to have simultaneous, opposing effects" (Harrison & Klein, 2007, p. 1218). Here they propose that diversity is multidimensional as disparate forms can co-exist and neutralise each other's effects.

Using the concept of centralisation as an example, which Harrison and Klein (2007, p.1207) define as "as a measure of how unequal the individual actor values are", they show this to be a form of disparity or the uneven distribution of desired or socially valued resources. These include disparities of pay, power, prestige, and status. When a network structure is highly centralized, network ties are unevenly distributed with a few highly connected members highly influential. They conclude that such a condition might translate into a social network with maximum centralization, in which unit members build ties to or prefer the highly connected persons over others. Gender as a source of separation diversity may thus be linked to disparate diversity through preferential attachment to male individuals with unequal access to resources. Gender comes to represent power disparity, and establishes a preference for males, thus developing into separation diversity.

Given this intertwined complexity, where gender can represent two forms of diversity, the Harrison and Klein tripartite taxonomy cannot be usefully used to categorise WOB research, as all three forms of diversity are inextricably linked in individual studies. The simpler dimension of difference/similarity can be used to distinguish the philosophical underpinnings of a piece of WOB research that determines what is important and what gets the investigative focus that ultimately filters the research outcomes. There is a degree of overlap, but WOB research can be grouped into a three category taxonomy: the mandatory quota school, the incremental change school, and the business case for WOB school.

Profiling studies undertaken to provide information for informed debate explicitly seek similarities and differences between the gendered demographic data. For example, Pajo et al. (1997), in the first profile of female directors in New Zealand's top 200 companies, examined demographic characteristics and then asked successful women directors what they perceived as influential in their selection. Their questions relating to factors such as 'similar political allegiance' or 'fit' with a specific board, tap into implicit similarities or differences. Similarly, Davies-Netzley (1998) looked for differences between women above and below the glass ceiling and found that elite women highlighted the importance of peer similarities for achieving success.

Emphasizing the agent responsible for change is a central element in the taxonomy as most WOB research is applied research, seeking reasons for inequities that can be remedied. Terjesen and Singh (2008) see diversity research as the basis for change to a more equitable gender representation at the decision-making levels of the corporate world. Diversity research focuses on improving corporate governance by using the full range of social and human capital available to it (Terjesen et al. 2009). Hillman and Shropshire (2007) seek to understand which types of directors benefit a firm most. While explicitly asking how women and racial minority directors differ in the boardroom, Hillman et al. (2002) find that their study contributes to corporations seeking to become more diverse and to individual women wanting advice on how to get board appointments. Their solutions of additional education and experience in community influential occupations appoint the aspiring minority director as an agent of self change. The value in diversity school seeks to convince businessmen that their financial status will benefit if they become the agent of change by appointing more diverse boards (Nguyen & Faff, 2007; Carter et al., 2003; Erhardt et al., 2003). In countries where mandatory quotas are being considered, the agents of change become the lawyers and legislators seeking policy guidance and legitimating research to underpin social engineering (Izraeli, 2000; 2003).

The introduced taxonomy thus speaks to the two main issues underlying WOB research, the extent to which male and female directors differ and how gender equity should be achieved and by whom.

Table 1.
Women on Boards Research Taxonomy

Classification	**Female Directors Similar or Different to Male Directors**	**Locus of Action for Change**	**Current Theory**
Mandatory quota	Similar	Men/ Legislators by forcibly relinquishing control over gendered board appointments	Human Capital / Social Capital Theory / Sex-based bias theory / Glass ceiling theory
Incremental Change	Different	Women by becoming more like men	Human Capital / Social Capital Theory /Career Development Theory / Director Ingratiation theory / Experience-based bias theory
Value-in-diversity/Business case for WOB	Different	Men/Boards/Investors Shareholder activists by voluntarily embracing diversity	Agency / Resource Dependency Theory / Value-in-diversity / Critical Gender Ratio Theory

2.3.1.1 Mandatory quota school

This school holds that women are similar in attributes and abilities to men and therefore it is discrimination or prejudice that keeps women out of the boardroom. Men must be forced to change, as they will not voluntarily increase the number of women on their boards. The problem does not lie within individual women, but externally in businessmen who protect positions of power, privilege and prestige by refusing to appoint women to their boards. The locus of action for change is external in society and can only be achieved with mandatory quotas and affirmative action, forcing male directors to relinquish gender control over board appointments by appointing specific percentages of women to their boards.

This school holds that women are being kept out of boardrooms by overt and covert discrimination (Branson, 2007a). Westphal and Stern (2006) found direct evidence of social discrimination in actual hiring decisions that is, appointments to corporate boards. While overt prejudice and discrimination have become less pronounced in US organizations in recent years, relatively subtle, 'covert' forms of discrimination may have persisted. Consistent with aversive racism and related theories of social discrimination, their findings suggest that while ethnic minorities and women who seek access to the highest level of the corporation may not come up against a glass ceiling per se, they also do not receive equal treatment or consideration in the director selection process.

Adams and Flynn (2005) see one of the rationales for quotas as the enforcing of change through the creation of cognitive dissonance. By forcing a behaviour change, attitudes to women in the boardroom will subsequently change as the new women directors prove themselves competent. The hope is that once the benefits of women on boards become apparent barriers will fall away. Adams and Flynn (2006) further suggest that more may be achieved by combining quotas with an approach characterised by facilitative, collaborative change management. This is known as the tempered radical approach (Meyerson, 2001). Women are known for leadership strengths in collaborative styles of interaction that involve increasing the amount of listening, social support, and win-win problem-solving (Kramer, Konrad & Erkut, 2006).

Introducing quotas is of necessity linked into prevailing political practices and notions of egalitarianism in the country concerned, resulting in the emergence of differing forms of gendered boards. Gender quotas are likely to be linked to other governance reforms or driven by corporate scandals. There are four recent examples where quotas have been applied or affirmative action legislation enacted namely, Israel, Norway and South Africa with Spain currently implementing equity legislation.

Izraeli (2000; 2003) records the event history and impact of legislated affirmative action in Israel, illustrating how affirmative action programs can be achieved in paradoxical political circumstances. Izraeli (2003) concludes that the construction of a quota system must be carefully considered, as it may inadvertently result in being honoured in the breach. In the Israeli Labour party a 20% quota for women in the party hierarchy resulted in women getting fewer votes, with the system protecting a handful of influential women. In the campaign to introduce affirmative action legislation, women lawyers working with the constitutional committee rejected quotas as stigmatizing them, fearing that the awarding of preferential appointments threatened to devalue hard-earned individual achievements. The prevailing legislation was ultimately legitimated in terms of the value-in-diversity discourse and that women's human capital merited their appointment which was denied to them by discrimination and political patronage. However, the wording of the law was sufficiently ambiguous for male politicians to continue to ignore it, and court action was eventually taken reversing some appointments and forcing the selection process to be re-opened. Izraeli (2003) points out that there were:

> strong structural and cultural constraints working against women directors who championed the cause of women in the respective firms. The women [already present] did not perceive themselves as appointed either to represent women's interests or because they were assumed to have a special woman's perspective, but because of their similarity to men (Izraeli, 2003, p.122).

Between 1993 and 1998 Izraeli (2003) reports significant improvements in boardroom gender balance, but the long term effect of this legislation was to keep Israeli women directors locked in a gendered social order, reflecting the political imperatives of a country in transition from a colonial to a civil society with strong ethnic and religious groups choosing between liberal and ethno-nationalist discourses (Shafir & Peled, 1998).

The Scandinavian countries, with Norway in particular having introduced quotas, are being closely watched. An analysis of the political processes involved and the several years it took to implement in Norway reveals that widely accepted notions of equity were not sufficient to produce change (Hoel, 2008; Huse, 2007). Only when coupled with legislation designed to improve board governance following extensive public debate and several changes of government and after a number of years of grace, were board quotas finally implemented when it became apparent that change was not going to happen voluntarily. Norway is now approaching the phase of compulsory enforcement and sanctions and is seeing consequences such as 'aunt' boards appointed to comply with the law, but the women directors so appointed not expected to be active directors (Huse, 2007).

The other European country to introduce quotas is Spain, which from 2007 introduced wide-ranging laws dubbed the 'Equality Law' with an eight year implementation time period. One of the most controversial provisions of this law is that boards of corporates must achieve balanced membership, that is, gender balance of 60/40 of either sex. With a high rate of churn in Spanish listed companies of over 50%, issues over the supply of qualified candidates have been raised, with a corresponding increase in initiatives to empower aspiring directors (de Anca, 2008).

Spain and South Africa were both subject to conservative and repressive political systems until the late decades of the twentieth century, which may partly explain the move to legislated affirmative action in each country. Spain was ruled by a conservative military dictatorship for four decades where it was illegal for women to work, own property, open a bank account or travel without their husband's permission. The death of General Franco in 1975 led to growing female emancipation, known in Spain as the 'destape' or 'taking the lid off' (Campbell & MÍnguez-Vera, 2008).

In South Africa a political system of legal racial segregation, known as apartheid, was enforced by the National Party government from 1948 to 1994. Patterns of discrimination against women were racially determined. Black women had very few or no legal rights, no access to education and no right to own property.

> Not only are African, Coloured and Indian women denied political rights, but they are also in many parts of the Union denied the same status as men in such matters as the right to enter into contracts, to own and dispose of property, and to exercise guardianship over their children (South African Women's Charter, 1954).

With the change in government in 1994 following universal franchise, this discrimination fell away. The situation of women board directors in South Africa is an example of intersection issues where race and gender combine and is globally unique. The South African legislated affirmative action regime specifically promotes the economic advancement of Black women, a group that includes Black, Coloured and Indian women, but excludes White women and women of Asian origin. The Broad Based Economic Empowerment Act of 2003 specifies in Clause 2d that its objective is to "increase the extent to which black women own and manage existing and new enterprises, and increasing their access to economic activities, infrastructure and skills training".

With this legislation it would be expected that South African women directors would hold a greater proportion of board seats than women directors from countries with no affirmative action program. The 2009 Business Women's Association annual census shows that women directors of all races in 380 Johannesburg Stock Exchange-listed (JSE) companies and State Owned Enterprises (SOEs), show the same low percentages as their global counterparts, marginally up from 13.1% in 2007 to 14.6% in 2009, having increased from 7.1% in 2004 (BWA Census, 2009; BWA & Catalyst Census 2004). The 2008 BWA report authors ask why the yield of female leaders is so low in a country where 5.3 million working women produce only 1227 women in executive management positions, 419 directors, 13 CEOs and 13 women board chairpersons whereas 7.3 million working males produce 3618 executive managers and 2505 male directors. Similarly to New Zealand there are greater proportions of women directors in the state sector: the percentage of women directors in South African SOEs is 40.5% compared to 12.6% in JSE-listed companies. All the South African SOEs have three or more female directors, while only 8.2% of JSE-listed companies do (BWA Census, 2008).

The impact of the Black Economic Empowerment program across the monitored racial groupings is slow, but observable, in South African boardrooms. April and Dreyer (2007, p. 69) report that "with the power-pie being sliced up under Employment Equity legislation, black women are the big scorers and white women have now found themselves almost at the back of the queue". As a percentage of women directors from 2005 to 2008, Black women directors increased from 48.4% to 57.3%; White women directors decreased from 43.8% to 33.2%; Indian women directors increased from 3.2% to 5.5% and Coloured women directors marginally decreased from 4.9% to 4.1% (BWA Census, 2008). From these figures it can be concluded that the percentages of female directors is remaining relatively static with the racial percentages slowly changing at the expense of one group of women directors to another.

The South African, Israeli and Norwegian experiences with legislated affirmative action indicate that it is unrealistic to expect existing boards to appoint women or individuals of other racial groups without stringent economic, judicial or statutory incentives. Passing legislation is insufficient without monitoring and enforcement. This thesis suggests that a better understanding of the structure and functioning of director networks could set boundaries with reasonable expectations of success in future affirmative action attempts.

2.3.1.2 Incremental change school

The incremental change school believes that women are different in attributes and abilities to men, therefore women must change themselves to be more similar to men if they aspire to board appointments. The locus of action for change is in women directors themselves, who must persuade businessmen to accept them into management teams and onto their boards, once women acquire the necessary human capital (education, qualifications or experience) or possess the required social capital (social or networking). This research implies that there is no limit to what a determined woman could achieve through her own merit.

Early WOB research generally falls into this category by comparing successful women directors to their male colleagues, highlighting deficiencies of human and social capital and making suggestions as to how aspiring women directors could emulate their more successful sisters in meeting the expectations of male directors (Burke, 1997a; Burke, 1997b; Burgess & Fallon, 2003; Burgess & Tharenou, 2001; Joy, 2008; Pajo, et al., 1997; Shilton et al., 1996; Singh et al., 2001). Experience-based bias researchers established that women were equally well qualified as men and that board appointments or appointment to board committees was subject to gender bias (Bilimoria & Piderot, 1994). Sex-related evaluations that value male directors above female directors with the same qualities and qualifications were found to operate most powerfully against women directors in ambiguous situations.

In a study investigating the factors crucial to attaining a board position, Sheridan and Milgate (2005) stressed the similarities between the views of Australian men and women directors recounting the similar factors that led to their success, that is, the need for a strong track record, a good understanding of business principles and business contacts. However, women directors highlighted the need for visibility and family connections. The need for visibility or a 'name-brand' is an attribute that women have to acquire for themselves over their careers. It is described as a proxy for past experience that reassures hiring boards of the suitability of the individual candidate and an important factor in the USA, UK, Australian and New Zealand corporate scene (Daily, Trevis Certo & Dalton, 1999, 2000; Vinnicombe et al., 2000; Sheridan & Milgate, 2005; McGregor, 2000). Daily et al. (2000, p.19) conclude that a bias for name-brands may reflect a "reliance on a core set of women for Fortune 500 directorships" leading to multiple directorships. This has implications to be discussed later for Glass Network theory.

The recent research focussing on the road to the boardroom through ingratiating behaviour falls into the incremental change category. Westphal and Stern (2006) show that increased flattery, opinion conformity, and favour-rendering by managers towards their CEOs will be more likely to result in board appointments at other firms where their CEO serves as a director or is connected through a board interlock. This behaviour triggers a similarity-attraction response in the flattered individual. 'Social fit' or conformity to the norms of social interaction is an important criterion for selection onto corporate boards and aspiring directors who signal such conformity in submissive and deferential behaviour are more likely to be successful, especially if they lack the elite indicators of social status. Westphal and Stern (2006) see this as especially important for first time board members, with different factors being more influential for those already holding outside board appointments. In a further study, Westphal and Stern (2007) found the situation to be more complex for minorities and women, with ingratiatory behaviours being less rewarding and punishment greater for engaging in controlling behaviours.

In another study, Westphal and Khenna (2003) found that directors who participated in actions that limited managerial autonomy at a particular firm, such as making changes in board structure that reduced the CEO's control over decision making, experienced 'social distancing' from directors at other firms and they were less likely to be invited to informal meetings, their input and advice was solicited less often, and others were less likely to build on their comments. They concluded that board control over management violated social norms of directors' conduct, resulting in social sanctions. Suggestions to change board diversity may be seen as a form of limiting managerial control, and directors anxious to avoid social distancing will refrain from suggesting this, while not challenging CEO suggestions for new board appointments.

Promoting women directors is not seen as part of social norms and this non-conformist behaviour is avoided. Research that has shown that one of the barriers faced by aspiring women directors is the fear that women directors will want to raise gender matters at board level or have a 'women's agenda', or want to discuss 'women's issues' (family care or health benefits), or want to 'level the playing field for women' in the organization (Bilimoria 2000, p.32). In refusing to espouse an activist role representing or championing women in the boardroom, women themselves wish to be seen as professional that is, have modified their behaviour through extensive vocational training, and "rather it was their similarity to men that entitled them to be included in the boardroom" (Izraeli, 2000, p.93). It is suggested that the 'queen bee' concept, (to be discussed later), describes women directors with two or more seats, who adopt the behaviour patterns of male directors, and are perceived as violating the norms of feminine behaviour by behaving in an imperious manner. Seeing other women as competitors, queen bees do not champion aspiring directors of their own gender.

Japanese corporates represent an extreme of conformity to male gender norms, illustrating this point further. Renshaw (1999) suggests that the idea of women managers is 'incomprehensible' to Japanese men older than 40 and that major corporations at one extreme follow a policy of hiring only male graduates. At the other extreme, many Japanese women abandon the corporate track and start their own businesses in environments more open to women. Despite Japanese women moving into management and the boardroom, with numbers doubling in ten years, their presence is perceived as 'invisible', with exceptional women having single-handedly to overcome cultural, organizational, and personal barriers. Birth order and the lack of an older brother appear more significant in Japan than Western countries, where such women are given the resources and attention lavished on boys in other families. The few who succeed are moulded by circumstance over a long period of time into habits of business success appropriate in Japanese culture (Taylor, 2000).

In global female director comparisons, Japan appears very low in the rankings of percentages of women directors (2004 0.7%; 2007 1.3% of the Fortune Global 200 companies) but from a global perspective Japanese companies are disproportionally represented in the rankings of the largest companies (Corporate Women Directors International, 2004 and 2007). Japanese companies with their all male boards are therefore likely to skew global director data and reduce gender diversity. Japanese companies have sufficient foreign directors or Japanese directors on Western boards to ensure they are linked to global director networks.

2.3.1.3 Value-in-diversity/Business case for women on boards of directors school

The value-in-diversity school focuses on the positive nature of the differences between men and women. Diversity is valued for its own sake and, if harnessed correctly, will result in better corporate performance and increased shareholder value (Carter et al., 2003; Erhardt et al., 2003; Nguyen & Faff, 2007). The economic implications justify appointing more women to a board even though diversity brings its own demands with it. The locus for change thus resides in male directors and investor/shareholder activists of either gender.

This school assumes that fewer men will have board appointments, but the corporate sector will be compensated for this by being more profitable, along with the social benefit of being more equitable. Farrell and Hersch (2005) found evidence to suggest that women were appointed at the expense of male directors, but the addition of another woman director to a board was negatively related to the number of women on the board the previous year. Women directors also tended to replace departing women directors.

The 'varying ratio' school suggests that women behave differently in the boardroom depending on whether there is a single token woman or whether the gender balance approaches parity (Erkut et al., 2008). The individual woman director actively suppresses certain behaviour when she is the lone woman on the board, presenting a persona that conforms to the board dynamic. The varying ratio theory suggests a minimum of three women is the critical ratio, giving the women directors the confidence to express themselves more freely and openly, negating the pressures of gender norms on boardroom behaviour (Konrad et al., 2008; Erkut et al., 2008). With one woman, Rosener (1995) calls this the invisibility phase, with two the conspiracy phase and with three or more women, the normality phase. In the normality phase, the influence of women directors should be translated into measurable effects.

The varying ratio school urges the appointment of more women to boards that already have a woman director. To do this, nominating committees should "not try to be gender blind" and insist that "candidate slates always include qualified women" (Erkut et al., 2008, p.231). The locus of change for this school is both in the women and the male directors who make board appointments.

It should be noted that the number of companies with these critical ratios are small. Campbell and MÍnguez-Vera (2008) point out that a 2006 Catalyst study found only 84 of the Fortune 500 companies had achieved this critical mass of women on their boards, a slight increase from 76 in 2005. From a network point of view these women are the connector directors and core members of women-only director networks, but very little attention has been paid to the women who form the critical mass on these boards.

Erkut et al.'s (2008) study, which was based on interviews with 50 women from Fortune 1000 companies, does not provide quantitative evidence, but the varying ratio school does find some support in studies showing that women tend to serve on better performing boards (Carter et al., 2003; Farrell & Hersch , 2005). In an early exploratory study into both female managers and directors, Schrader, Blackburn and Iles (1997) found the higher the percentage of women managers the better the company's financial performance; no relationship between the percentage of women on top management teams to financial performance; and unexpectedly a weak negative relationship between women directors and financial performance. This study, which examined 200 companies from the Fortune 500 companies, took place in 1993; few firms in the sample had more than one woman on their boards.

In a later study of the diversity/firm performance relationship by the same authors (Erhardt et al., 2003), a mixed measure was used to calculate diversity, that is, a percentage calculation of race, ethnicity and gender combined and averaged over two years. Harrison and Klein (2007) question the validity of such measures, as the underlying diversity constructs may be different. Although director diversity was positively associated with both return on investment and return on assets, the methodology used precluded a finer analysis determining the point at which the number of 'diverse' directors became significant.

Carter et al. (2003) compared a 1997 sample of US Fortune 1000 companies with no women on their boards to companies with two or more women on their boards, finding significant differences in their matched and unmatched groups. Companies with multiple women are larger, have more minority directors and fewer insiders and greater firm value as measured by Tobin's Q. Regression analysis confirmed this result using the percentage of women as the dependent variable.

Campbell and MÍnguez-Vera (2008), in a study of Spanish directors, found a positive relationship between gender diversity (measured by the percentage of women and by the Blau and Shannon indices) and firm value. They concluded that the presence of female directors affected firm performance rather than the reverse direction of influence. Their findings will find acceptance, they believe, in Spain's current affirmative action programs even though Spanish business is characterised by a high proportion of family firms with the likelihood that many women directors are family members whose qualifications may not translate directly into performance. Their study stands in contrast to other non-US studies done in Scandinavian countries where no link between gender diversity and firm performance has been found (Rose, 2007). It should be noted that the Rose (2007) study found that the percentage of women on Danish boards in the sample period of 1998-2001 was only 4%, with only 22% of companies having one woman on their boards. A finding of no correlation to firm performance is thus not unexpected. Rose (2007) did find surprising the low numbers of women on Danish boards as the country has a strong climate of egalitarianism.

Given the complexities relating to the operationalisation of diversity and firm performance measures as well as intertwined theoretical constructs, value-in-diversity research has to be regarded as in its infancy.

2.3.2 Glass Network theory: Using metaphors to unify and extend WOB theory

I propose a fourth approach, Glass Network theory, which considers similarities or differences between individual directors as irrelevant, as the rules of network formation and functioning override individual differences. I introduce the metaphor of the glass network to link current WOB research to theories of small-world and scale-free networks. I introduce a second metaphor, a glass net, to conceptualise in a different way the invisible and semi-permeable barriers that prevent male and female minority directors from participating in director networks except in specific proportions.

Apart from the link to social capital theory, there is no research into the networks of women directors, despite social network analysis being a well established research area. The strong research tradition into director interlocks, which are network links under another name, also did not extend to gender. There are two reasons why these areas have been overlooked by researchers interested in gender.

Firstly, the interlock research primarily sees board and director interlocks as channels of influence and communication providing access to resources. As women directors are perceived as powerless and peripheral by interlock researchers, they have assumed that these channels are not available to women, therefore women-only interlocks and networks are non-existent.

Secondly, the WOB literature has focussed on barriers to the boardroom. A barrier by definition prevents the development of connections to other directors that will result in board appointments. This focus on blockages in the path to the boardroom has culminated in the widespread use of the glass ceiling metaphor to describe the transparent barriers that keep women out of the boardroom. This metaphor has been extended to include glass houses, glass cellars, glass corridors and walls, glass floors, glass elevators and the bizarre sounding glass cliffs. Part of the success of the glass ceiling metaphor may be ascribed to the ease with which it has been extended to multiple aspects of women's careers from the factory floor and office to the boardroom.

Baxter and Wright (2000, p. 275) suggest that the "glass ceiling is one of the most compelling metaphors for analyzing inequalities between men and women in the workplace". The glass ceiling metaphor incorporates an emotional dimension best expressed in the drawing of the angry female figure standing on a chair hammering on a glass ceiling (Hymowitz & Schellhardt, 1986), and reproduced in Figure 1 (p.ii). Eagly and Carli (2007a; 2007b) believe that metaphors matter because they are part of the storytelling that can compel change in organizations. Their own metaphor, that of a career labyrinth, where the lack of women leaders is the result of a number twists, turns and dead ends in the route to the top rather than a single barrier, has not enjoyed the same uptake even though it may be descriptively more accurate.

Despite the popular uptake of the glass ceiling concept, a search of the literature shows that no researcher has linked this metaphor to social networks as glass networks. In framing gendered director networks this way, attention is drawn to a burgeoning field of knowledge about small-world and scale-free networks that may ultimately lead to new kinds of interventions in gender inequity.

Implicit in the term 'net' are both concepts of linking and catching, and both senses of the word have been used in diversity research. The concept of 'invisible nets' that catch women is also current in gender focused literature. In relation to gendered beliefs of status and hierarchy that create stereotypes, Ridgeway (2001) concludes that:

> Gender status beliefs create multiple, nearly invisible nets of comparative devaluation that catch women as they push forward to achieve positions of leadership and authority and slow them down compared to similar men. In my view, this unacknowledged network of constraining expectations and interpersonal reactions is the principle cause of the 'glass ceiling'. The cumulative effect of its multiple, often small effects, repeated over many contexts throughout a career, is to substantially reduce the number of women who successfully attain positions of high authority in the work world, especially in occupations and contexts not culturally linked with women (Ridgeway, 2001, p. 652).

Invisible nets have also been conceptualised as safety nets around women and children (Currie, 2006). As disadvantaged sectors of populations, policy makers perceive women and children as needing protection and barriers from harm. By catching the most vulnerable sectors of the population before they 'fall through the net', social intervention is justified and promoted. WOB researchers likewise advocate social intervention to ameliorate board gender inequities to avoid losing talented women, making the metaphor of a glass net appropriate in the context of women directors.

Another similar metaphor that has been used in management research with limited uptake, is that of a 'web'. This has been conceptualised as both a structure and as patterns of interacting forces that limit the participation of women. Helgesen (1995) argues that women prefer and flourish in 'webs of inclusion', an organic form of a non-hierarchical social structure that constantly changes to meet the demands of the postindustrial knowledge age. Powell (1999, p. 345) has suggested that "an intricate web of forces has influenced the proportions of women in management overall and in top management and will continue to influence the status of women in management in the future".

The concept of a glass net can also be used to describe a structure that creates different levels in a director network or distinguishes between classes of directors. It can also be used to describe a pattern of behaviour or interacting forces that achieve the exclusion of most women and men from elite director networks and inner circles (Useem, 1984).

Before introducing Glass Network theory, several related schools of thought are reviewed as Glass Network theory is rooted in these disciplines.

2.3.3 Scholarly antecedents to Glass Network theory

Glass Network theory is derived from network theory, which has its antecedents in chaos and complexity theory concurrently with advances in mathematical graph theory commencing in the 1950s (Waldrup, 1992; Williams, 1997). It is also a form of social network analysis, which in turn had its origins in the late 1960s work in the social psychology of groups and the sociological and anthropological study of factories and communities (Freeman, 2004; Scott, 2000). The late 1990s saw the development of small-world and scale-free network theory, using concepts and techniques from physics and information science, which were also tested against social networks (Newman et al., 2006).

Traditional social network theory grew incrementally from the 1970s, but the new network perspective, driven by mathematicians and physicists following Watts and Strogatz seminal paper in Nature (Watts & Strogatz, 1998), has grown dramatically. The work of Duncan Watts at Cornell University and the early work by a group around Albert-László Barabási at Notre Dame University was followed by several hundred papers on the topics of small-world and scale-free networks, and other related concepts for example, power laws. In the space of ten years, spurred on by the availability of powerful and inexpensive computers analysing large datasets, researchers across mathematical, biological and social sciences have made “substantial progress on a number of previously intractable problems, reformulating old ideas, introducing new techniques and uncovering connections between what had seemed to be quite different problems” (Watts, 2004, p.243).

The development of this new school of network analysis provoked a backlash from traditional researchers in social network analysis. Freeman (2004, p.165) in a historical review of developments in this field notes laconically that Watts and Strogatz "managed to succeed in interesting other physicists in the structural approach to the study of social phenomena" but, he believed, they knew very little about the existing social network research tradition before publishing their results.

Finding that these two groups of scholars remain largely independent of each other, Freeman (2004, p. 66) sees the consequences of this split unfortunate as "it necessarily leads to wasted effort – re-inventing existing tools and rediscovering established empirical results". In an effort to be conciliatory and pay due homage to preceding academic traditions, Watts (2004) acknowledges that the flow of ideas has been bi-directional, with many of the core ideas (as well as applications), coming from sociology. He sees "physicists as being marvellous technicians but mediocre sociologists", requiring guidance from other disciplines and in particular from sociology as to "the interpretation of empirical and theoretical findings, particularly in the context of policy applications, and also in suggesting measures and models that are increasingly relevant to the important problems at hand" (Watts, 2004, p.264).

I suggest that Glass Network theory takes on Watt's challenge by applying recent developments in the fields of small-world and scale-free networks to the important problem of gender equity and board diversity, presenting measures and models that can be used to monitor intervention attempts and guide policy applications. It answers in a fresh way questions such as 'Are female director networks similar or different to male director networks?' and 'Where are women directors to be found in director networks?'. Glass Network theory also proposes answers to questions that have been previously asked such as 'Do director interlocks matter?' (Haunschild, & Beckman, 1998) and 'How do old boy networks resist change and perpetuate the status quo?' (Davis & Thompson, 1994). Several other scholarly traditions have been grappling with similar questions. Glass Network theory is also rooted in the schools of gender studies, economics, business science and psychology. There are five specific focal areas, namely 'director interlocks', 'director busyness theory', 'old boy' networks and social elites, 'glass ceiling' theory and its variants and 'queen bee' theory.

2.3.3.1 Director Interlock theory

An interlocking directorate occurs when a person appointed to the board of directors of one company, accepts an appointment to the board of another company. The other directors on that board are automatically linked to each other through the common board member. Easily constructed from highly reliable public sources, director interlocks have become a primary indicator of intercompany network ties (Mizruchi, 1996). It is necessary to distinguish between company interlocks and director interlocks. Director interlocks are of interest as there are political, legal and fiduciary responsibilities such as the principle of avoiding conflict of duties and interest. Securities regimes require the disclosure of executive compensation where there are multiple directorships or seats (Johnson et al., 1996).

In the 1970s and 1980s there was concern that director interlocks were increasing, with undue influence being exerted by groups of businessmen. Interlocks were seen as reducing the opportunities for access to board positions, leading to poor business decisions with director's attention spread too widely amongst multiple companies (director busyness theory), concentration of economic power in the hands of a few (old boy networks) and providing opportunities for collusion and anti-competitive behaviour (Tan & Keong, 2006).

The extensive director interlock literature can be grouped into three streams of investigation; namely, interlocking seats as a form of managerial control, as a form of class integration or hegemony, and finally as a tool for reducing uncertainty (Davis, 1993, 1996; Mizruchi, 1996). Director interlocks were seen by agency, resource and social capital theorists as being the mechanism through which boards exerted their influence, sourced information, channeled capital flows, made acquisitions as co-optive mechanisms (Burt 1979; Scott, 2000) and disseminated governance practices such as the 'poison pill' (Davis, 1991). A common theme in the literature is that interlocking seats facilitate political cohesion among corporate elites or 'inner circles' and encourage the flow of valuable (but general) information on business practices across multiple companies on multiple topics (Useem 1984). This is supported by Burris's (2005) recent work which found that influence and communication (as illustrated through the political campaign donations of individual directors, not corporate donations) is not at the direct dyad level of two directors on a common board, but through extended chains of indirect ties to other directors.

In the sociological literature these indirect ties are known as 'weak ties' and are a property of the group in which the individuals are embedded. Only by looking at the network structure can it be ascertained if the ties are weak or strong. Granovetter (1973) introduced the phrase 'the strength of weak ties' to illustrate the power of indirect ties in producing social cohesion. He later demonstrated how weak ties enhance the prospects of getting a job (Granovetter, 1995). Barabási (2003, p.42) calls this paper "one of the most influential sociological papers ever written" and Watts (2003, p.50) believes it to be a "remarkable premonition of what is now the new science of networks." These concepts of the power of weak ties have moved into the WOB literature and underlie articles that advise aspiring women directors to use their networks to gain board nominations (Sheridan, 2002).

The emphasis in Granovetter's work on social embeddedness has had a continuing legacy in interlock research, with the presence of director interlocks acting as an indicator of social embeddedness and a mechanism for corporate reform (Davis & Greve, 1997; Davis & Thompson, 1994; Granovetter, 1985). Successful governance reforms, whether based on incentivisation of executives or legislative reforms such as the Sarbanes-Oxley regime, are filtered through the social structures in which boards are embedded. Davis and Thompson (1994) acknowledge that these may not have the direct effects intended. In network terms this is adaptive behaviour on the part of the director cadre and every possibility exists that such adaptations may be perceived as contrary to intentions.

Australasia has not been exempt from concerns of undue influence through board interlocks. Both Australia and New Zealand's director and company interlocks have been the subject of a number of repetitive studies dating from 1970 onwards, reflecting an intense interest by economists and management scholars in company control, potential conflicts of interest, hegemony of financial institutions and competitiveness (Alexander, Murray & Houghton, 1994; Firth, 1987; Murray, 2001;

Roy, Fox and Hamilton, 1994). Fluctuations in the numbers of companies listed on the New Zealand stock exchange were observed and explained as being due to stock market crashes, regulatory changes, takeovers and mergers. High levels of director interlocks were seen as desirable collusion to increase sector size in a small market to promote international competitiveness (Firth, 1987). The subsequent decreases in the numbers of directors, seats and companies and reduced interlocks observed by Roy et al. (1994), were regarded as undesirable, concentrating control of the economy in a small group of companies, with insurance companies dominating the interlock pattern. These papers are largely descriptive and thin on theory, which is focused on political or economic control.

In an update of earlier studies, Walker and Borrowdale (1994) found a marked drop in the number of New Zealand public listed companies from 221 to 133, while the number seats fell from 1143 to 666. This fluctuating pattern is reported here as it may be a persistent pattern to which the director network adapts. The authors distinguish between potential and actual interlocks and stress that the existence of an interlock does not imply that a relationship exists or that influence flows between interlocked companies. Poor methodological descriptions hamper these studies as it is unclear how potential interlocks are counted beyond adding up the number of directorships held by individual directors. It is not stated if these are limited to listed companies or include all directorships. This analysis of potential interlocks is of historical interest as they later form the basis of probability distributions favoured by scale-free network researchers, but not utilized in this thesis.

These studies do report the distribution of seats per director or the ‘seat spread’. The results in these studies are re-analysed in Tables 3 (p.114) and 5 (p.118) and presented in Figures 16 and 17 (p.118 and 119) in Section 3.2.3.1. Firth (1987), Roy et al., (1994) and Walker and Borrowdale (1994) observed the director network, but did not appreciate the significance of the patterns that they reported. These articles do not mention director gender and the assumption is that the numbers of women are so few as to be irrelevant.

2.3.3.2 Director Busyness Hypothesis

A sub-school of director interlock research is known as the director busyness hypothesis (Ferris, Jagannathan, & Pritchard, 2003; Kiel & Nicholson, 2006). As part of the movement for governance reform, suggestions were made that a director with too many directorships undermines the ability of the board to monitor and control management. This is particularly true of CEOs and inside directors, but opinion is divided on imposing limits on outside directors. Shareholder associations now give recommendations as to reasonable workloads. For example, the Australian Shareholder Association concludes that directors who sit on more than five boards are potentially doing a disservice to the companies' shareholders (Kiel & Nicholson, 2006).

Ferris et al., (2003) found that firm performance in 1995 in large US companies had a positive effect on the number of appointments held by a director and no evidence that 'multiple directors' or connector directors shirk their responsibilities to their appointed board committees. Furthermore, they concluded that directors who serve in larger firms and sit on larger boards are more likely to attract directorships. From a network perspective, this phenomenon is known as 'preferential attachment', where a director is more likely to be invited to join other boards with a successful track record and the corollary, not have board appointments extended if associated with unsuccessful companies.

Murray (2001) found in the Top 30 Australian companies that, contrary to expectation, there was not a dense pattern of interlocking directorships given the financial ownership of the top 30 companies. Kiel and Nicholson (2006) found no link in Australian listed companies between multiple directorships or multiple chairmanships and firm performance as measured by an investor returns index that controlled for industry risk. The seat spread across all ASX listed companies ranged from 4 to 38 with a mean of 15. These authors took the position that limits to the numbers of seats should not be imposed. However, from a network perspective, it is their other findings that are of more interest. Of 5468 directors across all ASX listed companies, 4317

(79%) held one seat, while a further 734 (13%) held two seats and the remaining 8% held three or more seats.

Kiel and Nicholson (2006, p.539) comment that in the ASX Top 200 companies there are “relatively low levels of multiple directorships” finding that 976 directors held one or two directorships (83 per cent) and 35 individuals (3 per cent) held five or more directorships. The concept of relatively low levels is misleading as it is not related to what would be its corollary of ‘high’ levels. From a Glass Network perspective, combining categories in the seat spreads, as done by Kiel and Nicholson (2006), obscures the relationship of each level to the other and conceals the underlying patterns. The seat spreads reported in these studies are further analysed in Table 7 (p.125).

2.3.3.3 Old boy networks and social elites

Old boy networks have historical roots extending back to the formation of the first companies (Micklethwait & Wooldridge, 2003). Directorships were seen as conferring favours on old friends, who had honorary or advisory roles or were appointed for the prestige viz. “ornaments on the corporate Christmas tree” (Burke, 1997a) or “guinea men” who were paid a guinea a meeting and given lunch, on appointment to British boards. Old boy networks originally refer to informal associations of former pupils of elite male-only schools who use these connections to advance business and career activities. As a way to mutually recognize each other, they wear the ‘old school or university tie’. The term has been extended to cover groups, for example, gentlemen’s clubs, which work to preserve their elite status and control access to channels of power and resources (Maddock & Parkin, 1993).

The extensive sociological literature, particularly the Weberian schools focusing on bureaucratization and hierarchical forms of organization, extended these concepts of elite political control into business organizations and managerial control (Escover, 1994). Another influential political concept is that of oligarchy, from which flows Robert Michel’s (1911) ‘iron law of oligarchy’. This states that no matter how democratic or egalitarian an organization is at its inception, as it grows in size, oligarchies or small groups of leaders will emerge to run the organization. The mechanics of running large organizations require this form of leadership, which is self-reinforcing, automatically creating social elites. Large companies generate and reinforce leadership by the few who control access to resources, power and privilege and by definition boards of directors are identified as oligarchies (Caldarelli, 2007).

These “small important but insulated groups of men” (Burke, 1997a, p.125) use two mechanisms to exert control over younger men and women, namely ‘paternalism’ and ‘informalism’ (Collinson & Hearn, 2003). Notions of paternalism extend to the protection and cherishing of women provided they remain within the confines of female identities, while those of informalism relate to the building of in-groups that exclude women through the currency of humour, alcohol, sport, and cars. Travis and Collins (1991) refer to this behaviour as ‘old boyism’, but prefer the gender neutral term of cronyism as this behaviour is not limited to men, but rather a characteristic of social elites. Kantor (1977) terms this behaviour ‘boundary heightening’, the act of a dominant group exaggerating differences between themselves and tokens. Appelbaum, Audet and Miller (2003) attribute malign intentions and active resistance to women by old boys in corporate organizations, who generate institutional impediments to stall women’s advances and at a cultural level, foster solidarity between men which sexualizes, threatens, marginalizes, controls and divides women.

Old boy networks can serve a useful social function by informally authenticating the qualifications, aptitude or character of its members (Taylor, 2000). As old boy networks are necessarily exclusive in nature, qualified individuals outside the network, such as women, are pooled with unqualified individuals. Another feature of exclusive networks is that new members are incorporated through pre-existing relationships with other members rather than on merit, limiting the benefits of membership to a limited range of qualified individuals. Nomination, occasionally by formal committee (Conyon & Mallin, 1997) or ‘shoulder tapping’ (McGregor, 2003) is the favoured method of appointment to boards of directors, with Burke (1997a) concluding that this method indicates the presence of old boy networks in operation. Saloner (1985) saw old boy networks as screening mechanisms in the informal aspects of matching a job applicant's intangible characteristics such as motivation and prospects for success, to a vacancy. He noted that this function has also been extended to 'old girl networks'.

Having searched the literature for old boy networks, I conclude that there is no theoretical home for the concepts relating to this term as it is a vague and peripheral term that diffuses the discourse of discrimination and gender inequity. There are no clear measureable definitions or methodology to use to identify individuals belonging to an old boy network. The question continues to be asked how will the new technologies of the 21st century impact existing old boy networks, assuming that they exist at all (Gamba & Kleiner, 2001).

Having said the above, there is one discourse where the concept of old boy networks is emerging as a strong counterpoint to the major theme of the discourse, namely the 'Glass Ceiling' discourse. It is from this discourse that the concept of Glass Networks is directly derived. Where a glass ceiling or transparent but impenetrable barrier to women's or minorities advancement is said to exist, the group of men creating and maintaining this barrier is an old boy network (Broome, 2008; Davidson & Cooper, 1992; Klenke, 1996; Li & Wearing, 2004). For example, Jackson, (2001, p.32) in an article on women middle manager's perceptions of glass ceilings states that "in most organizations that are male-led, the good old boy network still exists, and studies show that women have been largely excluded from these networks". He further states that "women are not only excluded from informal networks, but also from important meetings where decisions are made. Women tend to be given lower level projects with less visibility. Women's ideas are frequently discounted or ignored, creating the invisible woman syndrome". Such statements reinforce Moore's (1988) findings that even after reaching elite positions, women are still 'outsiders on the inside' and often feel invisible or excluded from informal relationships and networks of all-men colleagues.

2.3.3.4 The Glass Ceiling and its variants

The implicit question that drives most Women on Boards research is why women, who appear to be succeeding in many other spheres in Western society, appear unable to break through into higher business echelons. If this is not due to any inherent deficiencies in aspiring women directors, then the assumption is that some form of external barrier prevents their progress up business hierarchies and into boardrooms. Burgess and Tharenou (2002), in a review of women board members in Australia, Canada, USA, New Zealand and Israel, 'blamed' the low numbers on the 'glass ceiling'.

The term 'glass ceiling' was coined in the mid 1980s and brought into the lexicon through an article in the Wall Street Journal (Hymowitz & Schellhardt, 1986). Figure 1 (p.ii) taken from this article, shows the now famous image of a woman executive trying to penetrate a glass ceiling. The concept of an invisible barrier was further developed in the first book on the topic by Morrison, White and Van Velsor (1987). By definition a glass ceiling is a transparent barrier in businesses and organizations that has prevented females and people of colour from gaining access to higher level positions, while all observers could see that such positions are invariably filled by white males. The glass ceiling has also been viewed as an "impermeable barrier that blocks the vertical mobility of women" (Baxter & Wright, 2000, p.276).

Initially, the glass ceiling referred to the barrier into general management, with Morrison et al. (1987) describing an additional wall blocking the way to the executive suite. They saw the glass ceiling not only as an individual barrier, but a group barrier, where women were kept from advancing higher because of their gender. Women directors are not mentioned at all in the early literature. Similarly, in a review of the progress of New Zealand women from 1975 to 2004, Herd (2005) reported positively on the cracks in the glass ceiling and female achievements in previously unheard of spheres, but also failed to mention women directors.

The Glass Ceiling phenomenon was quickly described as particularly persistent. This is also linked to frequent references of 'glacial' change (Joy, 2008; McGregor & Fountaine, 2006, Ross-Smith & Bridge, 2008). The metaphor of a glacier, that is, a large mass of transparent ice that moves very slowly, is invoked to express frustration at the slow pace of change. The glass ceiling is also described as an 'effect' dependent on a number of organizational variables ranging from occupational differences, levels of authority, positions in corporate hierarchies or pay disparities (Cotter, Hermsen, Ovadia & Vanneman, 2001). In exploring the notion that glass ceiling effects are more severe at the top of hierarchies and become worse later in careers, Cotter et al. (2001) found evidence that glass ceilings are gendered phenomena with racial inequalities for minority men not following the same patterns.

As a useful metaphor the term quickly passed into common usage. It was absorbed into political agendas, most famously ending up as a political initiative in the USA called the Glass Ceiling Commission established in 1995 to bring down the barriers preventing women from reaching the top of the organization (Gatrell & Cooper, 2007). The Hansard Society Commission in the United Kingdom referred to the fact that:

> for too many [women] there is a glass ceiling over their aspirations – it allows them to see where they might go, but stops them getting there. In any given occupation and in any given public position, the higher the rank, prestige or power, the smaller the proportion of women (Nicolson, 1996, p.101).

2.3.3.5 Glass houses, glass cellars, glass walls and corridors, glass floors, glass escalators, glass elevators and glass cliffs

The term, glass ceiling, has quickly extended its meaning and application. The concept of a 'glass house' was introduced by Morrison et al. (1992), where women who have broken through the glass ceiling felt that their performance was visible to all and "dreaded even the thought that they might fail on the job because it would not only effect their own progress but also limit the opportunities given to the women who came after them" (p. 17).

Their study identified three levels of pressure facing a woman wanting to become a general manager or executive. Firstly, the intense demands of the job of manager, secondly the pressure of being a woman/minority, and finally the pressures of the home role without the support systems available to most married men. The authors also concluded that most of the successful women they interviewed had three 'extras' that the less successful did not. These were credibility and a presence due to some prestigious personal quality, a mentor or 'help from above', and a lucky break of some sort. Levels of pressure have also been identified as 'bottlenecks', (another glass metaphor from glass bottles), which has implications of controlling and limiting the flow of women to senior positions (Akande, 1994; Dalton & Dalton, 2008).

Others, like Arfken et al. (2004, p180) talked of ‘glass walls’ or ‘glass corridors’, which “restrict women to certain fields and positions such as human resources and other staff duties”, but also used the term to apply to the boardroom barrier as the “ultimate glass ceiling”. Sullins (2000) points out that women in the clergy are over-represented in lower status congregational positions consistently over time and throughout their careers as they come up against the ‘stained glass ceiling’. Linehan and Walsh (2000) focus on the international glass ceiling or ‘glass borders’ and the many barriers facing women managers promoted to international positions. Insch, McIntyre and Napier (2008) call the barriers facing expatriate women on international assignments ‘the second pane of obstruction’.

Li and Wearing (2004) consider the existence of a second glass ceiling whereby women who make it to corporate boards do not get appointed to lucrative committees, thus earning significantly less. Bell and Nkomo (2001) acknowledge the glass ceiling as a barrier facing all women, but stress that for Black women it is more in the nature of a concrete wall or ceiling where there is no chance at all in breaking through or even to view the top of an organization.

Others have conceptualized the glass ceiling as permeable to some women at some point in their careers and may reflect greater levels of gender diversity at lower levels in an organization. Bilimoria (2006) found a positive relationship between women directors on the boards of the Fortune 500 companies and the diversity of management teams for firm size and industry type by profit level, number of officers, and number of board members.

‘Glass elevators’ and ‘glass escalators’ are two terms in the literature that extend the glass ceiling metaphor further. These are used interchangeably (with glass escalators being the more common term) to refer to men in traditionally female occupations such as teaching or nursing, who progress very rapidly up organizational hierarchies or young women who also rise faster than their peers into management (Altman, Simpson, Baruch, & Burke, 2005; Howard, 1998). Williams (1992) concludes that under-represented men not only escape the negative consequences of tokenism, they actually receive preferential treatment in the work place as they take their gender privilege with them. He argued that male nurses, elementary school teachers, librarians and social workers ride a glass escalator up internal career ladders.

These discrepancies may be a consequence of ageism operating against older women, with a younger generation of women pursuing career goals more aggressively. Not only is the glass ceiling permeable, it may also be moving and relocating further up the organizational hierarchy. This has also been called the ‘cohort effect’, which is a function of the earlier starting date of groups of women career pioneers in occupations such as engineering versus younger cohorts of women professionals who work in less discriminatory environments and therefore progress faster (Morgan, 1998).

In a comparative analysis focusing on management hierarchies in Sweden, the United States and Australia, Baxter and Wright (2000) hypothesized that the glass ceiling would become more visible higher up corporate hierarchies as a greater negative probability of a manager at a specific level being female. Their research, being the first to quantitatively measure the glass ceiling in this manner, indicated that in different countries the glass ceiling was apparent at different levels, at entry level to management in the US and in the middle levels in Australia and Sweden.

Hultin (2003) also sees glass ceilings as a matter of degree rather than as a dichotomy, finding support for the opposite proposition that women in male dominated careers experience even less job mobility across their careers than women in gender neutral jobs. She points out that the glass escalator hypothesis and the glass ceiling hypothesis rest on notions of discriminatory processes in the workplace, which can be either positive or negative. In this context, Farrell (2005) introduced the ‘glass cellar’ by which women were excluded from the high pay of hazardous jobs and the ‘Catch-22’ situation where women fear to take on physically demanding jobs that a macho male culture makes more hazardous than they need to be. Branson (2007a) found demoted or out of favour male executives, unlike women in similar circumstances, rebound off a ‘glass floor’ to other high ranking senior positions.

Recent glass cliff research by Ryan and Haslam (2005) into gendered board appointments suggests that patterns of appointment are related to the financial performance of the company concerned. Investigating the share price performance of

FTSE 100 companies prior to and after the appointment of directors of both genders, Haslam and Ryan (2005) unexpectedly found that share prices were stable both before and after the appointment of a male director, but companies that appointed a woman director had experienced consistently poor performance in the months preceding the appointment in a poorly performing market. In this extensive data set it was apparent that men and women were being appointed to board seats under very different circumstances. Ryan and Haslam (2007) framed this as a high risk strategy that they called a 'glass cliff' followed by women keen for board appointments and forced into the practice of accepting precarious opportunities in financially unstable companies. Although this research is in its early stages and has not been examined in relation to women directors in other countries, these results appear transferable to experimental conditions and managers in other industries (Haslam & Ryan, 2008; Wilson-Kovacs, Ryan & Haslam, 2006). Explanations for these findings range from women being perceived to be more 'expendable' in the workplace than are men, and thus are deemed to be more suited to risky positions, sexism in the work place, the belief that women are especially capable in risky situations, and a desire to signal change when companies are failing.

Halford and Leonard (2001, p. 120) suggest that the glass ceiling is not a solid barrier, but similar to "geological cross-sectional patterning", where counter-productive layers of influence intersect. These can range from demands of family, traditional expectations and stereotypes, patchy access to networks, mentorship and training versus structural elements in the work place. This metaphor, like the Baxter and Wright (2000) study, suggests that glass ceilings exist at multiple layers in organizations, industries and countries.

2.3.3.6 The Queen Bee syndrome

All these authors acknowledge that a few women have managed to break through to the top levels and these particular women have been of intense interest to WOB researchers (Burgess & Tharenou 2002; Hillman et al., 2008). In 1999, as the first woman chief executive of a Fortune 500 company, (Hewlett-Packard), Carleton Fiorina in a now famous quote claimed that “Women face no limits whatsoever. There is not a glass ceiling“ (Cotter et al., 2001, p. 655). Five years later, in the midst of controversy, the board of Hewlett-Packard terminated her employment and replaced her with a man. This high profile appointment illustrates the strategies and behavioural patterns necessary for women to attain senior appointments in large corporations. These include denying discrimination and claiming success as a consequence of personal attributes and frequently choosing to forego marriage and families.

These behaviour patterns are sufficiently ubiquitous to be recognized as a phenomenon called ‘the queen bee syndrome’. This term has no male equivalent and is derived from bee keeping terminology where the sole egg laying female in a bee hive is known as the queen bee. The characteristic of queen bee behaviour that is encapsulated in this metaphor is the biological necessity for only one bee of this type in the hive and the fight to the death with new rivals (Matheson, 1997; Woodward, 2007). This metaphor has been extended to include women directors who enjoy the position of being the sole woman on a company’s board, but does now incorporate certain behavioural characteristics implicit in the term ‘queen’, that are described in disparaging terms.

Identified as early as 1974, Staines, Tavris and Jayaratne (1974) call the queen bee “the woman who has scrapped her way up in a man’s world, tacitly joins with the traditionally successful woman to oppose the aims of feminism”. Gatrell and Cooper, (2007, p. 66) define queen bees as women who are “protective of their own position and unhelpful and unsupportive of women trying to climb their way up”. Queen bees have personal success on two levels, namely a high status job with good pay along with social success that may include popularity with men, physical attractiveness and a good or influential marriage or family connections. Mavin (2006) suggests that the queen bee concept reflects the gendered nature of organizations with misogyny perpetuating a culture of blaming women for their own apparent lack of success while maintaining the status quo of male dominated organizations.

Davies-Netzley (1998) calls these the ‘women above the glass ceiling’ and compares their personal self-reported reasons for success with those of male colleagues. When discussing what it takes to make it to the top, male executives primarily attribute their success and elite status to their own individual qualities. Davies-Netzley (1998) argues that these men uphold the dominant stratification ideology in the United States by emphasizing that success and economic reward come from individual talent and effort. The significance of peer similarities for success is downplayed in favour of individual talents and qualities. She finds too that top male executives deny the presence of significant race or gender barriers, and partly attributes this to them not having personal experience of discrimination. When male executives consider their female and minority peers they assign the same attributes to them of previous successful track records based on individual talents and qualities.

Top women executives all acknowledge experiencing discrimination and having to adjust behaviour to conform to peer similarities. The tendency of successful women to attribute their success to their own efforts, achieved without any extra assistance or special access to resources, mirrors the prevailing male ideology. The acquisition of advanced degrees and qualifications appears to be an additional strategy used by the successful women in Davies-Netzley's (1998) study to level the playing field.

Thomson and Graham (2005) suggest that there are fewer queen bees in the USA than in the UK and that American women tended to perform better in the UK business scene. This, they suggest, is the result of American women having longer track records than their UK counterparts and their differences make them stand out when appointed to high profile roles in the UK. Part of the queen bee syndrome is a tendency for some senior women to prefer their unique status and to find other women threatening. In response to perceived competition from other women, they then "pull up the ladder behind them" (Thomson and Graham, 2005, p. 163).

Kang, Cheng & Gray (2007) suggest that two factors reinforce queen bee behaviour. Firstly, women are perceived as unlikely to be part of the 'old boy' network, which allows them to be independent (meeting governance requirements for independent directors) but lacking in influence and therefore unlikely to undermine the status quo. Secondly, they may have a better understanding of consumer behaviour, the needs of customers, and opportunities for companies in meeting those needs. Women may therefore be appointed to a board to specifically provide ‘the women's point of view’. To provide this service only one woman is required.

Gender limiting strategies in the boardroom that promote queen bee behaviour and tokenism appear to be a norm. Research by Farrell and Hersch (2005) indicates that departing women directors are replaced with women and the likelihood of a firm adding a woman to its board in a given year is negatively affected by the number of woman already on the board. Kantor (1977) finds that tokenism creates performance pressure to behave in specific ways or situations where gender or aspects of femininity obscure contributions in the boardroom. Token women directors may respond to performance pressures in several ways, including constructing a facade that minimizes peer concerns or developing a persona (mascot, mother figure or jokester) that masks deeper thinking and accomplishment.

Branson (2007a, p.67) defines the queen bee stereotype as “the first woman to reach a certain job classification or management level who tries to exclude other women from the same level, status or job classification”. He points out that most women directors have taken an indirect route to the top, having risen through the ranks of the academic, not-for-profit and governmental spheres. Very few come through the traditional male route of the ‘C-suite’ or executive role of Chief Executive Officer, Chief Financial Officer or Chief Operating Officer.

In categorizing directors, Branson also introduced the concept of the female trophy director, a concept similar to that of the queen bee. He defines these explicitly as “one who occupies four or more seats at publicly held corporations” and super-trophy directors as holding six or more seats on corporate boards (Branson, 2007b, p. 52). The term ‘trophy director’ is also used to label a director selected because of his or her high visibility and whose contribution to the board is generally limited to lending his or her name to the board list, rather than a serious dedication of the individual's time and expertise. Branson describes these directors as having celebrity status.

In addition, a further new category has been identified by Branson (2007b), the ‘academic trophy director’. He believes that the best way for a woman to become a director of a Fortune 500 company is to be a tenured professor at Harvard in law, economics, business, or even medicine. As a pathway to the boardroom, this rules out all but a very few exceptional women and perversely highlights just how few board seats are truly available. To be a female trophy director is a mark of great distinction in the American and global business worlds and Branson (2007a) concludes that the appellation ‘golden token’ should be applied to such women. Branson is signalling with the concept of trophy directors that aspiring women are encouraged to think they could become directors of a Fortune 500 company, but in reality this is absolutely unattainable.

This section on ‘queen bees’ is included to highlight the presence of a small, but identifiable, group of high achieving women directors in large public companies. Branson’s definition of these women as holding multiple seats is noteworthy from the networking perspective. These women are the ‘connector directors’ in the glass network, and it is their networks or interlock patterns that are the focus of this thesis.

From this survey of the WOB literature, it can be concluded that research is patchy, with only a few researchers, each investigating very specific issues. There is no unifying theory and vague metaphors abound. This represents the early stages in the development of a field (Carlile & Christiansen, 2005) where the processes of description and categorisation are incomplete. I conclude that very little is known about director networks and nothing about gendered director networks. What is known are the percentages of women in the companies of most Western countries, as reported in several censuses over a number of years. What is not known is the location of women directors in the director networks of those countries, whether on the periphery or included in influential companies. Through extensive qualitative work, largely the interviewing of male and female directors and their chairmen, a biographical picture of the typical woman director has emerged. This shows her to be a little younger, often better qualified than her male colleagues, but lacking experience as an executive, although with skills in other areas. In terms of attitude, she is more similar to her male colleagues than different from them.

From director interlock research, the connectedness of companies and directors has been documented and seat spreads recorded. Good records exist here. The relationship of director interlocks to cronyism and undue influence by old boy networks on business outcomes is tenuous and research here has produced confusing results. The value-in-diversity school has produced early results indicating that firm performance and board diversity are positively correlated, but explanations for this association do not as yet constitute a body of theory. In the terminology of Carlile and Christiansen (2005), WOB theory is still in the phase of descriptive theory, which is of necessity grounded in attribute-based categorisation and at best can only make preliminary statements of correlation.

Section 3. Small-world and Scale-free networks

2.3.1 Introduction

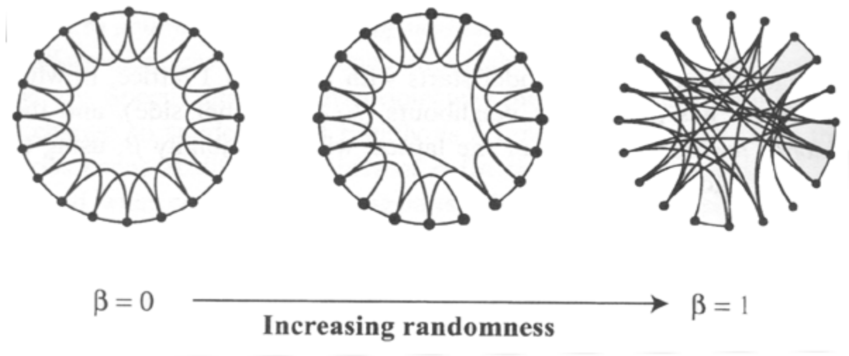
Study of small-worlds commenced with Stanley Milgram's (Milgram, 1967; Travers & Milgram, 1969) finding that it took approximately six steps for a message to reach an addressee. The unexpected result that the intermediary chains of people between a sender and a target person were a short average length, led to the phrases 'six degrees of separation' and 'it's a small world'. As Watts (2003) points out, this is not true in real life, as most people only have a small circle of acquaintances who all know each other. This is the 'paradox of small-worlds' as they show high clustering and the formation of cliques, yet there are enough links to people in other clusters for the degree of separation to be short. Although Milgram's findings stimulated much research (Kochen, 1989), neither boards of directors nor gendered small-worlds were studied, even though the sex of the subjects was recorded (Lin, 1984), and it was observed that the sender and recipients were frequently the same gender.

The small-world concept remained a sociological conjecture and conundrum in the academic domain. The concept did move into pop-culture, fiction, theatre and innovative computer games such as the trivia computer game known as the Oracle of Bacon, (http://oracleofbacon.org). This uses a database of film actors and calculates the steps linking them through their roles to actor Kevin Bacon assigning a number to the actor based on the steps it takes. As further analysis showed, Kevin Bacon is not the most connected film actor (Collins & Chow, 1998) but this game stimulated interest in identifying the best connected and most influential individuals in networks. The principles were also applied in the world of mathematics to link mathematicians to the prolific Paul Erdös through an Erdös number (Collins & Chow, 1998).

These games were made possible by developments during the 1950s in the mathematics of random graphs by Erdös and Renyi (1959), which stimulated the advances in the science of networks. It was the work of Duncan Watts and Steven Strogatz investigating the synchronization of cricket chirps that led to the small-world breakthrough (Davis et al., 2003; Strogatz, 2001, 2003). Until that point interest had focussed on random graphs. The Watts and Strogatz (1998) insight was that there was an intermediate form between a regular lattice or fully linked networks and completely random graphs. The now famous diagram, reproduced below, shows how a few random links shortens the average path length or geodesic distance between all nodes on the network while the clustering of the network into linked groups remains high.

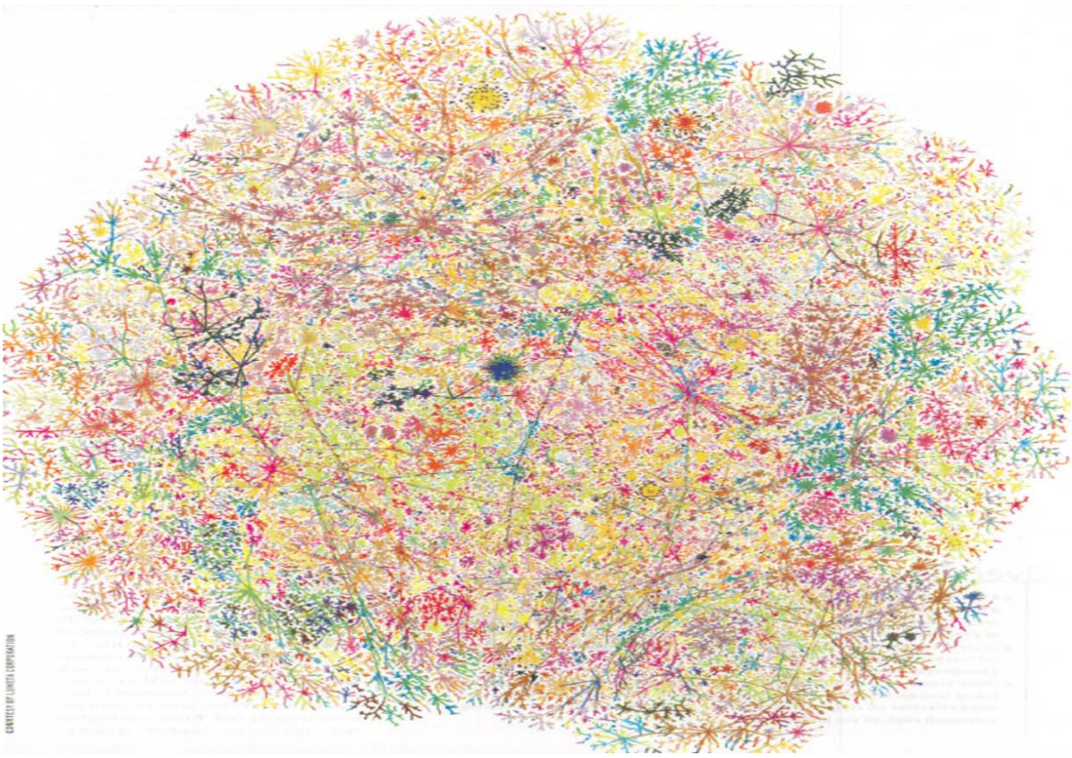
Figure 3.
Random rewiring procedure for interpolating between a regular ring lattice and a random network without altering the number of vertices (points) or edges (links) in the graph. Watts (1999a, p. 68)

Regular	Small-world	Random



Contemporaneously to Strogatz and Watts, Albert Barabási, a physicist interested in networks, had turned his attention to mapping the internet, resulting in the much-reproduced multi-coloured image in Figure 4. This shows a few highly connected nodes, like Google, surrounded by many smaller nodes. This was followed by additional analysis of other networks, including the actor database mentioned above. Concerned that others would pre-empt his findings, this research was quickly written up and submitted to Science magazine (Keiger, 2007). Barabási and Albert (1999) is regarded as a founding paper, stimulating wide interest in what came to be called scale-free networks. Physicists have turned their attention to director networks as these are ubiquitous networks showing the characteristics of small-world and scale-free networks. For this reason, much of the related director literature is in the physical science journals and not in the management or business journals. In particular the 1999 Fortune 1000 director database from Davis, Yoo and Baker (2003) used in this thesis has also been used by physicists exploring social networks, namely Battiston and Catanzaro (2004), Newman and Park (2003), and Newman (2003a; 2003c).

Figure 4.
Map of the Internet from Barabási and Bonabeau (2003) made on February 6, 2003, traces the shortest routes from the test website to about 100,000 others, using like colours for similar web addresses.



To understand what it is that makes small-world and scale-free networks relevant to the study of company networks, some core concepts must be explained. For the sake of brevity, these are discussed in a simple and summarised form in the next section, extracting the elements relevant to director networks. What is presented is not an attempt to summarise findings in this field and readers seeking more detailed information are referred to books such as Barabási (2003), Watts (1999a) and Newman, Barabási and Watts (2006).

2.3.2 Network concepts and terminology

2.3.2.1 Bipartite and one mode graphs

In a mathematical graph, networks are represented by a set of 'nodes' or 'vertices', for example, directors, are linked to each other by 'edges' such as the relationship or link created by sitting on a common board together. An 'edge' can have direction, known as in and out edges, such as a friendship network where one person nominates the other as a friend, but the target person does not identify the nominator as a friend. The edge can be non-directional as in director networks where directors who sit on a board together are equally linked.

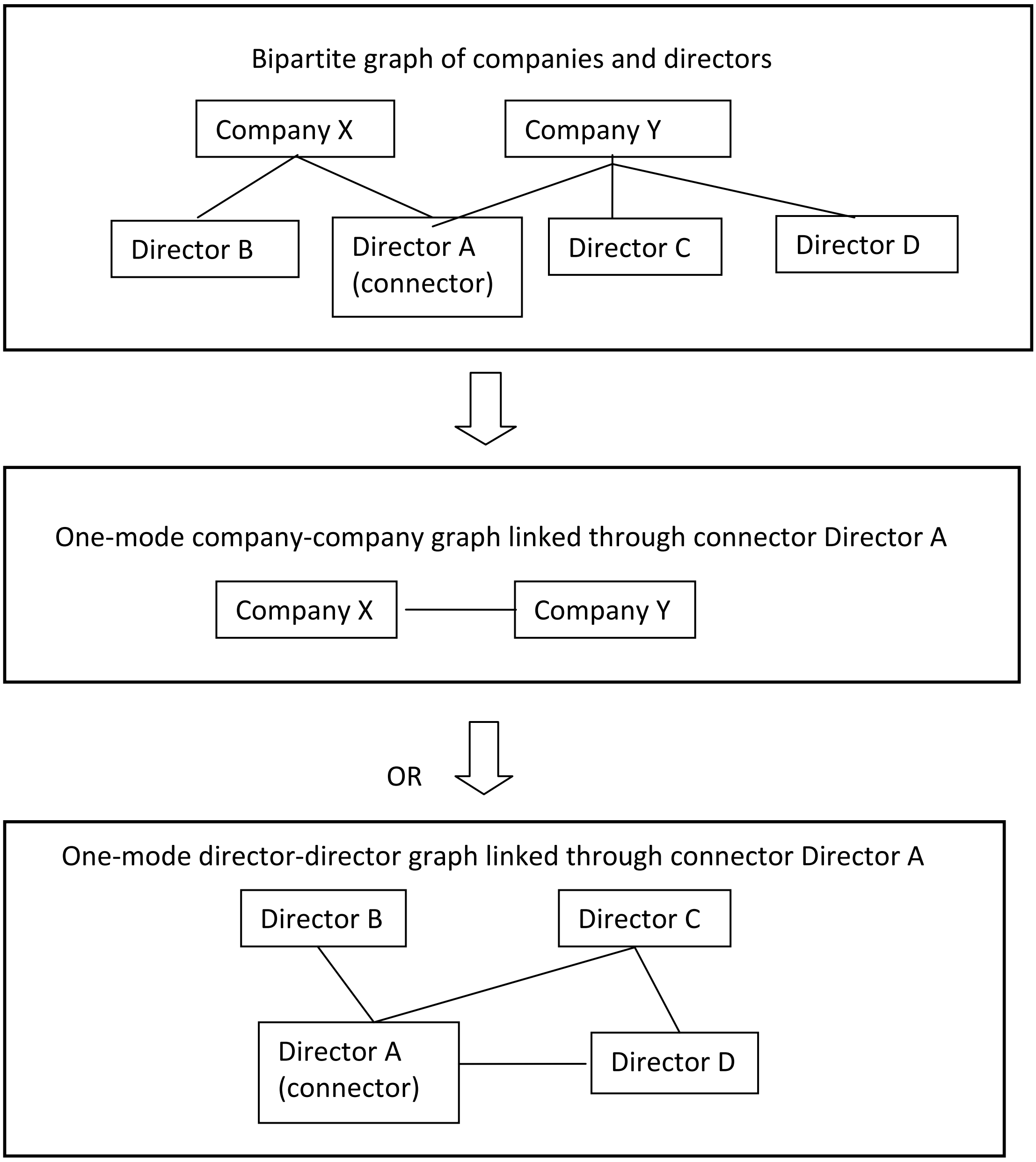
In addition an edge may have a directional strength. Occasionally two directors may sit on more than one company board together, often subsidiary companies in a group of companies. These subsets of directors have been called a 'lobby' and shown to be influential in board decision making (Battiston & Catanzaro, 2004; Battiston et al, 2003).

This implies that some directors may have stronger ties to each other as they meet frequently around other boardroom tables and the edge between these directors should have a greater weight. Multiple interlocks between directors are further complicated as they may consist of directors who sit on the boards of two, three or more companies together. Director network research needs to explicitly state whether these extra edges are counted, the norm being to exclude these multiple interlocks to simplify the derived network (Davis et al. 2003; Newman & Park, 2003). This is the practice followed in this thesis.

Director networks fall into a class of networks known as affiliation networks. These "involve at least two distinct types of social entity: commonly, individuals and the groups of which they might be members" (Robins & Alexander, 2004, p.70). These may be represented as two-mode or bipartite graphs consisting of two classes of nodes, that is, directors and companies. One class of nodes is linked to another class of nodes by an edge or link. Director A and Director B sit on the board of company X while Director A, Director C and Director D sit on the board of company Y. Director A has two seats and the other directors have one each. Director A is called a 'connector director' in this thesis and has two seats in a director network. Director B is only linked to directors C and D through Director A.

The bipartite graph can be mathematically converted into two one-mode graphs as in Figure 5 below. The one-mode graphs, either the company-company graph or the director-director graph or both, may be used in social network analysis. In this thesis only director-director graphs are used.

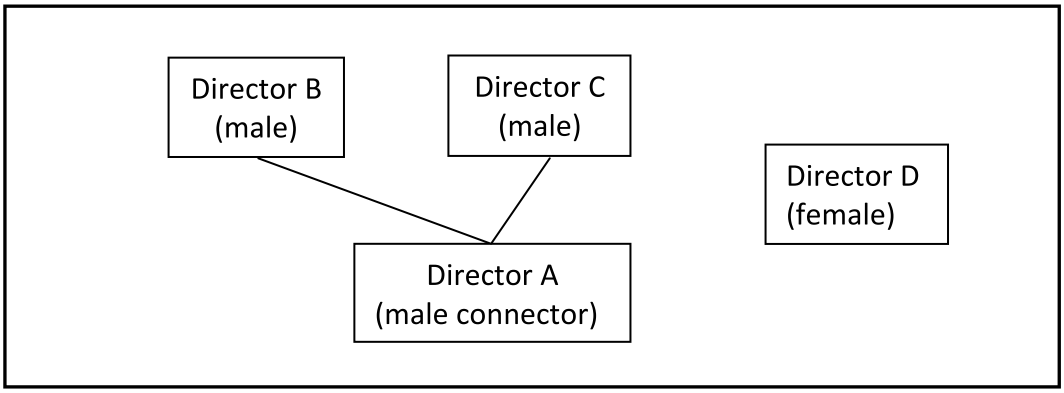
Figure 5.
A bipartite graph of companies and directors which is converted into two one-mode projections, a company-company graph and a director-director graph.



In network terminology, this group of linked directors in a one-mode director-director graph is called a connected component as it is possible to reach every director along a path of edges in the connected component. The example above does not specify the gender of the director. If Director D is a woman, then she is in the connected component of the combined gender network.

If the male-only director network is extracted then Director D is dropped out of the network as shown in Figure 6. Without any more females, Director D is not linked to any other directors and has no network that can be analysed, whereas male directors B and C are still linked to each other through the connector Director A and their network can be analysed.

Figure 6.
One mode male director network showing the linked component of male directors and the excluded female director who is no longer part of a network.



In a gendered network extracted from a larger network, the gender of the connector directors determines which directors are in a linked component or excluded from it. If a male director has only one link and this is through a female connector director to the greater network, in a male only network this male director would be excluded, as his female connector director would be dropped in the extraction process. This process of extraction to analyse same sex networks also may result in a large network breaking down into a number of smaller components.

2.3.2.2 Network boundaries, scale and power laws

The description of gendered networks in the above section makes it clear that inclusion in or exclusion from a network is a function of the criteria used to determine membership, either at the individual or at the company level. These criteria determine what are called the boundaries of a network and may be artificially determined, as in the gendered and random networks created in this thesis, or socially determined by the society in which directors conduct their business operations.

To illustrate socially determined network boundaries, two cases are considered. Firstly, the individual attributes of directors can determine whether a director is included or excluded from a network. A female director may be the member of a powerful family or married to an influential man and is included in the network as a consequence of this attribute and her gender overlooked. Branson (2007a, p. 181) noted that a woman trophy director sitting on eight boards should recognise that her employment is in part an attempt to curry favour with her Senator husband. Similarly, Black male directors may be qualified by their gender to be included in male only networks, but in practice their racial attributes exclude them from the network.

Secondly, at the company level director networks are usually constructed from stock exchange listings which set the boundaries for inclusion. Where the stock exchange has a number of groupings, referred to as markets, different listing criteria apply, such as the New Zealand stock exchange's Alternative Market (NZAX) and the Debt Market (NZDX). Companies listed on the alternative market do not qualify on financial grounds for the main market (NZX) and they may have very recently commenced business. The level of risk for the investor determines where companies can list and the boundaries of the network in which they participate. These socially determined listing requirements are likely to result in other differences. The gender balance is different, being composed of 5% women as opposed to 8.65% in the NZX (McGregor, 2008).

Each market has a company and director network of its own, known in network terminology as sub-graphs. Research imperatives usually exclude these subsidiary markets (Stablein et al., 2005) even though the director networks are linked to the main market through connector directors who have seats in companies listed in both markets. Similarly, it is usual in the network analysis of very large markets to limit the analysis to the top companies, such as the Fortune 1000 or the FTSE 100. These networks are determined on criteria of financial performance set by Fortune magazine. These criteria may change over time and need to be monitored in longitudinal network analysis, as Davis et al. (2003) did. Their study spanned 1995, the year the Fortune 500 company index included both manufacturing and service companies in the top 500 listing.

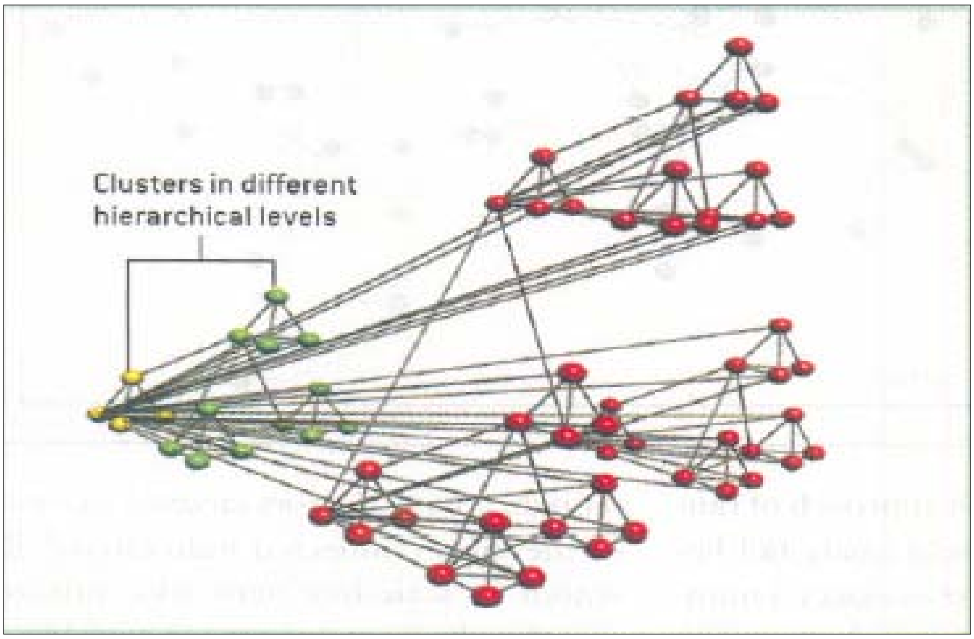
This is an important point because network analyses should explicitly state where the boundaries of the network are and the criteria used to select the nodes in the network. Robins and Alexander (2001, p.88) call this the "vexed" question of the network boundary "because in principle networks do not have boundaries". This has implications for scale-free networks as one meaning of the term 'scale-free' implies a lack of boundaries which can be used to determine the scale. The observer therefore needs to be told the scale when viewing a director network graph; for example is the network local, national or global?

Research into director networks has concentrated on national networks, although WOB research is now extending to regional networks (Adams & Flynn, 2005; Arfken et al., 2004). Global director networks have not previously been subject to social network analysis. Analyses at the global or inter-country level do present additional comparison problems relating to differing national legislative requirements. For example, in certain European countries such as Germany, boards are required by law to consist of 20 members and peaks in analyses of board sizes are found at 20 members. Lack of research into global director networks may be the consequence of inadequate theory to conceptualise and explain the network structure.

Scale-free network theory provides a solution in the concept of hierarchical clusters. Figure 7 illustrates how these form a scale-free network. The red nodes may represent a global director network, the green nodes a director network from a national publicly listed stock exchange and the yellow nodes a local network. Networks may be nested within one another and the parts of the network resemble the whole. This characteristic is known by the technical term self-similarity (Mandelbrot, 1999) where repetitive smaller segments resemble the combined segments. Mandelbrot (1999) uses the example of enlarging a photograph to explain self-similarity, where every detail is blown up or reduced by the same ratio.

Self-similarity in complex networks is a consequence of another organising principle, that of a power law (Song, Havlin & Makse, 2005). The presence of power laws in networks, a well known phenomenon in mathematics, physics and economics, emerged when Barabási's research group mapped the internet. Rather than look at clustering and path lengths, Barabási's research group examined the degree or number of links to a node. Watts (2003) had assumed that the degree of a node was normally distributed and that non-normal degree distributions were irrelevant.

Figure 7.
Illustration of hierarchical clusters in a scale-free network from Barabási and Bonabeau (2003, p. 58).



Barabási's research group found that all nodes are not equal and the number of links connecting web pages and actors to each other followed a power law distribution, which can be described very simply as:

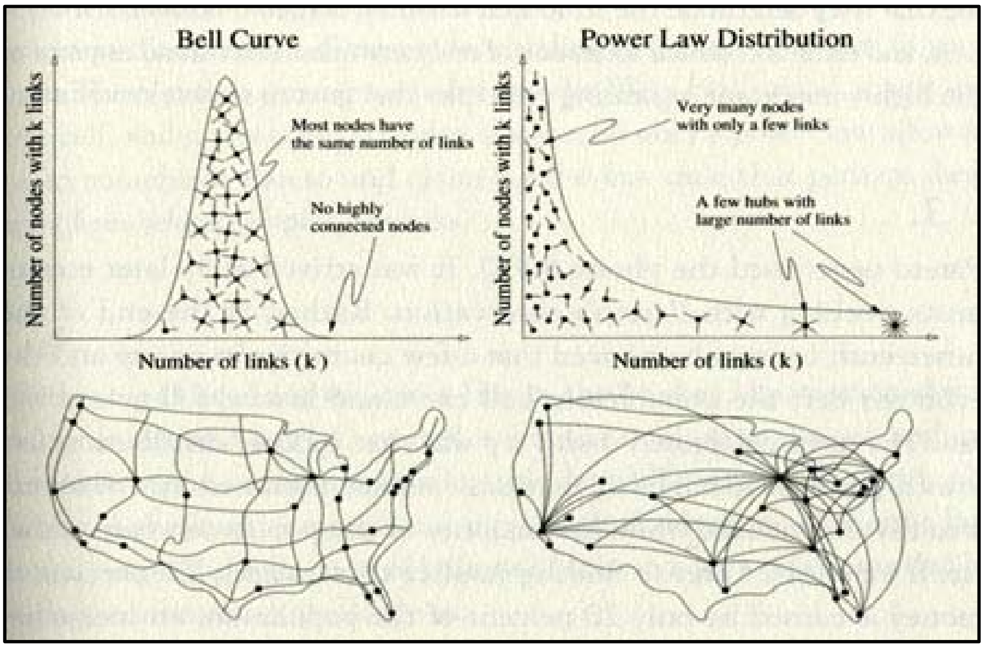
> "A graph of a power law resembles a hockey stick, with a single steep curve sweeping downward into a long, long tail. There's nothing bell curvish about it. A power law is a pattern of distribution in which large is rare and small is common. It's useful as a way of describing, for example, how wealth is distributed in a society (large wealth rare, small wealth common) or how books

sell (bestsellers rare, poor sellers common). When you hear "20 percent of people hold 80 percent of wealth," that describes a power law. The minority holding the most wealth will be at the top of the curve, and the long tail will be all the rest of the population" (Keiger, 2007, p. 52).

Power laws have a number of names such as Pareto's law, the Matthew effect or Zipf's law and can be expressed mathematically as $y = c\,x^{b}$ where c and b are constants. They are also known as the 'law of the vital few and the trivial many' or the 'rich get richer' effect. The distinguishing feature of a power law is "not only that there are many small events but that the numerous tiny events co-exist with a very few large ones. These extraordinarily large events are simply forbidden in a bell curve." Barabási (2003, p. 66).

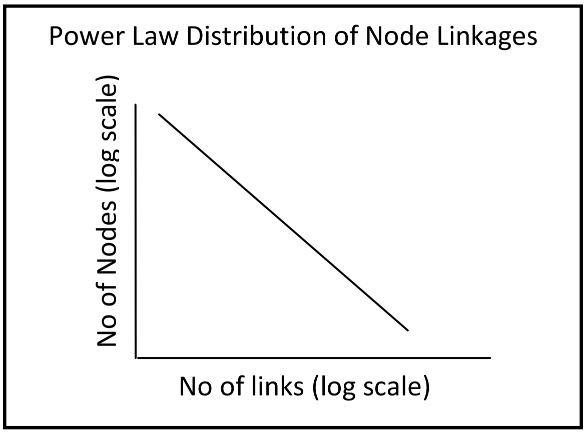
As these concepts are not well known in WOB research, the illustration from Barabási (2003, p. 71) included below as Figure 8 demonstrates the difference between normal distributions and power law distributions.

Figure 8.
Illustration from Barabási (2003, p. 71) comparing the random network of the US highway system on the left with the scale-free network of the US airline system on the right.



The random network in the left image resembles the US highway system. A plot of the distribution of these random links follows a normal distribution, with most nodes having approximately the same number of links. In contrast, scale-free networks, resemble the US airline system, and contain a few hubs with a large number of links, while the majority of nodes have few links. A plot of the distribution of these links follows a power law. The defining characteristic of such networks is that the distribution of links, if plotted on a double-logarithmic scale results in a negatively sloping (slopes downward left to right) straight line as in Figure 9, providing *b* is negative. The straight line can then have a trend line fitted to it and the resulting equation with its R^2 value determined. This offers a graphical way of comparing different networks at different scales or time frames.

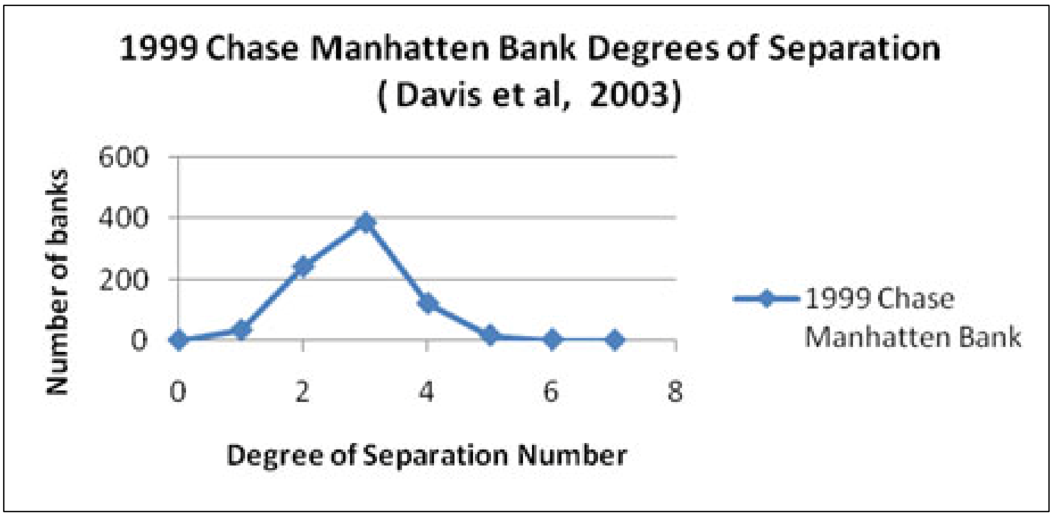
Figure 9.
The scale-free network plotted on a double-logarithmic graph shows the resulting straight line (Barabási, 2003).



When a central node is selected, such as the Chase Manhattan Bank in Davis et al. (2003, p. 320) and the degree of separation or number of nodes at each 'handshake' or degree away from the central node, is plotted, the resulting graph is not a normal distribution but a right-tailed or fat-tailed distribution. As can be seen in Figure 10, 97% of the largest firms in the US interlock network are within four degrees or 'handshakes' of this bank and only one firm is as far away as seven degrees.

Other network measures show the same pattern as illustrated in Figure 2 on page 13 from Watts, (2003). This is a plot of degree probabilities or the probability of a link between directors and their co-directors. The distribution shows that the majority of co-directors have a low degree while a few exceptions or 'outliers' in the long right tail have a high degree. Conyon and Muldoon (2006) find the same right tailed distribution for US, UK and German corporate boards and directors.

Figure 10.
Right tailed distribution by degree of separation or handshakes away of linked banks from a selected central node, the Chase Manhattan bank, data from Davis et al. (2003).



These right tailed distributions are the consequence of outliers or extreme data points. Conventionally, statisticians advise on the best way of removing outliers from data sets or devise measures to reduce the variance they introduce (Barnett & Lewis, 1994; Huffcutt & Arthur, 1995). However, these features are an integral part of small-world and scale-free networks and should not be removed. The effect of 'outliers' on data patterns is increasingly of interest to those attempting to predict extreme phenomena such as the speed of epidemic infection, earthquake and tsunami occurrences, stock market booms and busts, robustness of networks under attack, insurgent attacks, fashion fads and social or political success (Bohorquez, Gourley, Dixon, Spagat & Johnson, 2009; Buchanan, 2002; Gladwell, 2008; Taleb, 2007; Williams, 1997). Research into extreme phenomena stresses that large events are rare, but are not unusual and have been described in another metaphor as 'black swan' events (Taleb, 2004). The outliers in director networks are those rare directors who hold a high numbers of seats. They have been of concern to director busyness and interlock researchers, looking for evidence of poor performance due to high workloads and cronyism (Ferris, Jagannathan & Pritchard, 2003; Kiel & Nicholson, 2006). The conflicting research results may be explained by the normal presence of a few directors with multiple seats who perform well with a varying percentage who fail to fulfil their duties or meet their governance obligations.

These same seat spreads are critical in a network as they directly shape the structure of the director network. They link segments of the network together. A second or third board appointment not only shares a director between companies, but it has the effect of uniting what may have been previously unlinked components of the network, becoming connected components. Within a specific network boundary, a director network consists of both connected and unconnected components. As economies grow and decline, director networks also fluctuate in size, as do the components that make them up, frequently resulting in a few large connected components and very many smaller unconnected components (Baum, Shiplov & Rowley, 2003).

2.3.2.3 Connected components and giant components

The presence of a very large or 'giant' component, a component whose size scales linearly with network size, has been frequently observed in many networks including random networks (Callaway, Hopcroft, Kleinberg, Newman & Strogatz, 2001). The term 'giant component' refers to the largest connected cluster containing over 80% of the network nodes. A 'large component' would contain approximately 65-80% of the nodes (Wang, González, Hidalgo & Barabási, 2009). The handful of small-world director network studies has found a giant or large component in all cases (Battiston & Catanzaro, 2004; Baum et al., 2003; Kogut & Walker, 2001; Robins & Alexander, 2004). These components may persist over a long period of time. In a study into the origins of the small-world of Canadian investment banks over a 38 year period (1952 to 1990), Baum et al., (2003) found that the largest network component fluctuated in size. 57% of the 152 banks participating in 477 investment syndicates were always linked to each other and at some periods this large component expanded to include all banks in a single component.

The relationship of the large connected component to the unconnected components in director networks is unknown. The gender distribution across director network components is also unknown.

2.3.2.4 Small-world and related measures

Social networks that are tightly clustered, with sparse connections to other networks through connecting nodes, will have short average path lengths or geodesic distances across the network. Networks showing these characteristics are called 'small-world' (Watts, 1999a, 1999b) and it is the linchpin or connector directors that are responsible for this effect.

> Watts showed that the presence of a few linchpins whose personal (egocentric) networks have 'random' ties that cut across local clusters are enough to make the world small. These linchpins are short cuts in the overall network. One surprise from Watts's work is that as few as 1% of all ties have to be short cuts to create the small-world effect. Even a single shortcut can have 'a highly nonlinear impact' on the average path length in the network (Watts, 1999a, p.511). Just a few linchpins can turn a giant, sparse, locally clustered network into a small-world (Davis et al., 2003, pp. 311-312).

The linchpin metaphor used by Davis et al. (2003) implies that only a few directors in their personal capacities occupy a pivotal role in the network. This may be true for a few connector directors, whose business empires rise and then collapse or reduce with their retirement or deaths, but this is the exception rather than the norm. All connector directors play a linking role in the network as directors are replaceable entities in business networks. Importance or elite status should not be ascribed to a specific connector director who gains and looses board appointments over the course of a lifetime. This is a dynamic process occurring constantly to all directors without affecting the stable and robust existence of the director network. For this reason the value neutral term connector director is preferred to linchpin director.

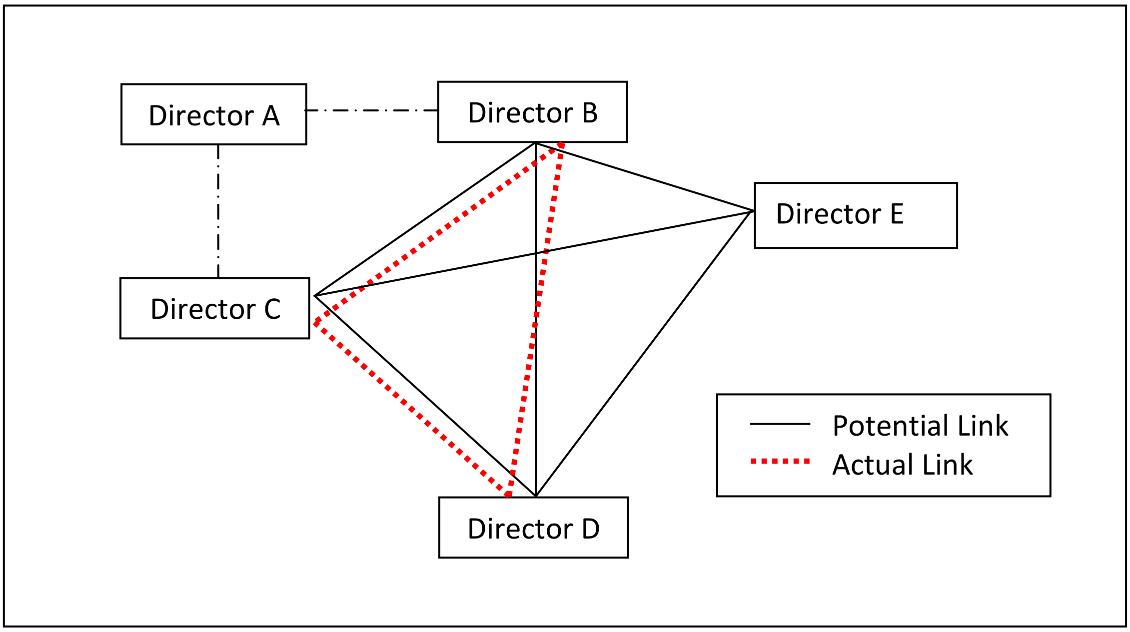
Watts and Strogatz developed a number of measures that encapsulated small-world concepts (Barabási, 2003; Watts, 1999a, 1999b). Network measures are grouped into categories such as cohesion, centrality, or ego networks. Cohesion measures considered here are correlation coefficient, geodesic distance and density. Measures of centrality included in this thesis are degree, reach centrality and Freeman betweenness. Ego networks of individual directors are not included in this thesis and do not appear to have been incorporated in director studies despite the interest in relations of power and control (Alexander, 2003; Alexander et al., 1994).

Clustering coefficient

Assume five directors meet around a boardroom table, as shown in Figure 11, and four of them are invited to join the board by Director A. There are six potential links between them if they sit together on other boards. If, for example, there are three actual links between them as Director B, C and D sit on another board together, then a clustering coefficient of 0.5 is obtained by dividing the actual number of links by the potential number of links. The 'clustering coefficient' is a measure of how close knit a group of directors are in relation to a director to whom they are all linked, in this case Director A.

A coefficient close to 1 indicates a highly connected group around their connector director, while a coefficient close to zero means that the directors who know the connector director do not know each other. If director A is a connector director sitting on multiple boards, the clustering coefficient calculation in a director-director network calculates the potential and actual links between all directors related to Director A. The calculation of the coefficient is performed in an iterative process for each director and the results averaged to obtain the network clustering coefficient.

Figure 11.
Illustrating the potential and actual links between directors invited to join a board by Director A.



The actual clustering coefficient (value for equivalent, but randomly generated networks, are given in parentheses where calculated) has been determined for the director-director network of the US Fortune 1000 to be 0.88 (0.003) for 1982 and 0.87 (0.004, 0.003) for 1990 and 1999 (Davis et al., 2003). The panel of directors who were present at all three points in time were more highly clustered at 0.91 (0.009) for 1982, and 0.89 (0.009) and 0.88 (0.009) for 1990 and 1999 (Davis et al., 2003). For the Italian stock exchange the clustering coefficient for 1986 and 2002 is 0.89 and 0.91 respectively (Battiston & Catanzaro, 2004). For the 2004 New Zealand Stock Exchange directors the clustering coefficient was 0.95 (0.012), but it is not known if the data was dichotomised that is, lobby board links between directors were removed or included in the count (Stablein et al., 2005). In the data above, the gender ratio of the directors is unspecified.

Geodesic or Path Length

The 'geodesic' is the shortest distance between two nodes or the length of the shortest path required to connect them. For a network it is the average number of edges that must be traversed in the shortest path connecting any two nodes. It requires a knowledge of the whole network to compute this measure.

Davis et al. (2003) found that the average geodesic or path length (path lengths from equivalent, but randomly generated, networks in parentheses) between US Fortune 1000 directors was 4.27 (2.94), 4.3 (2.99) and 4.33 (3.06) for 1982, 1990 and 1999 respectively. For the Italian stock exchange director network the average path length for 1986 and 2002 is 2.7 and 3.6 respectively (Battiston & Catanzaro, 2004). These authors also calculated the Davis 1999 US Fortune 1000 dataset as having a path length of 3.7 not 4.33 (Battiston & Catanzaro, 2004). For the 2004 New Zealand Stock Exchange directors the average geodesic was 5.04 (3.18) (Stablein et al., 2005).

Degree or number of links between nodes

The degree of a graph is the number of nodes adjacent to a given node in a symmetric graph (Borgatti, Everett & Freeman, 2002). Degrees may be directed and are referred to as in and out degrees, given different weightings or values (Caldarelli, 2007). In director-director networks this complication is avoided as edges are undirected. By dichotomising the data, lobbies are ignored and edges are of equal value. In calculating degrees, multiple links or lobbies are counted only once. As directors can only serve at any one time on a limited number of boards, this constrains the number of links between directors (Conyon & Muldoon, 2006). The distribution of degrees in a network strongly influences the expected values of the small-world measures and the average degree is divided by the number of nodes to determine random clustering.

Physicists have shown that degree cumulative probability distributions in scale-free (SF) network structures follow a power law (Caldarelli, 2007). Goh et al. (2002) call this "an interesting self-organized phenomenon in complex systems" where:

> Most vertices are connected sparsely, while a few vertices are connected intensively to many others and play an important role in functionality. While the emergence of such a SF behaviour in degree distribution itself is surprising, the degree exponent γ is not universal and depends on the detail of network structure (Goh et al., 2002, p.12583).

In other words, the degree power law is variable and dependent on the network structure. This suggests that a class of networks such as director-director networks may be characterised by power law equations that fall into a narrow range with the variation reflecting the specificities of a particular business environment.

Cumulative probability distributions are often implied in the scale-free network literature when referring to degree distributions, but may be confused with degree frequency distributions, that is, a ranking of the number of directors by a particular degree. Both Davis et al. (2003) and Battiston and Catanzaro, (2004) found that, when plotted, the degree frequency distribution also produces a right tailed distribution.

In the US Fortune 1000 data the average degree of a director was 19.0, 17.0 and 16.0 for 1982, 1990 and 1999 respectively (Davis et al., 2003). The average degree barely changed in the panel of US directors who were present at all three time frames indicating a constant level of linkage between directors over time. Davis et al. (2003) ascribe this stability to the continued presence of linchpin directors, who create shortcuts between the dominant firms of the time. Using a ratio measure of average degree to the degree of the network if all nodes were connected, Battiston and Catanzaro (2004) found the degree ratio between the same 1999 Fortune US 1000 directors and the Italian directors was very similar, ranging from 0.84 (1999) to 0.71 (1986) and 0.79 (2002).

Small-world quotient

The classic signature of a small-world network is a small geodesic distance coupled with a relatively high clustering coefficient (Watts & Strogatz, 1998). A convenient way of determining this has been by computing the 'small-world quotient,' which consists of computing the ratio between each of these two quantities compared to what would be expected for a random graph (Davis et al., 2003; Stablein et al., 2005). While not perfect, this is a convenient measure, and it is suggested that a small-world is shown by a quotient value significantly larger than 1. The small-world quotient provides a null model to compare observed networks with a hypothetical random network.

Suppose that a director network consists of n nodes with a mean of k edges (links or interlocks) per node. Let Lactual equal the average geodesic or shortest path length between nodes in the largest connected component. Let Lrandom equal the average geodesic of the same network in which the edges between nodes are random (approximated by $\ln(n)/\ln(k)$ where ln is the natural logarithm). Let Cactual equal the average degree of local clustering in the largest connected component. Finally, let Crandom equal the average degree of local clustering in the randomized network (approximated by k/n). Then:

Small World Quotient (SW) = [Cactual/Lactual] * [Lrandom/Crandom]

For 1982, 1990 and 1999 Davis et al. (2003) reported a small-world quotient for an average 5736 directors of the US Fortune 1000 of 186.82, 169.21 and 183.03

respectively. The panel of continuing directors, an average of 2120 directors in 195 companies, showed a stable SW value of 67.23, 67.26 and 68.35 for the same period. Stablein et al. (2005) reported in 2004 a value of 49.95 for New Zealand stock exchange directors. Kogut and Walker (2001) noted that the SW value should increase with the number of nodes in a network as illustrated here.

Baum et al. (2003) point out that there is no accepted critical value for SW, and chose the arbitrary value of 4 based on SW values from the earlier research of Davis et al. (2003), for the inclusion of Canadian banking syndicates in their derived small-world company networks. This is a company-company analysis and SW values are considerably lower than for director-director networks as the correlation coefficients are correspondingly lower.

2.3.3 Other network measures of cohesion and centrality

2.3.3.1 Density

'Density' is the total number of edges in a network divided by the total number of possible ties. It is a measure of the general linkage among nodes or the extent to which all possible relations are actually present (Scott, 2000). Density is also a proxy for inclusiveness. If board appointments favour one gender over another this should be reflected in that gender having more dense networks than the other. If affirmative action takes place, changes in density may be an indicator of increasing network openness or alternatively resistance to change. It is an easily calculated measure and can be reliably estimated from a sample and is one of the commonest measures in network analysis (Scott, 2000). Kogut and Walker (2001) reported that the finding of very low densities in company-company networks has led some authors like Useem (1984) to suggest that there is no basis for the belief in co-ordinated action in company networks. In other words, there is no evidence for the operation of old boy networks. There appear to be no studies measuring density in director-director networks. To establish base line measures density measures are included in this thesis.

2.3.8.2 Reach centrality and Freeman's betweenness centrality

Being embedded in a relational network imposes constraints on a director, but it also offers opportunities to the director by virtue of being connected to others. Network position determines which director is more favourably placed and therefore able to take better advantage of the available opportunities such as additional board appointments. Having a favoured position means that a director may extract better bargains in exchanges, have greater influence, and that the director will be a focus for deference and attention from those in less favoured positions (Hanneman & Riddle, 2005). Directors in 'old boy' networks or have links to each other beyond the shared board links, who are linked to each other through shared boards, are in a position to bring opportunities to the notice of their peers and to consolidate positions of power and influence as a result. Not only does the individual director benefit, but his peers do too.

Directors who can reach or link to many others will have a more central role in the network. This is known as 'reach centrality' and is a measure of the number of nodes each node can reach in *k* or less steps. Borgatti (2005) describes this measure as a natural metric for assessing each node when searching for key individuals who are well positioned to reach many people in a small number of steps. This measure may be used to identify influential connector directors and as an objective way of determining how influential female directors rank to other directors. As this measure ranks each director in the network in terms of reach centrality it is a proxy for inclusiveness of the network. This measure has not been used before in director network research and there is no information relating to the reach of male or female director networks.

In contrast, 'betweenness centrality' is a fundamental measurement concept in social network analysis (White and Borgatti, 1994; Newman, 2005a). It is a measure commonly used to measure how influential a given person is in a society (Goh et al., 2002). Freeman's betweenness measure sums the proportion of shortest paths from one node to another that pass through a given node (Freeman 1979). Thus, a node with high betweenness is responsible for connecting many pairs of nodes via the best path, but the assumption is that whatever flows through the network moves only along the shortest possible paths (Borgatti, 2005).

Goh et al. (2002) have demonstrated that not only does the degree probability distribution of a complex network show a power law, but so does the betweenness probability distribution. Betweenness is known to be strongly correlated with the node degree in most networks (Goh et al., 2003; Newman, 2005). The director equivalent is a connector director with multiple board seats and high degree who is therefore more likely to be on multiple paths between other pairs of directors.

If the two are strongly correlated, Newman (2005) asks, why go to the effort of calculating betweenness, when degree is almost the same and much easier to calculate? The answer is that betweenness is useful in identifying the small number of nodes for whom betweenness and degree are very different. Secondly, betweenness is more sensitive than degree in capturing the underlying structure of the network in a summary measure. Thirdly, networks that are robust to attack can be distinguished with this measure, as it measures the duplication of paths between nodes, offering an alternative if one is broken.

Only two studies measure director centrality, Davis et al. (2003) who used the Bonacich measure of centrality and Stablein et al. (2005), whose measure was not stated. Neither study looked at the betweenness distribution. Usefully, Davis et al. (2003) identified the top ten linchpin directors of the US Fortune 1000 in 1982, 1990 and 1999. These top ten directors were overwhelmingly male, although in 1990 one woman appears and is replaced by another woman in 1999. Inspection of the lists indicates that only one director was present in all three lists and the progress of that male director, Vernon Jordan Junior, is measurable up the ranking in that time period. Of the 2004 top ten directors in New Zealand listed companies, two were women and all directors were of European descent.

From this suite of measures, an overall view of director networks can be established. From the baseline of the mixed gender network, the female director network can be extracted, mapped and compared at the global and national levels. Only then can the research set of questions be answered. Before this can be done, some fundamental questions have to be asked and the literature examined for past answers. This is the question of the origins of networks, where do they come from and how do they grow and change over time?

Only when the mechanisms involved are understood can change be successfully induced in a social network. The attempts to change the gender mix of director networks have not been successful. Some countries are resorting to quotas to solve the problem and finding unintended consequences. By reviewing past research some light may be thrown on how networks resist change and maintain their structure despite changing inputs and outputs. This will give fresh insight and more confidence when devising new interventions.

2.3.4 Network creation, growth and change

When looking at director networks, it must be remembered that these are bipartite networks with directors and companies inextricably linked. What is of concern at the level of individual directors feeds into the other level and vice versa. What is of concern to the company is played out in the interaction of individuals, both employees and directors. When Baum et al. (2003) refer to a behavioural theory of small-world networks they move between the behaviour of the firm as an entity in its own right and that of participants who are ‘cliquey’, being connected to each other rather than outsiders, without differentiating the two. As this thesis is not concerned with company-company networks, the emphasis will be on networking mechanisms at the director level and the gendered behaviour that is one of the determinants of the network structure.

The simplest models looked at the creation of networks as a random event and the result of chance interactions of the participants (Erdös & Renyi, 1959; Watts, 1999a; Conyon & Muldoon, 2006). The other approach regards networks as resulting from the strategic actions of participants who maintain the structure of their cliques and deliberately create links to others (Carley, 1999). These links may be the result of chance partnering, deliberate partnering to improve a peripheral position in a network or partnering to remain in a controlling position (Baum et al., 2003). This behaviour may be driven by six exogenous drivers, namely regulatory requirements or necessity, legitimacy, reciprocity, asymmetry, efficiency, and stability (Oliver, 1990). These in turn are powered by the need to reduce cost and risk, enter new markets or grow existing ones, mitigate competition, or pursue resource specialization.

It is the endogenous processes of embeddedness in such organizations that determines who builds relationships with whom (Baum et al., 2003). This may take the form of relational, structural and cognitive embeddedness. Existing social structures determine the form that companies and boards adopt. The pattern of preferential relationships based on the competency and reliability of partners drives new relationships, while shared beliefs and mental models maintain certainty but limit innovation. All of these endogenous forces help shape the gendered workplace and boardroom.

Most models of network growth predict an ultimately stable phase that resists change (Carley, 1999). Complex network theory suggests that there are multiple endpoints or paths with the participant's actions determined by earlier choices, thus becoming path dependent (McKelvey, 2004). Ultimately, participants in a network will self-organise into mutually reinforcing groups; there are multiple attractors to which groups gravitate (Carley, 1999; McKelvey, 2004). Much of the early work around scale-free and small-world networks was concerned with stability and resistance to attack, particularly in relation to the internet and the epidemic rates of infection. Much of the modelling that took place tested the points at which networks disintegrated when hubs were removed (Barabási & Bonabeau, 2003; Watts, 2003).

2.3.4.1 Assortativity

Network nodes do not connect to each other independently of attributes or properties (Baum et al., 2003). A mechanism has been proposed as the key ingredient for the formation of communities in networks, known as ‘assortativity’ (Catanzaro, Caldarelli, & Pietronero, 2003). This is the tendency of nodes to preferentially join others that are similar or like them. ‘Assortative mixing’ is a term from epidemiology and ecology that is now being applied to social and natural networks. Somewhat surprisingly, studies have shown that natural and social networks can be distinguished by their degree assortativity (Newman, 2002; 2003a).

Biological and technological networks show negative degree assortativity or are disassortative, with highly linked nodes being more likely to be linked to nodes of low degree. For example, the internet is negatively assortative (Newman, 2002). So are dolphin and killer whale networks, a finding that has changed recommendations for the conservation of wild animals as killing the most highly linked individual largely destroys the social network of the pod (Lusseau & Newman, 2004; Williams & Lusseau, 2006).

Human networks on the other hand are positively degree assortative, that is, nodes of high degree or many links tend to connect to other high degree nodes and low degree nodes are more likely to connect to other low degree nodes (Catanzaro et al., 2003). Along with co-author networks and film actor collaborations, director networks are also positively assortative. Newman (2002) reports an assortativity value of 0.276 for the 1999 Fortune 1000 director network provided by Davis et al. (2003). Battiston & Catanazaro (2004) confirm the assortativity of the 1999 Fortune 1000 director network (0.27) and found that Italian director networks had an assortativity coefficient of 0.13 and 0.25 in 1986 and 2002 respectively. The extent to which a director network is degree assortative may conveniently be measured with the Pearson Product Moment correlation coefficient (Newman, 2002). This means that connector directors with multiple board appointments tend to sit on boards with other directors who have a similar number of board appointments. This may be an objective way of determining the presence or absence of an old boy network. It is not known how levels of degree assortativity grow in a new network or how they fluctuate in an existing director network. Gender is not identified in these studies and it is not known if female director networks are degree assortative or disassortative. As Quayle, Siddiqui and Jones (2005) point out, degree assortativity is a specialized form of assortativity and other node properties such as gender or race can exhibit assortative mixing.

2.3.4.2 Homophily

The principle that similarity leads to connectivity has a long history even though the physicists have given one aspect of it a new name. It is a pervasive organising principle and is immortalized in the proverb 'birds of a feather flock together' or more commonly in the literature, is called 'homophily' or love of the same. Grouped in the sociological literature of the 1980s on homophily are a number of investigations into the differences between the social networks of men and women, with a handful of studies investigating management networks. This research foreshadows the WOB research of the late 20th century and opening decade of the 21st century.

Homophily has been divided into two categories: status homophily and value homophily (Lazarfield & Merton, 1954). Status homophily includes the demographic characteristics of age, sex and race/ethnicity, whereas value homophily looks at similarities of values, attitudes and beliefs. Value homophily is often derived from status homophily and the local environment in which the individual is embedded (McPherson, Smith-Lovin & Cook, 2001). Gender homophily differs from race and ethnic homophily in that men and women are roughly in the same proportions to each other and linked through ties of family and kinship and as a result share values of class, economic status and religion based on common residences.

Any discussion of homophily must indicate whether it is being considered as a structural feature of a network or a dynamic behavioural feature, that is, the property of a dyadic interaction (Ibarra, 1997). Homophilous ties between a pair of people, for example, can be instrumental and task-focused, or close ties with an emotional content. Preferring to view homophily as a structural feature, Ibarra (1993, 1997) defined gender homophily as same gender ties that result from situational aspects of the workplace, such as the predominance of men in positions of centrality or power. This contrasts with the dispositional theorists, who argued that biological attributes and behavioural patterns acquired through socialization determine the barriers to women in the workplace, and that to succeed women should adopt male behavioural patterns (Riger & Galligan, 1980).

Homophilous networks can be 'induced' or 'baseline', in other words these are the result of a limited range of contacts such as all male armies or racially segregated neighbourhoods. Alternatively 'choice homophily' occurs where individuals associate with similar others even though there are different others with whom they could associate (McPherson & Smith-Lovin, 2001, 1987). Voluntary associations were of particular interest and clear patterns of sexual differences emerged. McPherson and Smith-Lovin (1982) showed that men join economically focused large organizations while women join smaller more domestically focused organizations and as a result men are exposed to more contacts and resources. Cooper (1997) related homophily to the Queen Bee syndrome by exposing traditional and non-traditional women college students to leaders with two styles of assertive leadership, finding support for a bias against female leadership in traditional women.

When men and women enter sex-segregated workforces research has shown that homophilous networks appear strongly as a preference over and above baseline gender choice, but there are differences at the managerial level between the networks of male and female managers (Ibarra, 1993, 1997). Male managers tended to have more gender homophilous networks, whereas high potential women managers had wider ranging information networks than high potential men. High potential women also had more extra group ties than non-high potential women. High potential women had stronger homophilous ties than non-high potential women, supporting Granovetter's (1973, 1995) theories that weak ties are less advantageous for those in socially or economically insecure positions. Ambitious women managers appear to creatively use the networks available to them and find alternative routes to the information provided to male managers through their homophilous networks.

In a study in an advertising firm using social network metrics, Ibarra (1992) found that the involvement or exclusion of women in workplace networks was more complex than expected. Men were more likely to form stronger homophilous ties across 'multiplex' networks, for example advice and friendship networks, while women obtained social support and friendship from female networks and instrumental access, that is, resources to accomplish tasks, through network ties to men. Men and women were differentiated on their centrality (bidirectional Bonacich centrality) as more central individuals would have greater access to resources and be preferred as high status contacts in a business network. As expected, Ibarra (1992) found significant differences between the centrality of men and women in this organization with centrality, homophily and status coinciding for men, but not for women. Women can be caught in a network double bind where network contacts are needed to make them preferred contacts and they need to be a preferred contact to further develop their networks. This has implications for the development of other relationships such as mentoring ties where some mentees are more desirable than others because they are perceived to have useful contacts (Keele, 1986). These studies predate the interest in women on boards of directors and have not been repeated at board level.

Related to homophily, but deriving from the study of scale-free networks, is the concept of preferential attachment. This is a mechanism to describe how networks grow and how the scale-free topology develops. In the natural world networks grow by adding both nodes and links and older nodes are more likely to have more links, as they have been in the network longer. However, seniority does not account for the scale-free structure unless a second principle is added, that of preferential attachment. This means that the probability of an incoming node linking to a node that already has links increases with the number of links already connected to that node (Barabási et al., 2002; Jeong, Néda and Barabási, 2003). In a study of co-authorship networks, Newman (2001) found that initially the relative probability of a new link being added was linearly related to the degree of the node, but fell off as the degree became large, indicating a limit to the number of collaborators an author could have. Barabási (2003, p.85) points out that the preferential attachment rule inherently creates a Catch-22 situation that sets aspiring individuals at a large disadvantage. In referring to Hollywood actors, he comments "You need to be known to get good roles but you need good roles in order to be known".

Director recruitment practices can be regarded as a form of preferential attachment where a track record of boardroom success is required to get board appointments in other successful companies. The practice of 'shoulder tapping' or inviting a known colleague to join a board is a form of preferential attachment that is strengthened by connector directors who are able to 'cherry-pick' the more prestigious and less risky appointments. Davis et al. (2003) use the term small-world and scale-free interchangeably to indirectly allude to preferential attachment as a mechanism in director networks by suggesting that:

> Boards preferentially recruit directors with experience on well-connected boards, and that directors have reason to prefer well-connected boards to peripheral ones, then sufficient conditions are in place for generating a small-world. Put another way, it is difficult to imagine a public policy that would eliminate the small-world property of the interlock network, short of banning shared directorships outright (Davis et al., 2003, p. 322).

In a further extension of the concept of preferential attachment, Catanzaro et al. (2003) suggest that not only do new nodes establish links preferentially to those nodes with many links, but nodes already in the network link to other nodes, similarly following the rule of preferential attachment. The complex mix of diverse micro-motives driven by preferential attachment gives rise to coherent macro-behaviour (Schelling, 1978). In the boardroom context this is the interface where the actions of individual directors translate into gendered boardrooms and director networks.

The next chapter on Glass Network Theory takes the first steps towards this to account for the reality of contemporary organizations that are top heavy with men and considers the likelihood of meaningfully changing gender ratios in boardrooms.

Chapter Two Summary

The literature review for this thesis is divided into three sections. The first section examines Women on Boards research as an emerging global research topic and the particular political and practical imperatives that are intertwined in this. Various schools of WOB research are briefly examined in relation to other network and governance research perspectives. In the second section, a new WOB theoretical framework is developed. It groups research along a dimension of similarity/difference with the responsibility for change in differing loci. This is expanded to incorporate theories of director interlocks, glass ceilings and its variants, 'Busyness Theory', 'Old Boy' networks and 'Queen Bee' theory. In the third section, the development of small-world and scale-free network theory is briefly described. Complex adaptive networks, small-world and scale-free networks, mechanisms such as power laws, homophily and preferential attachment, are related to director networks. Concepts from social network theory such as the small-world quotient, degree, betweenness and assortativity, are discussed. Extant research into director networks from these perspectives is described.

Chapter Three: Glass Network theory

3.1 Précis of Glass Network theory

Glass Network theory has developed from an exploration of gendered director networks trying to account for the well documented phenomenon that these are overwhelmingly male and resistant to change. The study commenced with a social network analysis of director networks looking for the structure of gendered networks, presuming there was one. In addition to using well established network metrics, a comparative methodology was developed to compare networks to others and across time. A model that generates expected seat spreads, allowing comparisons to actual seat spreads in director networks, has useful applications for tracking the effects of governance and diversity interventions.

A director network structure is not visible to the participants, that is, it is a transparent or glass network. The structure is only discernable with the tools of social network analysis, physics and mathematics. Director networks are also gendered, with sufficient numbers of women in the larger networks to allow for statistical analysis. To acknowledge the corpus of previous glass ceiling research, the new descriptive theory explaining the observed structure of gendered director networks is named Glass Network theory.

Before constructing Glass Network theory from its constituent parts and discussing the underlying network processes in detail, a short précis is given, following Carlile and Christiansen's (2005) three steps that researchers who are building descriptive theory utilize, namely, observation, categorization and association.

3.1.1 Describing and observing director networks

The first step in theory building is to observe and record the selected phenomena. In this process constructs are developed that encapsulate the essence of a phenomenon and how it operates. These constructs may be new and derived from direct investigation of the data, or old constructs from earlier research, which are refined and enlarged. Building on past research, using and acknowledging constructs developed in pioneer work into director networks, I expected to confirm specific earlier findings while seeking additional information from new observations.

An initial categorisation of director affiliation networks into company-company and director-director networks is assumed. Only director-director networks are examined in this thesis. A second categorization into the connected and unconnected components was necessary with measures from the largest connected component being utilized. Combining measures from connected and unconnected network components obscures network relationships and should be avoided or only done for specific reasons. For example, measures can be combined to determine if an observed relationship within the largest component also exists within the unconnected components and is universal across the network as a whole.

The following list is a summary description of gendered director networks, utilizing previous research and preliminary investigations, and is the starting point for the development of Glass Network theory.

a. Gendered director networks have a specific structure that is stable over time. Director networks vary in size, depending on the boundary criteria selected. The boundaries of director networks have to be specified, either socially, for example, by stock exchange rules, or arbitrarily, by creating random attributes. Gender as a director attribute can be used to set network boundaries.

b. Director networks are embedded in companies which have a physical location. Past research (Axtell, 2001) has shown that company size and city size follow power laws. Larger companies have larger boards with more women directors (Burke, 2000). Observation is needed to confirm the location of women directors in mixed gender networks.

c. The director networks consist of a giant or large connected component (Battiston & Catanzaro, 2004) and multiple smaller unconnected components of varying size, which show a specific relationship to each other. A frequency distribution by component size is right-tailed, indicating that components are not normally distributed by size. Observation is needed to confirm the location of women directors in the components of mixed gender networks and the component structure of women-only networks.

d. The spread of seats, or the frequency distribution of directors holding multiple seats or directorships, follows a specific structure in the largest connected component. Past research has reported seat spreads (Firth, 1987; Roy et al., 1994; Walker & Borrowdale, 1994) across full networks, but has not observed any underlying structure. Seat spreads need to be observed in the largest connected component of the director networks and differentiated by gender.

e. Past research has shown that the largest connected component of a director network shows high clustering (Battiston & Catanzaro, 2004; Davis et al., 2003; Stablein et al, 2005) as measured by Watts (2003) clustering coefficient, and short path lengths, as measured by geodesic distance. On the Small World quotient, the director network comprising the largest connected component shows a quotient greater than 1. The small world quotient for women-only networks needs to be calculated with the associated sub-measures.

f. On measures of degree and Freeman's betweenness, past research has shown that the directors in the largest connected component show a power law relationship to each other (Battiston & Catanzaro, 2004; Goh et al, 2002). Degree and betweenness need to be calculated for women directors in mixed gender networks and women-only networks.

g. The largest connected component of a director network shows low levels of density reflecting the sparse links between boards. Other measures of centrality such as reach centrality have not previously been measured in director networks. Density and reach need to be calculated for women directors in mixed gender networks and women-only networks.

h. Past research has shown that directors in the largest connected component of a director network shows positive assortativity (Newman, 2002). Assortativity needs to be calculated for women-only networks.

i. The director networks show high levels of director turnover; Davis et al., (2003) found this to be 95% in 17 years. Male and female director turnover is unknown.

j. In terms of gender, male and female directors in mixed gender director networks will be found in a ratio ranging from 19:1 (5% women) to 4:1 (20% women) (Terjesen, & Singh, 2008).

3.1.2 Classification and categorisation

Carlile and Christiansen (2005) state that the second step in theory building is classification of the observed phenomena, usually by a notable attribute. The three director networks chosen for study were categorised as follows:

a. Preliminary categorisation into a single mode network is required, followed by extraction of the largest connected component.

b. Categorisation by time, here director networks are observed over two time periods, namely 2004 and 2007.

c. Director networks can be categorised as global, national, regional and local networks. Global and national networks are studied in this thesis.

d. Director networks can be categorised by financial measures, for example capitalisation or profitability and limited to a specific number of companies, that is, the most frequently used categorisation being the Top 100, Top 200, Top, 500, and Top 1000 companies in larger networks. This thesis analysed the US Fortune Top 1000 network and the Fortune Global Top 200 network, while the other national network studied, the New Zealand stock exchange, comprised all companies listed on the main market of the NZX, which averages 188 companies.

e. Sub-networks can be extracted from larger networks, and categorised by gender into women-only networks. As male directors dominate the network, any measures in male-only networks will be substantially similar to the mixed gender network. In this thesis, extracted women-only networks are compared to the larger mixed gender network.

f. Director networks can be extracted from larger networks using randomly created attributes and assigned to sub-networks. In this thesis, directors in two 2007 networks were randomly assigned a number, sorted and then divided into sub-networks of two or three segments each.

3.1.3 Association and descriptive theory development

In the third stage of descriptive theory building, correlations and associations are made explicit and models developed to account for the differences between the categorised data and the outcomes of interest. In this process of anomaly identification, 'normal science' proceeds to push the current paradigm to its limits (Kuhn, 1962). In this thesis the outcome of interest is the extent to which male and female patterns of organization in mixed gender networks are similar or different and whether women-only and random networks differ from mixed gender networks. This thesis therefore tests current WOB paradigms by incorporating network concepts from other disciplines into WOB theorising.

The list below is a preliminary statement of Glass Network theory, derived from the initial description and categorisation of gendered director networks and is the starting point for the empirical investigation that follows.

a. Glass Network theory is a general and inclusive theory equally applicable to male and female directors. It can be extended to include directors categorised by other attributes such as race or ethnicity.

b. Directors are changeable entities in a director network, which accommodates a flow of directors through the network while maintaining a stable structure. Director networks show high levels of director turnover. The turnover of women directors in mixed gender networks is unknown.

   The organising principle is a power law, namely, the rule of the critical few and trivial many. The effect of this law may be observed in global and national networks, as well as gendered and random director networks. Power laws have already been observed in some measures of director networks, such as degree and betweenness and it is likely that more instances will be found. Director network data as a consequence does not follow normal distributions. In this thesis a close approximation of the underlying power laws can be derived by fitting trend lines to the director network data.

c. The underlying equations describing the trend lines will show variations in different segments of director networks at different times, particularly where local legislation and other social factors influence the network, that is, these are organic networks adapting to environmental conditions such as governance and affirmative action pressures.

d. The power laws vary within a set range. Predictive range limits can be set using a characteristic of power laws, which produces a straight line on a graph when the data is transformed by logarithms on both axes. This permits a comparative methodology whereby the equation for this straight line can be determined, allowing different networks at different times to be compared. These can be used to compare networks on multiple measures, in this thesis, component size, seat spreads, degree and betweenness. Glass Network theory predicts that most director networks will fall between the ranges for these networks measures.

e. Gendered director networks are small-world networks as they show high clustering and short path lengths. The derived SW quotient will be greater than 1 and related to network size. Director networks show low density but high reach as a result.

f. Gendered director networks are a form of scale-free network as they are driven by power laws and show self-similarity, irrespective of categorisation. As the number of multiple seats held by a director is limited, the scale free nature of director networks is truncated. Individual merit and ability is irrelevant at the network level. Gender differences are likewise irrelevant, as male and female director networks are similar in function and structure, in proportion to their presence in the network. This is also likely to be true of other director attributes such as ethnicity. This property is also illustrated in networks created by the allocation of random attributes. This explains the finding that degree and betweenness follow a power law in director networks because these are measures derived from seat spreads, which will also be shown to follow a power law.

g. The structure in director networks is, in complex network terminology, an emergent structure whose organization is the result of many seemingly random and unrelated director selection processes. The underlying power laws are the result of innumerable selection decisions that are driven by ‘shoulder tapping’ or inviting peers to join other boards, and by connector directors with multiple seats, ‘cherry picking’ the less risky and more prestigious board seats.

h. One mechanism that drives the creation of scale-free networks is ‘preferential attachment’, where new nodes have a preference to attach to nodes that already have edges. This mechanism is also a driver in director networks, where recruiting boards prefer directors who are like them and who already have board appointments. Two forms of this are known. Firstly, ‘homophily’ or preference for the similar, whether by gender, ethnicity or other social factor, leading to the creation of ‘old boy’ groupings. Secondly, ‘assortativity’ or the preference for directors of the same ‘degree’ or number of links to other directors. Gendered director networks as a consequence will also be positively assortative. Gender preference and assortativity interact determining the gendered structure of director networks.

i. Power laws determine the component structure of director networks. If the largest connected component is included or excluded, the ranking of the components by size, or number of directors in each component, also follows a power law. A frequency distribution by component size will show a right-tailed distribution of components. Average board size is related to the size of the components.

j. The metaphor of the glass ceiling is incorrect, the metaphor of a glass network is more appropriate for gendered director networks as some women are found in all director networks. A small proportion of diversity, approximately following the Pareto ratio of 80/20, is found in all director networks. Its role is to permit the adaptation of the network as environmental circumstances change, perpetuating the network (Andriani & Passionate, 2004). This accounts for the presence of 5-15% of women in director networks where no affirmative action has taken place. In a stable director network only a few women will have board appointments, but those women who do become connector directors in the network will have the same network structures as male connector directors.

k. A characteristic of power laws is the ‘rich get richer’ effect, also known as the Matthew effect, Zipf’s law or ‘accumulated advantage’. This explains why a few directors get more board appointments than their peers, becoming connector directors, with a few of these directors becoming trophy and super-trophy directors (Branson, 2007a). This effect is also the result of certain directors possessing enablers that allow them through a filter or ‘glass net’, despite barriers such as race or gender. These may be family connections, celebrity status or another attribute that creates an advantage over equally well qualified and experienced peers.

The metaphor of a glass net is also used to describe the filtering rule or underlying power law that permits a few directors to become connector directors in a local network, a smaller number to become the linking directors in a national network and finally a select few to become the connector directors in a global director network. Women directors are subject to the same power law effects and also become connector directors, in proportion to their presence in mixed gender director networks.

l. Power laws create the illusion of glass nets which determine the seat spreads that have regularly been observed in director networks. A theoretical model is presented, based on a non-symmetrical generating function that derives the numbers of male and female directors at each level in the seat spread. This is a good fit with actual seat spreads, especially in networks where there has been little governance or affirmative action pressure. Gendered networks where women constitute a big enough grouping in the network, will also conform well to this model. This generating function will also permit a 'world of gender equity' to be modelled, allowing seat spreads to be predicted if a gender quota is imposed on a network.

m. Director networks are embedded in companies that have physical locations. As city size and company size follow a power law, so do director networks through component size and seat spreads. These are likely to be related phenomena, but the nature of this relationship is unknown. It may be a function of larger companies with larger boards being found in larger cities.

n. Finally, Glass Network theory accounts for three findings in the WOB literature, namely the 'glass cliff' phenomenon, the 'queen bee' syndrome and the positive correlation of performance and board diversity.

    i. Boards prefer women directors in time of financial crisis. As there are few board positions for women available and competition for these is high, aspiring women directors choose to accept risky board positions to get board experience or become connector directors and increase the likelihood of further board appointments.

ii. Connector directors of both genders display different behaviour patterns to single seat directors. Being a chairman enhances this behaviour. In female directors these behaviours are seen as violating the norms of feminine behaviour and are couched in derogatory terms as the ‘queen bee’ syndrome, whereas these are normative behaviours associated with male leadership.

iii. Larger companies tend to be found in the largest component because these companies may have larger boards with more connector directors of similar degree. These companies are financially more successful. Larger companies tend to have a token woman director and a critical few appoint more than one. More women directors are therefore found in the largest component of a director network and the presence of women directors correlates positively with financial performance.

3.2 The structure of Glass Networks

3.2.1 The network components

Complex network theory suggests that new networks start off with several small components joining up as links or edges are added either randomly or by following specific rules, such as preferential attachment, to form a large or giant connected component (Barabási et al., 2002).

When each node has an average of one link (Barabási, 2003), the disparate segments unite to form this dominating component. This may happen very suddenly and resemble a ‘tipping point’ (Gladwell, 2000) or a moment of critical mass (Ball, 2004) or ‘a phase transition’ in physics (Newman, 2003b; Watts, 1999a). Once the large component has formed, the remaining components are not random in size, but appear to follow a power law pattern.

To illustrate this, Table 2 presents the component breakdown of the 2004 New Zealand stock exchange data for the combined male and female directors' network (Stablein et al., 2005). There is one large component of 639 directors (66.2% of the nodes) and 54 smaller components. This data was then plotted using Microsoft Excel 2007 and a trend line fitted by regression. This is shown with its associated equation and R^2 value, in Figure 12.

The trend line with the R^2 value closest to 1.00 has the best fit to the data. Here, this was a power law trend line, a regression trend line that is used to compare measurements that increase or decrease at a specific rate (Dodge & Stinson, 2007). For the 2004 NZX network components, excluding the largest component, the resulting power law trend line equation was $y = 22.68x^{-0.46}$ and $R^2 = 0.927$. Concerns with the reliability of regression analysis to calculate power law exponents accurately (Goldstein, Morris & Yen, 2004; Newman, 2003c) requires that the assigned power law be confirmed with other methodologies.

As an alternative methodology avoiding these problems, this data was converted to a log-log plot and a linear trend line fitted with its associated equation and R^2 values. Inspection of Figure 13 (a graph of the log-log scores) shows the left slanting straight line characteristic of a power law. The resulting best fitting linear equation is $y = -0.527x + 1.449$ with $R^2 = 0.932$. This methodology is developed further in this thesis and used to examine the other director networks for the size of the remaining components in the network and to determine whether they follow the same pattern of a few large components and many smaller components that decrease in size in a specific ratio to each other.

Table 2.
Stablein et al.'s (2005) 2004 NZX director-director network.

Mixed Genders		
Ranking from Largest to Smallest	Component Size by # of Directors	# of Components
1	639	1
2	21	1
3	15	1
4	14	1
5	13	1
6	10	1
7	8	4
8	7	6
9	6	11
10	5	10
11	4	9
12	3	9
Total Components	55 components of 965 directors	

Figure 12.
Stablein et al. (2005) 2004 NZX male & female directors' network components with power law trend line (largest component excluded).

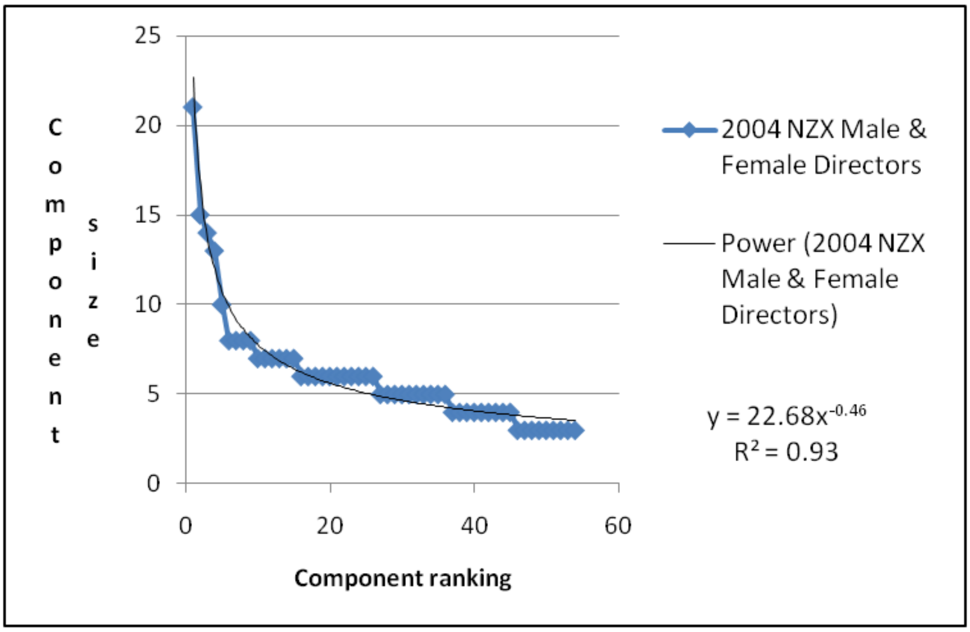
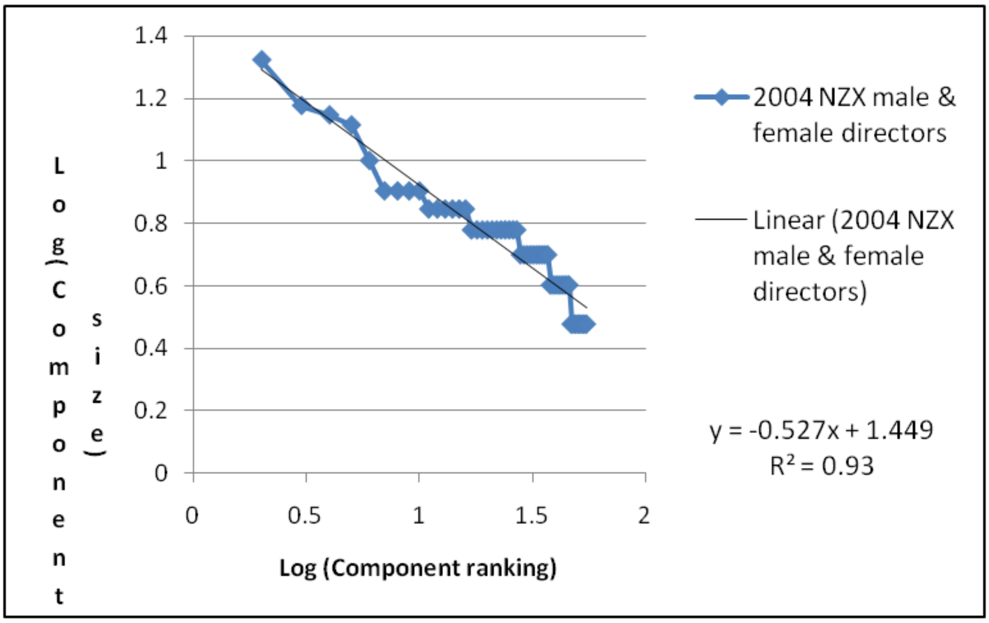


Figure 13.
Stablein et al. (2005) 2004 NZX male & female directors' network components log-log plot with linear trend line and equation (largest component excluded).



A explanation for this pattern can be found in the recent work done on microeconomic models of theories of the firm (Ball, 2004), where models of firm growth are derived from the aggregation of many worker's or agent's actions following their own agenda to best suit their own advantage, resulting in firms whose sizes follow power law distributions. Component size may be linked through board size and numbers of connector directors on a board to company size. Axtell (2001), using the entire population of tax-paying firms in the United States, showed that a Zipf distribution (an alternative name for the Pareto or power law distribution) characterizes firm sizes with the probability that a firm is larger than size *s* being inversely proportional to *s*. Axtell (2001) finds that:

> Firm sizes in industrial countries are highly skew, such that small numbers of large firms coexist alongside larger numbers of smaller firms. Such skewness has been robust over time, being insensitive to changes in political and regulatory environments, immune to waves of mergers and acquisitions, and unaffected by surges of new firm entry and bankruptcies. It has even survived large-scale demographic transitions within work forces (e.g., women entering the labor market in the United States) and widespread technological change (Axtell, 2001, p.1818).

Rules of assortativity and preferential attachment would suggest that connector directors prefer boards not only with directors of the same degree, but of the same size company, giving rise to a similar power law in the smaller components in the director network. This contention is not tested in this thesis but noted here as a possible reason for the power law relationship in the components of director networks.

The power law driving the component distribution is examined further in this thesis and the location of women directors in the network components is also considered. It is not known if women directors are to be found clustered in the large component (if one is present), or are to be found in the peripheral and smaller components. If business women are seen as marginalised in an economy and peripheral on boards of directors, who appoint them with reluctance, then it can be hypothesized that the few women directors in the network would be found on the periphery of the director network in the smaller components.

However, Glass Network theory makes the opposite prediction that women directors are more likely to be found in the largest or giant component. Larger companies are likely to be clustered in the large or giant component as they have larger boards and directors of higher degree. Women directors tend to be found in larger companies with larger boards, often as the token woman (Nguyen & Faff, 2007; Farrell & Hirsch, 2005; Carter et al., 2003). In addition, women directors may prefer larger established companies, with connector women directors cherry picking the more prestigious and safer boards appointments.

3.2.2 Assortativity, network degree and betweenness in glass networks

The number of links or edges connecting nodes or directors together determines the shape of the glass network. The forces of preferential attachment and assortativity (or homophily) determine which nodes attract edges or which directors are successful in getting board appointments. Glass Network theory hypothesizes that director networks being social networks will be positively degree assortative, with both male and female connector directors preferring to sit on boards with connector directors of similar degree. Using the 2004 NZX male and female director network (Stablein et al.,

2005) as a historical example, the assortativity of this network is r = 0.247, very close to the r value of 0.276 for the 1999 Fortune US 1000 directors studied by Newman (2002).

Degree assortativity, or the preference for directors of similar degree, may be regarded as a proxy for status within a director network and directors classified according to the prestige of their company appointments. Glass Network theory would suggest that directors of the Top 100 listings of any director network will show greater assortativity than the next scaling, for example Top 500 or Top 1000.

Glass Network theory suggests that the rule of self-similarity at all scales applies to all directors irrespective of gender and that extracted female and male director networks will show a similar assortativity where female director networks have sufficient connector directors to calculate this. However, it must be considered that when calculating assortativity in mixed gender director networks, pairs of directors may be male-male, male-female and female-female, with possibly differing patterns of preferences. For example, male directors who are mentors may prefer to invite female protégés of a lower degree to join a board. This is an area requiring further analysis not covered in this thesis.

Preferential attachment and assortativity determine which directors have a higher degree than others and are more central in the director network. As Newman (2005a) has pointed out, having a high degree is correlated to network centrality, but betweenness is a better measure as it captures those directors who are centrally placed on critical pathways, but have a lower degree. Network degrees exhibit a power law if individual scores are plotted as a probability function, as does betweenness centrality (Goh et al., 2003; Newman, 2005a).

Following a similar methodology to the component analysis, the degree and betweenness scores of the largest component of the 2004 New Zealand Stock Exchange director network (Stablein et al., 2005) were plotted to illustrate how this pattern may be found in the New Zealand director network in Figures 14 and 15.

Figure 14.
Stablein et al. (2005) 2004 NZX male & female directors' degree plot (largest component only) with power law trend line

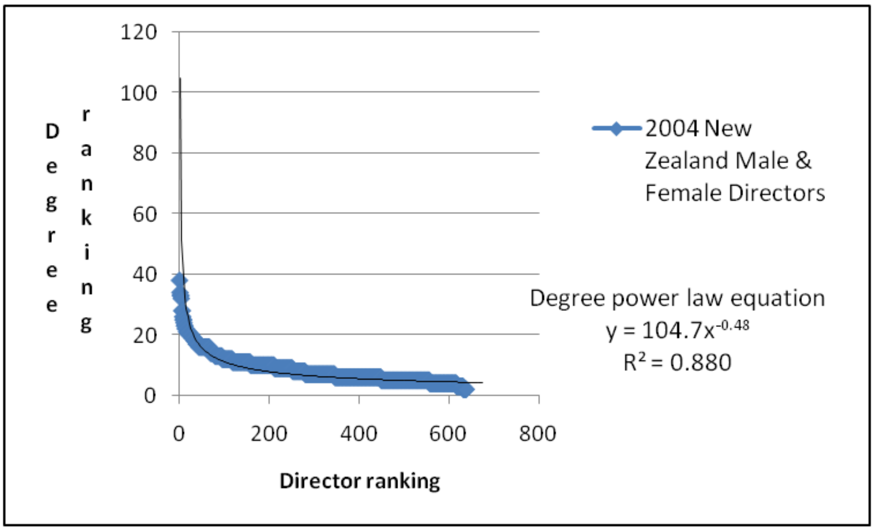
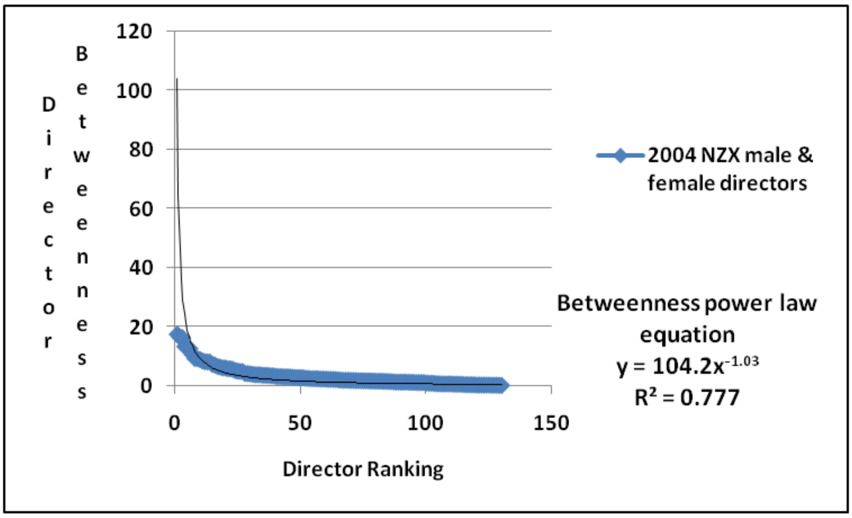


Figure 15.
Stablein et al. (2005) 2004 NZX male & female directors' betweenness plot (largest component only) with power law trend line



The degree power law equation of $y = 104.7x^{-0.48}$ $R^2 = 0.880$ is a moderate fit, as is the betweenness power law equation $y = 104.2x^{-1.03}$ $R^2 = 0.777$, as illustrated in Figures 14 and 15. Plotting the log-log values of the ranked data and fitting a linear trend line, the resulting equation and R^2 value for the NZX mixed gender degree scores was $y = -0.482x + 2.020$ $R^2 = 0.880$, and the betweenness scores was $y = -1.031x + 2.018$ $R^2 = 0.777$.

The moderate fit is not unexpected given that the two measures are closely related and the small sample size of 639 directors in the degree distribution, with only 130 (20%) directors having a betweenness ranking. In small sample sizes a logarithmic fit may be a better fit than a power law.

In these examples, male and female directors were not separated out. Glass Network theory suggests that the rule of self-similarity at all scales applies to all directors irrespective of gender and that extracted female and male director networks will show a similar trend lines in degree and betweenness scores, if the sample sizes are large enough.

3.2.3 Seat spreads and the ratio of connector directors to single seat directors

Glass Network theory predicts that the ratio of connector directors with multiple board seats to the majority of directors with only one seat follows a specific pattern. Obviously, to become a connector director with two seats, the director must already have one board appointment. To become a director with three seats a director must already have two seats and so on. The pool of directors gets smaller as connector directors gain more seats. In a director network, the numbers of directors who have consecutively increasing seats can be tabulated. The resulting table showing decreasing numbers of directors as they gain additional seats is a format common in the director interlock literature. Table 3 gives an example from Walker and Borrowdale (1994) for the New Zealand stock exchange.

Seat spreads should not be confused with degree distributions, or the number of links to each director. Seat spreads is the term introduced in this thesis to differentiate the two frequency distributions. A degree distribution is a summary statistic that lists the degrees that occur in a director graph and the frequencies with which they appear (Barabási et al, 2002; Newman, 2001; Conyon & Muldoon, 2006). Obviously, a connector director with five or six seats will have a higher degree than a connector director with two or three seats. Board size impacts on degree as directors who are members of bigger boards will have more links from their co-directors than smaller boards.

Table 3.
Walker and Borrowdale's (1994) NZX director and seat spread for 1984 and 1993.

Seat range	**1984 Directors**	**1984 Seats**	**1993 Directors**	**1993 Seats**
1	927	927	567	567
2	122	244	65	130
3	34	102	23	69
4	30	120	7	28
5	14	70	3	15
6	9	54	1	6
7	1	7		
8	4	32		
9	2	18		
Total	1143	1574	666	815

Seat spreads must also be distinguished from director spreads, which are a count of the actual numbers of directors who hold seats of a particular category. Seat spreads are derived from director spreads by multiplying the seat category by the number of directors. To maintain consistency, only seat spreads are used in Glass Network theory.

The seat spread ratio may fluctuate depending on the size of the director network being analysed, but follows a remarkably consistent pattern. For example, Conyon and Muldoon (2006) find that in their US, UK and Germany director databases the percentage of directors with one seat was 80.4%, 84.2%, 88.3% respectively. The percentage of directors with two seats was 13.0%, 10.1% and 8.9% respectively. The larger the director network, the more statistically reliable is this pattern, as small and random variation is cancelled out.

The bigger the director network or size of the economy, the more opportunities there are for connector directors to gain additional board appointments. As economies grow or shrink these seat spreads grow or shrink, but still maintain the same ratios to each other. For example, Walker and Borrowdale (1994) found that seat spreads in NZX companies, which ranged from one to nine in 1983, had shrunk to a range of one to six in 1993. Within these ratios, gender balances respond to prevailing pressures on the director network. Seat spreads for women will reflect the smaller total numbers of women in a network and the range of multiple seats will be less than that of the men.

Sealy et al. (2007) found a consistent range, with female connector directors holding one to four seats from 2000 to 2006.

What has not previously been considered is that the seat spreads exist in a specific ratio to each other and in a similar ratio across director networks, once network size is taken into account. In unrestrained business environments where there is no affirmative action, I suggest that, irrespective of personal attributes or behaviour, a select few connector directors of either gender become the beneficiaries of preferential attachment and assortativity, normal mechanisms of social networks gaining additional board seats, resulting in a predictable pattern of multiple seats.

These stable seat ratios contribute to the stability of complex networks, which become robust and resistant to change despite continually changing inputs and outputs. This may be a valuable quality in natural networks such as power grids or the internet, but a problematical one when attempting social change.

3.2.3.1 Model of expected seat spreads from a generating function

Glass Network theory postulates that seat spreads follow a truncated power law, as directors are ultimately limited in the number of seats they can hold, unlike the internet where a web page may have unlimited links. In the terminology of complex networks this is known as a bounded distribution (Ball, 2004; Gleick, 1987; Taylor, 2001).

Complexity and chaos theory also provide insights into the mechanism underlying the appearance of a power law in the seat spreads of director networks. Complexity theorists investigating non-equilibrium steady states in convecting fluids and other materials found these to be the result of cascading bifurcations, critical points at each of which a system must choose between two alternatives. Random fluctuations determine this choice so that “two initially equivalent systems driven out of equilibrium can end up in different branches in different steady states” (Ball, 2004, p.132). This principle was applied to population growth rates with parameters determining the rate at which populations doubled with variable cycles of growth called ‘boom or bust’ periods. The parameter determines the point at which a population splits in two and when each arm of the subsequent division splits further in a similar bifurcation process. The bifurcation processes are double-sided creating a symmetrical pattern. When graphed, these processes result in the well known pattern called the 'window of order inside chaos' (Ball, 2004; Gleick, 1987; Taylor, 2001).

In the director network literature generating functions have been used to produce similar models. One set was devised by Newman et al. (2001) to bypass the necessity of creating multiple simulated networks from a boot-strapping process such as used in Conyon and Muldoon (2006) to generate expected values. Newman et al.'s (2001) approach was to take board size and seat spreads as input variables and then to generate degree sequences for the company and director one-mode projections. Subsequently, Conyon and Muldoon (2008) in a study of company ownership and control, used a refined version of a similar generating function introduced by Chung and Linyuan (2002) to generate random graphs.

Glass Network theory uses the same empirical seat spreads, but uses them to model expected seat spreads, not degree spreads (which are derivative spreads). The model that achieves the best fit to the empirical seat spreads is a bifurcation process, but it is not symmetrical. Only one branch of the system continues to divide into two.

For example, taking Walker and Borrowdale's (1994) NZX director seat spreads for 1984 from Table 3, the NZX network consists of 1574 seats with 927 single seat directors. This leaves 647 potential seats for connector directors. If these 647 directors are divided in half, 323 seats are available as a second seat for 161 directors. The remaining seats then become available for a third seat. If these remaining 323 seats are halved, then 161 seats become available as a third seat for 80.5 directors. The remaining seats become available for a fourth seat and so on until all seats are allocated to connector directors and the cumulative seat count closely approximates the network total number of seats. This process requires information about three elements: the number of total directors in the network, the number of single seat directors and a tuning or division parameter. As it happens, setting the division parameter at 2 results in the seat spread approximating most closely the network totals. Dividing by 1.9 results in too many seats in the cumulative total, whereas dividing by 2.1 results in too few. This is illustrated in Table 4, which shows the variable cumulative totals as the seat spread parameter is varied. Hence the conclusion that this generating function gives the best fit if the parameter used to divide the available seats is exactly two for the datasets used in this thesis. The resulting seat spread gives a theoretical spread against which an actual seat spread can be measured. This is illustrated in Table 5.

Table 4.
Testing the seat generating function with three parameters to determine the optimal divisor to match to the total actual seats for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX director networks

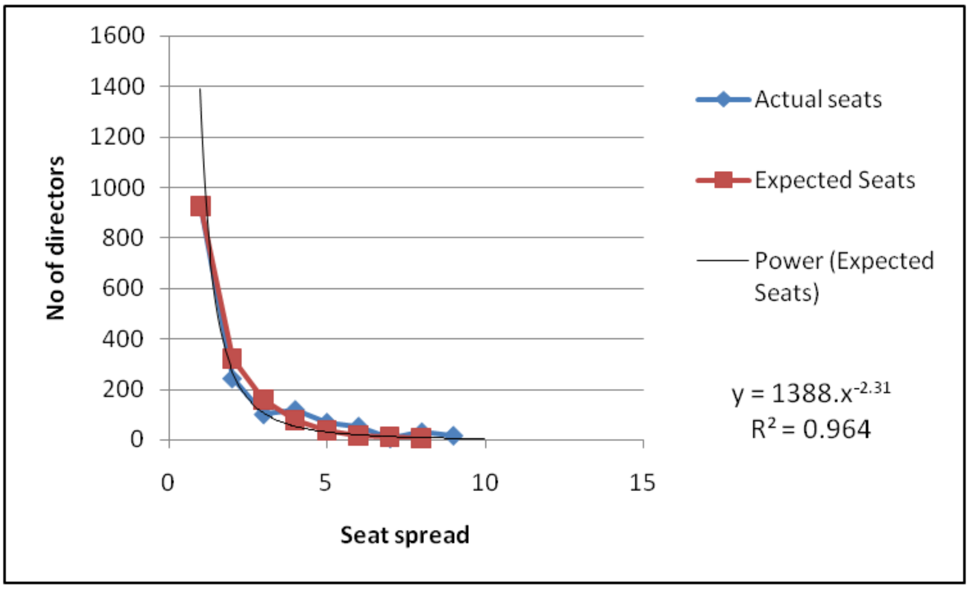
Seat spread generating function	Total actual Seats	Cumulative total of expected seats with parameter = 2	Cumulative total of expected seats with parameter = 1.9	Cumulative total of expected seats with parameter = 2.1
		Optimal	Excessive	Insufficient
US Fortune 1000	9130	9114	9550	8755
2004 Fortune Global 200	1805	1798	1841	1763
2007 Fortune Global 200	1788	1782	1822	1749
2004 NZX	830	825	859	797
2005 NZX	898	892	930	860
2007 NZX	585	582	897	556

When plotted, the actual and expected seats from Table 5 display the familiar hockey stick curve, as illustrated in Figure 16, with the actual seat spread closely following the expected seat spread. Fitting a trend line to the expected values gives a power law trend line with a value of $y = 1388.x^{-2.31}$ and an $R^2 = 0.964$.

Table 5.
Expected seat spreads from a non-symmetrical bifurcation process
with a seat spread parameter = 2
using Walker & Borrowdale's (1994) NZX director seat spreads for 1984

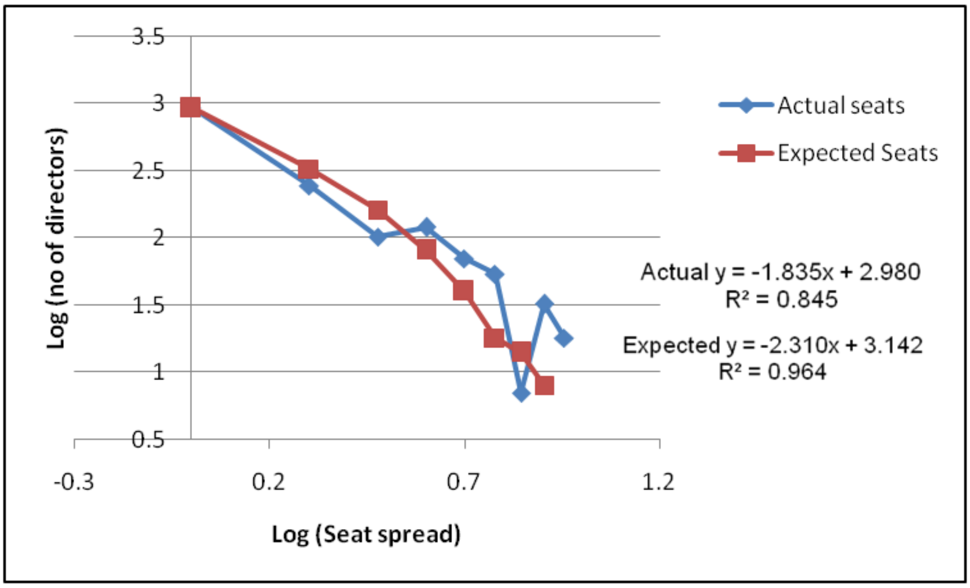
Seat category	Actual directors	Actual seats	Expected directors	Expected seats	Seats available for distribution	Cumulative total
1	927	927	927	927	647.0	927
2	122	244	162	324	323.5	1250.50
3	34	102	54	162	161.8	1412.25
4	30	120	20	81	80.9	1493.13
5	14	70	8	40	40.4	1533.56
6	9	54	3	18	20.2	1553.78
7	1	7	2	14	10.1	1563.89
8	4	32	1	8	5.1	1568.95
9	2	18	0	0	2.5	1571.47
Total	1143	1574	1177	1574		1572.74
Seat spread parameter =2						

Figure 16.
Plot of the actual and expected seat spreads of
Walker & Borrowdale's (1994) NZX director seat spreads for 1984.



A log-log plot of the seat spread in Figure 17 shows a reasonable convergence between the expected and actual values with a small kick up at the tail of the actual seats. This reflects the fact that a director with eight seats has fewer seats than a director with nine seats, which the expected distribution ignores. Fitting a straight line to the expected and actual data in the log-log plot in Figure 17 gives an equation of *$y = -1.835x + 2.980$* with an *$R^2 = 0.845$* for the actual data and an equation of *$y = -2.310x + 3.142$* with an *$R^2 = 0.964$* for the expected data. Visual examination of Figure 17 reveals that the expected data line, although close to a straight line, does curve at the head portion which is confirmed in the less than perfect R^2 value of 0.964.

Figure 17.
Log-log plot of actual and expected seat spreads of
Walker & Borrowdale's (1994) NZX director seat spreads for 1984.



This analysis can be extended further into gendered networks by dividing the seats available for distribution in quarters, with a quarter each available for male and female directors and the remaining half available for directors to acquire *$n + 1$* seats. This can be used to model a world of perfect gender diversity where male and female directors share 50% of the board seats. By adjusting seats proportionally between genders, the generating function can be used to model the actual world where men and women share seats approximately 80/20. It can also be adjusted to generate expected values for a specific director network in the gender ratio of that network.

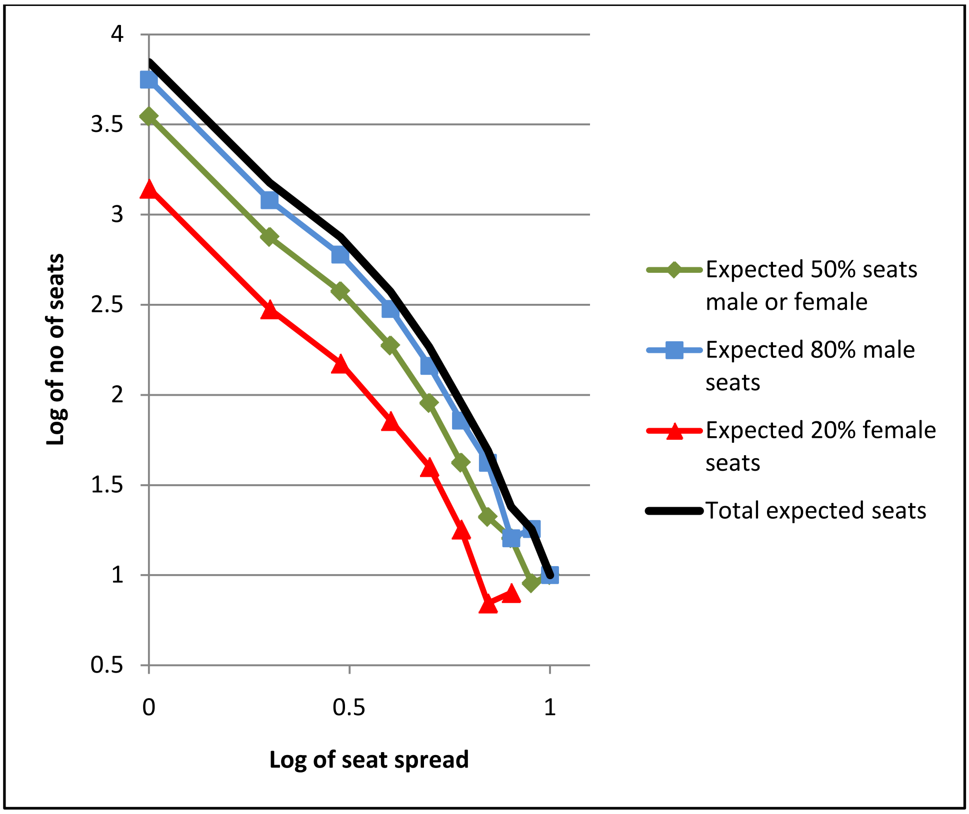
For example, taking a theoretical population of 10,000 directors with 70% of single seat directors, the effect on the director network of enforcing a quota of gender equity, that is 50%, or encouraging an incremental improvement in the numbers of women directors to 20%, can be compared with this methodology. A seat spread parameter of 2 is used. Table 6 gives the resulting seat spreads. Figure 18 is a log-log plot of the seat spreads giving a visual comparison of the expected seats. The blue line represents 80% expected male seats, the red line 20% expected female seats while the green line represents ‘perfect’ gender equity, that is 50% male and female expected seats.

Table 6.
Theoretical plot of expected seat spreads for a 10,000 director network with 70% single seat directors with a seat spread parameter = 2, allocated 80% to males, 20% to females and a perfect gender diversity of 50%

Seat category	Gender equity - expected 50% seats	Expected 80% male seats	Expected 20% female seats	Total expected seats	Cumulative Total	Seats available for distribution
1	3500	5600	1400	7000	7000.0	3000.0
2	750	1200	300	1500	8500.0	1500.0
3	375	600	150	750	9250.0	750.0
4	188	300	75	375	9625.0	375.0
5	90	145	40	185	9812.5	187.5
6	42	72	18	90	9906.3	93.8
7	21	42	7	49	9953.2	46.9
8	16	16	8	24	9976.6	23.5
9	9	18	0	18	9988.3	11.7
10	10*	10	0	10	9994.2	5.9
Total	5001	8003	1995	10001		
Seat spread parameter = 2 *one male only						

This model can be used to compare actual and expected values both before and after diversity interventions. In a country like France considering imposing quotas (Donner & Hymowitz, 2009), this model can show the impact of a quota on their director network, and the different gender ratios of directors needed at each level to achieve a stable pattern of sustainable equity. This model could be used to track the effect of quotas in a country like Norway which has already imposed a 60/40 quota on boards. The line for male directors should move down away from the total line towards the expected quota line as the numbers of male connector directors at each level in the seat spread declines, while the numbers of women should move towards the expected quota line as the number of women connector directors increases.

Figure 18.
Theoretical log-log plot of expected seat spreads for a 10,000 director network with 70% single seat directors with a seat spread parameter = 2, allocated 80% to males, 20% to females and a perfect gender diversity of 50%



If the ‘actual’ line is above the ‘expected’ line, then this will indicate that companies are packing their boards with single seat directors, women who are ‘aunts’ (Huse, 2007), there to meet quotas rather than contribute to the functioning of the business. This may be the initial impact of a quota on a director network, but over time more women connector directors should emerge as competent women are invited to join additional boards. Boards prefer women ‘through the glass net’ so this trend should occur without any additional incentives.

3.2.3.2 Review of historical research using the comparative methodology

To support these contentions, earlier studies were reviewed that report the seat spreads of connector directors. In these studies, gender was not reported and in later WOB studies only female data is reported. It is fortunate that many director studies report the seat spread with some reporting annually as in the UK FTSE100 reports for

UK women directors from 2000 to 2006 (Sealy et al., 2007). This analysis was dropped from 2008 onwards (Sealy, Vinnicombe & Singh, 2008).

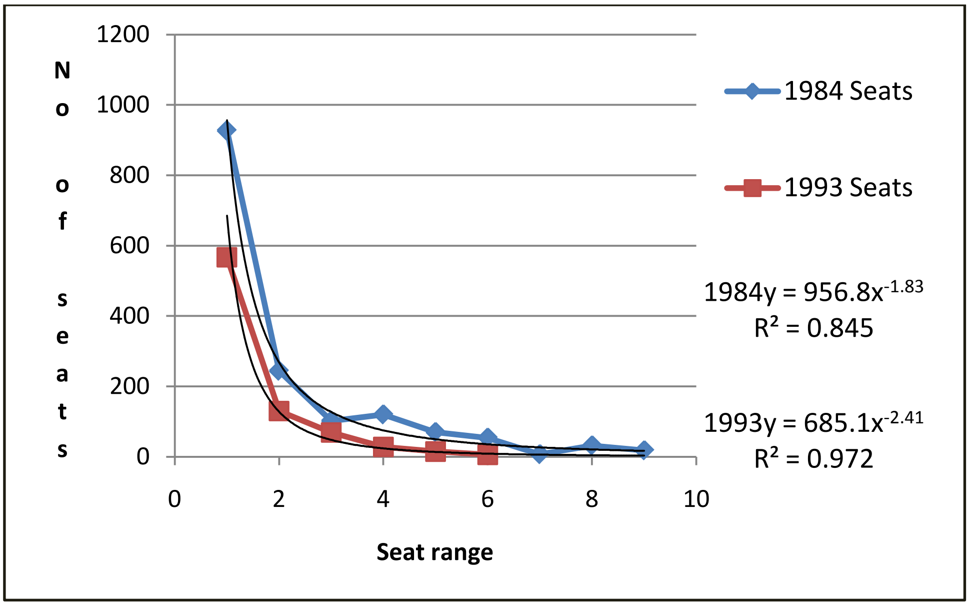
Scholars have only compared longitudinal seat spreads, but have not compared this data with other director networks, nor considered the implications of what they have reported. At best, they have reported the seat spreads as an indication of the extent to which director networks are interlocked and thus can transmit information and influence. Given that there was no theory that explained this pattern, it is not surprising that very little attention has been paid to it. Glass Network theory suggests that the observed director seat spreads are not random and follow a specific pattern approximating a power law based on an underlying non-symmetrical bifurcation process, which can be extended to incorporate gendered director networks.

In order to analyse the historical director literature reporting seat spreads in director networks across time, regions and varying sizes of director networks, the same methodology as the component analysis was followed and the resulting seat spread analysis presented in Table 7 (page 125). A more robust mathematical analysis is certainly possible, but is unlikely to detract from the fact that this pattern exists and is observable without further sophisticated statistical transformations. This also forms the basis of comparison with the results of a similar analysis in the director databases analysed in this thesis.

In order to understand how the results in Table 7 were arrived at, the methodology used will be illustrated using the Walker & Borrowdale (1994) data for New Zealand directors, which compared the seat spreads of New Zealand stock exchange directors in 1984 and 1993. This was across all directors of the New Zealand stock exchange. The component structure of the director network is unknown. The numbers of directors in New Zealand listed companies shrunk considerably from the 1984 high of 1193 directors to 666 in 1993. Again, director gender was not reported. Table 3 (page 114) shows that in 1984, 927 directors had only one seat whereas there were two directors of degree 9 who held 18 seats between them. In 1993, 567 directors held only one seat, with only one director with the highest degree of 6.

The data relating to the number of seats (not directors) was then plotted. Figure 19 shows the resulting steeply declining curve of the underlying power law.

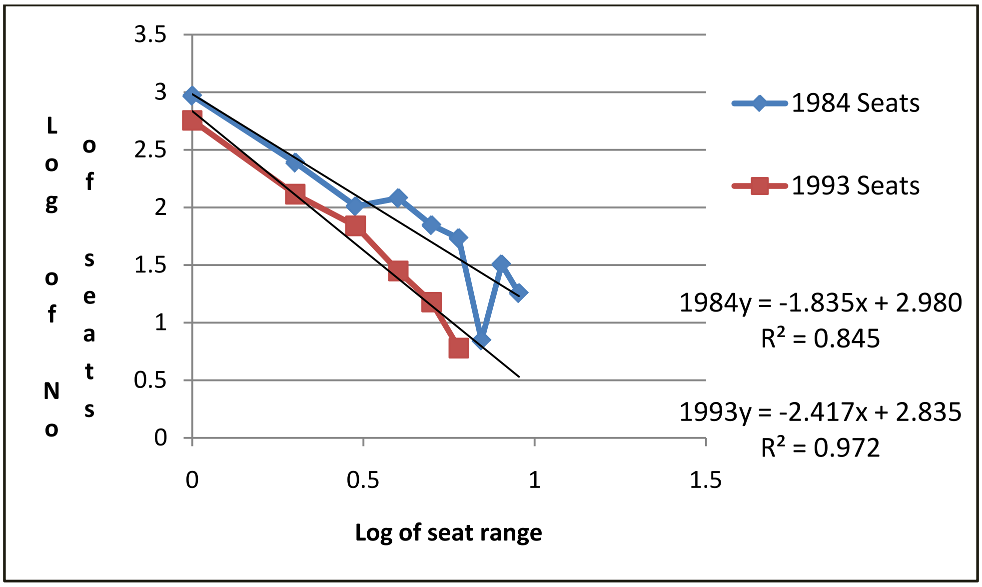
Figure 19.
Walker and Borrowdale (1994) NZX seat spread for 1984 and 1993 with best fitting trend lines.



These seat spreads were then converted to logarithmic values to the base 10 on both axes and plotted. A straight line or linear trend line derived from regression analysis could then be fitted to the graph

As can be seen from Figure 20 the resulting linear trend line has a negative exponent of -1.8 in 1984 and -2.4 in 1993. The axis intercept changes little from 2.8 in 1984 to 2.9 in 1993. The R^2 value in 1993 at 0.972 represents a significant straight line fit and clearly demonstrates the underlying power law that most directors have only one seat and a sharply decreasing minority hold multiple seats. The R^2 value of the 1984 data at 0.845 is not as good a fit.

Figure 20.
Log-log plot of Walker and Borrowdale (1994) NZX seat spread with linear trend lines.



The same analysis was conducted for historically reported mixed gender data on the 1995 US corporate directors (Ferris, 2003), the Australian Top 100, Top 200 and full Australian stock exchange directors (Kiel & Nicholson, 2006), and the 1972, 1984 and 1993 New Zealand Stock Exchange directors (Firth, 1987; Walker & Borrowdale, 1994). The female director only data similarly analysed was the 2000 to 2006 UK FTSE 100 women directors (Sealy et al, 2007) and the 2004 to 2008 South African JSE Ltd Stock Exchange (Businesswomen's Association, 2008). In addition, the percentage of connector or multiple seats to total seats was calculated and the results are shown in Table 7.

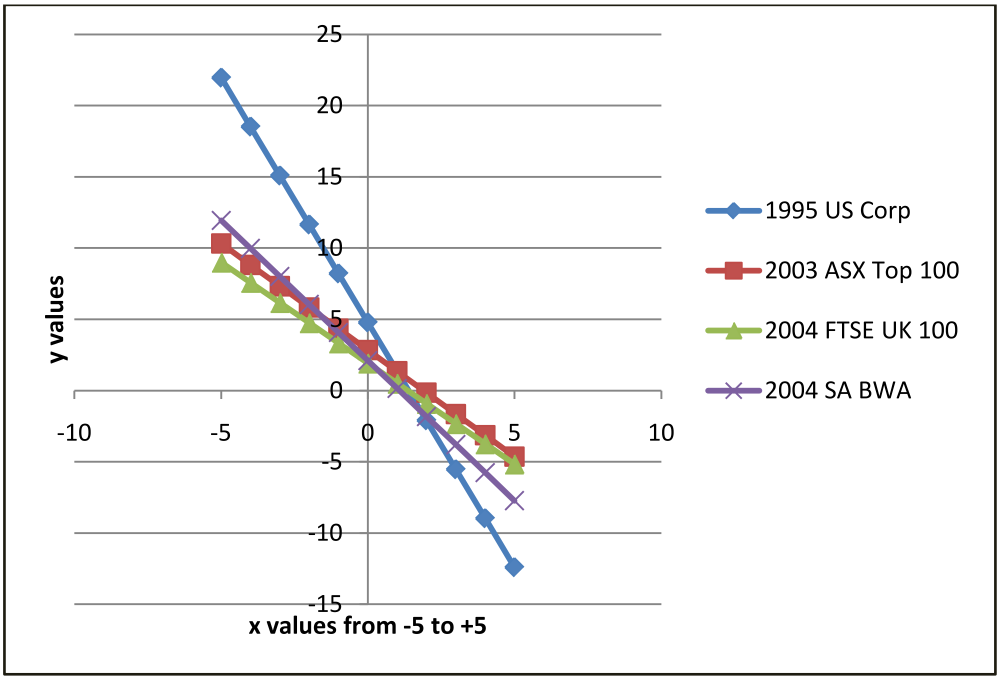
From the results presented in Table 7 it can be seen that the linear trend line equation is negative in all the data and ranges from -1.36 to -3.43. The trend line is stable over time and falls into a limited range comparable across multiple unrelated director data sets of mixed or women-only directors.

Year	Director Network	Gender	No of Directors	No of Seats	% Connector Seats to Total Seats	Linear Trend Line Equation from log-log plot of degree distribution	R Value	Authors
1995	US corporate ($100 Million assets)	Both	23673	29554	19.9	$y = -3.437x + 4.779$	$R^2 = 0.823$	Ferris, 2003
2003	Top 100 Australian Stock Exchange	Both	656	1209	45.7	$y = -1.495x + 2.841$	$R^2 = 0.780$	Kiel & Nicholson, 2006
2003	Top 200 Australian Stock Exchange	Both	1178	1973	22.8	$y = -1.827x + 3.161$	$R^2 = 0.829$	Kiel & Nicholson, 2006
2003	All Companies Australian Stock Exchange	Both	5468	7344	25.5	$y = -2.600x + 3.933$	$R^2 = 0.910$	Kiel & Nicholson, 2006
1993	New Zealand Stock Exchange	Both	666	815	18.3	$y = -2.417x + 2.835$	$R^2 = 0.972$	Walker & Borrowdale, 1994
1984	New Zealand Stock Exchange	Both	1143	1574	27.4	$y = -1.835x + 2.980$	$R^2 = 0.845$	Walker & Borrowdale, 1994; Firth, 1987
1972	New Zealand Stock Exchange	Both	1291	1646	21.6	$y = -2.393x + 3.147$	$R^2 = 0.802$	Firth, 1987
2006	FTSE 100 UK Stock Exchange	Female	106	147	27.9	$y = -1.361x + 1.925$	$R^2 = 0.974$	Sealy et al., 2007
2005	FTSE 100 UK Stock Exchange	Female	108	151	28.5	$y = -1.473x + 1.959$	$R^2 = 0.867$	Sealy et al., 2007
2004	FTSE 100 UK Stock Exchange	Female	98	139	29.5	$y = -1.416x + 1.914$	$R^2 = 0.873$	Sealy et al., 2007
2003	FTSE 100 UK Stock Exchange	Female	90	123	26.8	$y = -1.407x + 1.854$	$R^2 = 0.929$	Sealy et al., 2007
2002	FTSE 100 UK Stock Exchange	Female	78	101	22.8	$y = -2.490x + 1.955$	$R^2 = 0.719$	Sealy et al., 2007
2001	FTSE 100 UK Stock Exchange	Female	72	90	20.0	$y = -2.643x + 1.934$	$R^2 = 0.832$	Sealy et al., 2007
2000	FTSE 100 UK Stock Exchange	Female	73	89	18.0	$y = -2.978x + 1.949$	$R^2 = 0.893$	Sealy et al., 2007
2008	South African BWA Census	Female	324	418	22.5	$y = -1.715x + 2.369$	$R^2 = 0.806$	Businesswomen's Association, 2008
2007	South African BWA Census	Female	298	383	22.2	$y = -1.703x + 2.357$	$R^2 = 0.955$	Businesswomen's Association, 2008
2006	South African BWA Census	Female	296	361	18.0	$y = -1.972x + 2.367$	$R^2 = 0.963$	Businesswomen's Association, 2006
2005	South African BWA Census	Female	278	341	18.5	$y = -2.188x + 2.369$	$R^2 = 0.938$	Businesswomen's Association, 2006
2004	South African BWA Census	Female	170	221	23.1	$y = -1.967x + 2.107$	$R^2 = 0.610$	Businesswomen's Association, 2004

Table 7. Comparative analysis of historical research giving directors' seat spreads with linear trend line and R^2 values from log-log plots.

Four of the datasets were selected to illustrate the clustering of equations with similar slopes and intercepts in Figure 21. These four were the mixed gender 1995 US corporate data and Top 100 Australian ASX equations as well as the 2003 FTSE UK 100 female and 2004 South African BWA female data sets. The equations are plotted with x values ranging from an arbitrary -5 to +5 to allow for comparisons across a wide range of values.

Figure 21.
Selected sample of plotted equations from historical director seat spreads analysed in Table 7, illustrating the slope, intercepts and clustering of similar equations.



From this data the UK, ASX and SA data cluster together irrespective of gender but the 1995 US corporate data (Ferris, 2003) is immediately identified as an anomalous outlier warranting further investigation.

The Ferris (2003) data should be regarded with caution. Although a large dataset, the Ferris (2003) data is derived from a 1995 Compustat corporate listing database and no evidence is available to estimate the network connections between these companies and size of the components in the network. This dataset has a large director degree, with two directors having eleven seats between them. The trend since this time has been for fewer seats per male director. This is in contrast to the women director data, which shows increasing numbers of multiple seats.

In the longitudinal data analysis of the UK FTSE 100 women directors and the BWA South African census of women directors the percentage of connector seats follows an upward trend, indicating that women through the glass net are getting more board appointments. The trend line equations, including the exponents and intercepts, for both the female director datasets are remarkably constant over time, despite the increasing numbers of women directors and multiple seats. The South African dataset is interesting as it illuminates a business environment with legislated affirmative action favouring Black women. The dataset does not distinguish between the races of the women directors, but compared to the much slower growth of female connector directors in the FTSE 100 dataset, the increasing numbers of South African connector women directors reflect the business response to this legislation. Over the comparable period of 2004 to 2006 only eight additional female seats were added to the FTSE 100 tally compared to 126 in the South African JSE companies. Even in this environment, which is so favourable to women directors above the glass net, the degree distribution of the South African women directors follows a power law pattern, with the R^2 values close to 1.00 indicating an extremely good fit to the linear trend line.

This preference for women above the glass net has led to the hypothesis that there will be more opportunities for women and minority connector directors than men connector directors as they will have overcome issues of 'lack of fit', salience and credibility (Hillman et al., 2002). This study also looked for differences between the attributes of 1993 Fortune 1000 White males and female and racial minority directors. No support was found for the hypothesis that female and African-American directors were more likely to serve on multiple boards than White male directors.

This study is in essence a test of Glass Network theory and some of Hillman et al.'s (2002) anomalous findings can be explained if the results are viewed from a different theoretical framework. In particular, reworking their data for their third hypothesis shows that African-American seat spreads follow the same pattern as White directors using the seat spreads of the connector directors as given in their Table Three (Hillman et al., 2002, p. 755). See Appendix Four for the detailed reworked calculations.

Firstly, the random sampling of a 100 White male and female directors must be ignored as this is not a valid method in terms of Glass Network theory to select comparative directors groups, as it ignores network structures. Using only the actual numbers of African American directors reported (71 males and 16 females in a ratio of 4.4 men to women) and grouping them into four groups, namely, single seat and connector directors by gender, a Chi-squared analysis with Yates correction and one degree of freedom using 4.4 as an expected ratio gives a value of 5.77, which is significant at $p < .05$. Hillman et al. (2002) indicate that in their total sample the percentage of female directors was 7.53% (18.39% in the African American sample) giving a gender ratio of 12:1 male to female directors. Repeating the calculation, using this ratio to calculate expected values for the African American single seat and connector director groups, Chi-squared analysis with Yates correction and one degree of freedom gives a significant value of 26.91 with $p < .001$. Hillman et al. (2002) found no support for differences across 'director categories', whereas these results show the opposite, that African American female directors are more likely to have connector seats than African American male directors.

The Kiel and Nicholson (2006) study of Australian directors is another interesting study, as it takes a snapshot at three scales, namely the Top 100 companies, Top 200 companies and all ASX directors. The authors found that board size varied with company size, with the larger the company, the larger the board. Across the ASX, board size averaged 5.7, while among the Top 100 firms it averaged 8.2. In the Kiel and Nicholson (2006) study theTop 100 companies comprised 88% of the Australian stock exchange's market capitalisation and 95% of the Top 200. The percentage of connector seats in the Top 100 companies increases to 45% from 22-25% in the wider director networks, indicating that multiple directorships are more likely to be held by directors in the larger companies.

If more women are found in companies with larger boards and in larger companies per se, then Glass Network theory suggests that more women with multiple seats will be found in the Top 100 and Top 200 companies than the stock exchange as a whole. This suggests that a positive relationship may exist between the female connector directors (who can pick and choose boards as they are above the glass net), and firm value or performance. This matches the findings of the value in diversity schools such as Carter et al. (2003), Erhardt et al. (2003) and Nguyen and Faff (2007).

Glass Network theory suggests that the seat spreads of women directors will follow a power law pattern even though the numbers of women directors will be considerably less than men directors, that is, below 20% in a director network. What is not known is how this female power law, as represented by the linear trend line equation, will compare to that followed by male directors. The scale-free network principle of self-similarity suggests that the slope m of the female linear trend line as expressed in $y = mx + c$, will be parallel to that of male connector directors.

Examination of the plotted data will allow for the estimation of lower and upper bounds or ranges to the trend lines derived from observed networks. These ranges, which themselves have a defined equation, can then be used with log-log plots of other networks and provide graphical prediction of how other networks conform to the expected equation ranges. Conforming networks will fall in the ranges in a parallel manner, whereas non-conforming networks will fall outside the range or cross it diagonally.

3.3 Stable Ratio of Male to Female Directors

The network constrains the overall ratio of male to female directors and maintains this as a relatively constant ratio over time. Like many phenomena, for example sound waves or share prices, this ratio may fluctuate within a limited band depending on the scale at which it is viewed, but trend lines are discernable over longer periods of time. Over a thirty year period, the global percentage of female directors has remained below 20%, where there are no external pressures to change this. This ratio suggests a Pareto ratio in the order of 90/10 or 80/20 reflecting the underlying power laws driving the observed patterns (Barabási, 2003).

In countries where there are no affirmative action programs to which the network adapts, women directors co-exist with male directors in a specific proportion that will stay stable over time despite considerable churn in the director body as new directors are appointed with the resignation or death of existing directors. The inherent stability of networks and their resistance to change explains why interventions to increase the numbers of women on boards of directors have made so little progress unless there is enforced affirmative action. The Norwegian (Hoel, 2008; Huse, 2008) and Spanish (de Anca, 2008; Campbell & MÍnguez-Vera, 2008) experiences indicated that changes to companies' gender balances do not occur voluntarily even under the threat of quotas.

The theoretical proposition of Glass Network theory is that networks maintain an inbuilt and limited amount of diversity amongst nodes. In terms of gender diversity, this manifests in the overarching male to female director ratio in the network. This diversity is a function of a complex adaptive network that facilitates changes to node attributes such as preferences for one gender over another should network survival require such adaptations. This diversity is also manifest in the presence of extreme values or outliers, with the effect of this being that the network data is not normally distributed.

To test propositions of stability over time, a longitudinal study is a necessary starting point. There is a historical precedent in the Davis et al. (2003) study that is continued in this thesis. Baseline measures of director churn, and in particular turnover rates for female directors, have not been measured, although indications are that the percentage is likely to be over 40%. The contribution of the stable core of continuing directors to the structure of a director network needs more investigation, but the principle of self-similarity would suggest that the differences between full networks and continuing director networks are unlikely to be extreme.

As earlier studies have shown different results when different techniques for constructing random networks are compared to actual director network data (Conyon & Muldoon, 2006, 2008; Davis et al.,2003; Newman et al., 2001), Glass Network theory is also tested against randomly constructed networks. By randomly allocating a number to each director, creating an artificial attribute, and then numerically sorting directors, the networks can be broken into random sub-graphs that preserve the original relationship to other directors and to the company. The rule of self-similarity suggests that random director networks of this nature are also scale-free and small-worlds.

To paraphrase Davis et al. (2003 p.307), if interlocks are largely unplanned and without strategic intent, then what is the structure of the network created through interlocks and why does it follow such a particular form? I suggest that Glass Network theory with gender as its analytical tool describes and explains this form linking by director network theory to scale-free network theory.

3.4 Research Question Set

Before the major research question, "Are male and female director networks similar or different?", could be answered, a series of questions relating to gendered director network structures required answers. To empirically test Glass Network theory, a set of research questions is outlined. The structure of this thesis follows the sequence of these questions.

3.4.1 Network description and component analysis

3.4.1.1 What does a gendered director network look like? Where are the women directors in the mixed gender and women-only networks?

3.4.1.2 How many components does a network break into and what is the size of the largest component? Do the unconnected components ranked by size follow a specific distribution, assuming the data is not normally distributed?

3.4.1.3 Where are the women directors in the network components? Are they in the largest connected component or in the unconnected components?

3.4.1.4 In the largest connected component of the mixed gender director networks, who are the connector directors, that is, directors with more than one seat, and what is their gender? Does the spread of seats held by connector directors to single seat directors follow a specific pattern? Do they conform to the expected seat spreads derived from the non-symmetrical generating function?

3.4.1.5 Are female directors with more than one seat, namely connector directors, being appointed to more boards than their equivalent male connector directors in the largest connected components of the mixed gender networks?

3.4.2 Social network analysis of the largest component

What is the social network structure of the largest component of the mixed gender and female-only director networks in terms of the density, reach, clustering coefficient, degree, geodesic distance and subsidiary measures derived from these calculations? How do they differ from each other?

3.4.3 Small-world networks

Are mixed gender and women-only director networks small-world networks at a global and national level?

3.4.4 Assortative mixing

Do mixed gender and women-only director networks show positive assortative mixing?

3.4.5 Degree and betweenness

3.4.5.1 Does the distribution of the degree, or number of links between a director and adjacent directors, in the largest component of the mixed gender and women-only networks follow a specific pattern?

3.4.5.2 On the Freeman betweenness measure, or the number of times a director is found on a geodesic path between two other directors, what percentage of male and female directors in the mixed gender and women-only networks have a betweenness score of greater than zero. Are these in a specific proportion to male and female directors respectively who have a zero betweenness score?

3.4.5.3 Does the distribution of betweenness scores in the largest component of the mixed gender networks follow a specific pattern, namely a power law?

3.4.5.4 Who are the top fifteen directors by betweenness and what is their gender?

3.4.6 Testing Glass Network theory against longitudinal and random networks

3.4.6.1 What is the rate of director churn or turnover from 2004 to 2007 in the Fortune Global 200 directors; and the 2004 and 2007 NZX directors' networks? What is the rate of director churn for male and female directors in these networks?

3.4 6.2 What does the gendered continuing director network look like? Where are the women continuing directors?

3.4.6.3 How many components does the continuing directors' network break into and what is the size of the largest component? Does the size of the unconnected components follow a specific distribution assuming the data is not normally distributed?

3.4.6.4 Where are the women continuing directors in the network components of the mixed gender networks? Are they in the largest connected component or in the unconnected components?

3.4.6.5 In the largest connected component of the mixed gender continuing director networks, who are the continuing connector directors, that is, directors with more than one seat, and what is their gender? Does the spread of seats held by continuing connector directors to single seat continuing directors follow a specific pattern, namely a power law?

3.4.6.6 Are female continuing directors with more than one seat, (namely connector continuing directors), being appointed to more boards than their equivalent male continuing connector directors in the largest connected components of the mixed gender networks?

3.4.6.7 Do the continuing directors' networks differ from the networks of all directors from 2004 to 2007 in terms of the density, reach, clustering coefficient, degree, geodesic distance and subsidiary measures derived from these calculations?

3.4.6.8 Do mixed gender continuing director networks show positive assortative mixing?

3.4.6.9 Does the distribution of the degree or number of links between a director and adjacent directors, in the largest component of the mixed gender continuing director networks follow a specific pattern? Is there a significant difference in the degree scores of continuing directors who are present in the network at 2004 and 2007 as well as those present only once?

3.4.6.10 On the Freeman betweenness measure, or the number of times a director is found on a geodesic path between two other directors, what percentage of male and female continuing directors in the mixed gender networks have a betweenness score of greater than zero. Are these in a specific proportion to male and female continuing directors respectively who have a zero betweenness score?

3.4.6.11 Does the distribution of betweenness scores in the largest component of the mixed gender continuing director networks follow a specific pattern? Is there a significant difference in the betweenness scores of continuing directors who are present in the network at 2004 and 2007 as well as those present only once?

Chapter Three Summary

Glass Network theory is introduced with a précis using Carlile and Christiansen's (2005) typology of theory building. Firstly, the known constructs from previous director research are stated and the areas requiring further observation are outlined. Secondly, the proposed classification by attributes such as time, gender, location, or random assignment, is also outlined. The third stage of descriptive theory building then explains the observed correlations as a function of underlying power laws and briefly describes a generating function to allow a comparison between actual and expected seat spreads.

The structure of Glass Networks is outlined in more detail and foundation concepts discussed. These include the forces of preferential attachment, homophily, and assortativity. Director networks are stable and resistant to change. The overall ratio of male to female directors is maintained as a relatively constant ratio over time. This is the manifestation of an inbuilt and limited amount of diversity that permits adaptations should network survival require change.

Seat spreads, or the distribution of multiple directorships, and the ratio of connector directors to single directors is discussed. A theoretical model deriving expected seat spreads from a non-symmetrical generating function is described in detail. Historical research is reviewed and reworked with the comparative methodology developed to compare networks over time and location.

Chapter Four. Methodology

4.1 Ethical Considerations

Director names have been included in this thesis as the names and associated company information are available in the public domain and this is the practice elsewhere in director network research (Davis & Mizruchi, 1999; Davis et al., 2003; Stablein et al., 2005). The New Zealand data in this thesis is available by purchase from the New Zealand Stock exchange and from their website, www.nzx.com. Company and director information is available for searching free of charge from the New Zealand Companies Office register of companies website (www.companies.govt.nz). The raw data for the Fortune Global 200 network is provided in an appendix to the 2004 and 2007 CWDI reports. The raw data for the 1999 Fortune US 1000 dataset was provided by Professor G. Davis, University of Michigan.

4.2 Determining Director Gender

Two of the datasets, the 2004 and 2007 Fortune Global 200 were already gender coded. Using methods similar to Hillman et al. (2007), the remaining 11 datasets were hand coded by research assistants based on their knowledge of gendered first names. When a gender neutral name, initials or unusual name was encountered this was highlighted for further checking and validation. Websites listing boys and girls names were also consulted. Most of the directors in the databases used are prominent individuals and have an internet profile. In order not to overstate the number of women directors in a network, a conservative approach was followed and the default of male assigned in the few instances where gender could not be determined. The author performed a final check and validation.

4.3 Software used in the data analysis

1. Microsoft Excel 2005 and 2007
2. Microsoft SQL 2000
3. UCINET for Windows Version 6.216 (Borgatti, Everett & Freeman, 2002)
4. Netminer Version 3.3.2.090304 (Cyram, 2009)
5. PAST Statistical Package Version 1.96 (Hammer, Harper & Ryan, 2001)
6. Sequential random number generator from www.random.org

4.4 Data collection and pre-processing

To examine director networks from the national to the global level at a number of points in time, seventeen datasets were obtained from several sources and converted into a format suitable for running comparable social network analyses.

Table 8.
Hierarchical outline of constructed director datasets.

Global network
2004 and 2007 Fortune Global 200 companies

National director networks
1999 Fortune US 1000 companies
2004, 2005 and 2007 New Zealand Stock Exchange

Longitudinal Subsets
2004 and 2007 New Zealand Stock Exchange continuing directors
2004 and 2007 Fortune Global 200 companies continuing directors

Female director networks
1999 Fortune US 1000 companies
2007 Fortune Global 200 companies
Random networks created from the global and national networks
2007 Fortune Global 200 companies 1st and 2nd Half
2007 Fortune Global 200 companies 1st, 2nd and 3rd Third
2007 NZX companies 1st and 2nd Half

The mixed gender datasets were:

i. 1999 Fortune US 1000 director dataset used in Davis et al. (2003).
ii. 2004 and 2007 Fortune Global 200 director datasets from the raw data published in the Corporate Women Directors International 2004 and 2007 Reports.
iii. 2004, 2005, 2007 New Zealand Stock Exchange director datasets. The 2004 New Zealand director dataset was used in Stablein et al. (2005).

iv. 2004 and 2007 Fortune Global 200 continuing directors, present in both datasets. 2004 and 2007 New Zealand Stock Exchange continuing directors, present in both datasets.
v. Five random datasets constructed from the 2007 Fortune Global 200 dataset.

The women-only datasets were:

1999 Fortune US 1000 women directors
2007 Fortune Global 200 women directors.

4.4.1 1999 United States Fortune1000 director dataset

The 1999 Fortune US 1000 director dataset was provided in raw format by Professor Gerald Davis of the University of Michigan. This is the iconic dataset used by a number of network researchers (Battiston & Catanzaro, 2004; Battiston et al., 2003; Davis et al., 2003; Newman, 2002; Newman, 2003a; Newman & Park, 2003; Newman et al., 2001), but has not previously been used in gender research.

Director information for the 1999 Fortune US 1000 dataset was derived from "Global Access (the Web-based successor to Compact Disclosure), supplemented by proxy statements filed electronically with the SEC via EDGAR (see http://www.sec.gov/edgar.shtml)" (Davis et al., 2003, p.310). This dataset is referred to as the US Fortune 1000 dataset even though it does not contain data from a thousand companies. Davis et al. (2003) selected this data from the largest 600 public firms that reported the compositions of their boards to the United States Securities and Exchange Commission (SEC) from among the Fortune 1000 for 1999, in order to be comparable with their 1982 and 1990 datasets. The 1999 data set included firms ranked 1 through 625 and the sample covered firms in both service and manufacturing industry groups. The authors followed this approach as in 1995 Fortune Magazine widened the definition of companies in the Top 500 to include service as well as manufacturing companies. This makes this dataset more directly comparable with the Fortune Global 200 and New Zealand datasets, which also cover service and manufacturing industries. The 1999 Fortune US 1000 dataset provided additional value as a validating dataset.

The data required extensive ‘scrubbing’. As it was the largest dataset, it could not be used in the Microsoft Excel matrix format due to the limitation of 250 columns in both Microsoft Excel and the UCINET version used for the network analysis. The data was captured into a Microsoft SQL database and a number of stored procedures written to remove duplicates and then extract files in the DL format required by UCINET.

Validating procedures reduced the number of companies from 967 to 916, the number of director seats to 10,098 seats and the number of directors to 7,644. Davis et al. (2003) utilized data from 5311 directors following their validation procedures, while Newman (2002) reported a sample size of 7673 directors. Validation followed similar steps to those reported by Davis et al. (2003) and included reading each name, standardizing the individual directors’ designations across boards (e.g. Andrew Lewis Jr and Andrew Lewis II) and removing ambiguity by verifying the individuals through a web search. If they could not be shown to be a single person, the default action was to leave them as two individuals, thereby reducing the number of linked directors.

4.4.2 Fortune 200 Global director datasets

The 2004 and 2007 Fortune Global 200 director data sets were derived from the detailed male and female director information for the Top 200 global boards ranked by Fortune magazine and studied by the Corporate Women Directors International organization (CWDI 2004 Report, CWDI 2007 Report). The global companies in the 2004 dataset were ranked by Fortune magazine according to global revenue in 2004 and were current on 30th June, 2004. The companies in the 2007 dataset were ranked by Fortune magazine according to global revenue in 2006 and were current on 31st March, 2007. The appendices containing the detailed director information were found to have proofreading errors and director totals did not always agree with totals in the text. Where possible, data was verified by an internet company search and the detail totals utilized rather than the summary totals of the CWDI report.

These were converted into a two mode matrix (director by company) in Microsoft Excel spreadsheets. This was a useful format as totals could be cross-cast and validated, especially when gender networks were extracted out of the main dataset.

4.4.3 New Zealand Stock Exchange director datasets

Three datasets spanning 2004, 2005 and 2007 were constructed, permitting a longitudinal analysis of the gendered New Zealand director network. At the time the data was initially collected, the NZX data was intended to be the only longitudinal dataset and the 2005 data was collected. When it was learned that CWDI intended to repeat the 2004 Fortune Global 200 study in 2007, the NZX data was collected again in 2007 to facilitate comparisons with the global dataset.

The 2004 New Zealand Stock Exchange dataset was provided in its raw format by Professor Ralph Stablein. This was the dataset utilized in Stablein et al., (2005) and also served as a validating dataset. The raw New Zealand Stock Exchange datasets were obtained from the stock exchange administration on 27th January, 2004, during January 2005 and January 2007 respectively. Only the main board companies were analysed, but comprised the full number of companies on the stock exchange for each year. This consisted of 184 companies in 2004, 197 in 2005, and 185 in 2007.

It can be argued that the NZX networks represent a natural or complete real life network unit. The US Fortune 1000 and Fortune Global 200 networks as a listing of the Top 1000 and 200 companies respectively, are extracted out of a bigger network and comprise a specific segment of those networks.

Similar validation procedures were followed as for the US Fortune US 1000 and Fortune Global 200 datasets. These three datasets were also converted into two mode matrices (director by company) in Microsoft Excel spreadsheets.

4.5 Testing Glass Network theory against longitudinal and random networks

The limited existing network literature includes few longitudinal director studies or those concerned with random simulations of director networks. This is partly due to the complexity and size of the resulting matrices and the difficulties in manipulating cross tabulated data. The underlying principle when attempting this is to strip away all relationships between directors and companies except for the relationship inferred from meeting around a boardroom table. Despite the drastic simplification of director networks into matrices of links, patterns of organization are observable and measurable, allowing predictions to be made against other networks.

4.5.1 Longitudinal datasets

As Glass Network theory suggests that director networks are robust and resist change, network structure and patterns of organization should persist over time. Davis et al. (2003, p.321) found the level of connectivity between directors in the Fortune US 1000 dataset “remarkably consistent over time” having analysed this dataset in 1982, 1990 and 1999.

To test for a similar consistency in the Fortune Global 200 and the New Zealand Stock Exchange networks, directors who were present in both the 2004 and 2007 datasets were identified. As both datasets were in two mode matrix format (director by company) in Microsoft Excel spreadsheets, the director names could be matched and the datasets sorted into matching names and those directors present only once using a column sort while keeping the row data intact. These were then extracted without destroying the network structure. The longitudinal director sub-networks were converted into affiliation networks with UCINET software, the network components determined and the largest component extracted for the same analysis as the parent networks.

This study differs from Davis et al. (2003), who analysed a panel of 195 firms that were still present 17 years later and the number and identities of the directors varied at three points in time. This study takes the same directors who were present at two points in time and whose directorships or seats will have changed in that period and examines the differences in their networks.

This allows for the continuation rate of directors to be established by comparing the percentage of the continuing directors to the numbers of directors in the full network. The results of the continuation rate calculations are given in Table 34 (page 192) as well as the gender breakdown. These percentages should decrease over time as directors resign their directorships. It is not known whether male and female directors' continuation rates are similar or not. It is also not known whether the consistency noted by Davis et al. (2003) in the small-world measures is influenced by gender.

To test for significant differences in degree and betweenness between longitudinal director networks, a non-parametric statistical procedure that was appropriate for ordinal, discrete and related data was selected. This was the Wilcoxon matched pairs signed ranks test (Siegal, 1956). The software used was the PAST statistical program (Hammer, Harper & Ryan, 2001).

The directors in the 2004 and 2007 Fortune Global 200 and NZX datasets were matched by name and sorted by presence or absence of a degree or betweenness score. A gender analysis was not done. It became apparent that the statistical test could be done two ways, namely on the first set of directors who were present in both data sets and had a degree value in both years and a second set comprising all directors with those who were only present once in either 2004 or 2007 and coded zero for the missing year. The null hypothesis for the Wilcoxon test is that there is no median shift or difference in the median degree values.

4.5.2 Random datasets

To meaningfully compare observed and random networks, the constraints introduced into the random simulation have to be carefully considered. Too few restraints will result in large meaningless differences and too many will result in no differences at all. This consideration forces a researcher to consider the level of simplicity or its corollary the level of complexity introduced in the random model or simulation.

Random simulations are only effective when matched to observed data, as Newman et al. (2001) demonstrate with the same Fortune 1000 director dataset as used here. In fitting simulated director probability distributions to those of co-workers, the generated model was a good fit at director level, but not at the board level. The model did not accommodate a distribution where a disproportionately high number of boards had very many or very few interlocks to others. This finding then generated the ‘‘big shots work with other big shots’’ hypothesis, later conceptualised as assortativity.

In another notable study of director networks using random simulations, Robins and Alexander (2004) tested bipartite director networks against 400 simulated networks incorporating both company and director structure into their random networks. These were only constrained to the same number of edges with the degree of each director at least two, and of each company at least one. These simple and limited constraints produced significant differences between the random and observed networks of US and Australian directors, but the authors could not conclude much more than:

> Both networks exhibit considerable similarity. They both differ, in substantial and similar ways, from the random graph distributions. Accordingly, we conclude that many of their important properties do not merely emerge from the programmed constraints of the modeling process. Additional social processes are operating and these seem to be similar in the two observed datasets (Robins & Alexander, 2004, p. 89).

The present study is a different design, that is, a 1-mode design concerned with largest connected components rather than a 2-mode design exploring the total network. This thesis, in comparing female to male directors in mixed gender networks, essentially uses extractive procedures and reduces director networks to smaller entities. Glass Network theory suggests that these smaller entities will be self-similar to the parent entity. This implies that the smaller entity will be as complex as the parent entity, not simpler. This compounds the issue of what is or is not a random network. Networks exist by virtue of being linked together, so unconnected segments being networks in their own right may or may not be seen as random objects.

It is possible to create artificial criteria or attributes and randomly allocate the value of that attribute to each director and divide the network into smaller segments on this basis. Networks created this way should also show similar patterns of organization to each other, however they are sliced or diced. In this process, values such as degree or betweenness must be within the bounds of other network values as they are derived from the same underlying structure. This also implies that the results from random networks should fall into the predictive ranges developed with the comparative methodology used in this thesis.

There is an additional complication in comparing random and real director networks and that is the impact of the presence or absence and size of a large component in the smaller random networks. If present, the size of the large component materially affects the network measures for this component. The extreme values in a director network, that is, the few directors with many seats, may or may not be excluded from the large component depending on the random allocation of that director and linked colleagues to a specific network segment. If sufficient connector directors are allocated to a random smaller segment and included in the large component, the derived network measures such as degree or betweenness will reflect these extreme values. Where distributions follow power laws, the results from random segments will reflect these distributions.

Random assignment of directors to different network segments may exacerbate the role of outliers where nodes of extreme degree are allocated by chance to one segment. Taleb (2007) calls this the ‘black swan’ effect. In the case of the division of the network into thirds, two segments will be similar and the third segment with the extreme values will differ significantly. Inspection of the data will indicate the presence of extreme values.

What is undertaken here is an exploration of network randomness that may deliver useful insights and information when compared to the data derived from gendered networks. To randomly assign a director to a dataset without destroying the network structure, the network must be divided into smaller portions, in this case halves and thirds. If self-similarity is maintained at all scales then the network measures in the smaller segments will not differ from each other or the originating dataset, provided the sample numbers are large enough. If the networks are not self-similar, random allocation of the directors to the smaller segments will result in significantly different network values.

The effect of this random assignment process is similar to coding directors by gender and then extracting the women-only or men-only networks. It is also similar to extracting the continuing directors, who are selected on the basis of presence in an earlier network. The purpose of this process of random allocation is to determine whether any gender or time-related similarities or differences can be differentiated from a random allocation of directors to network subsets. If director networks are self-similar then the networks generated by random coding, gender or time-related coding will not differ from each other.

The 2007 Fortune Global 200 and the 2007 NZX datasets were selected as the basis for the random datasets. Both are part of the originating datasets for the continuing director datasets and are also the latest datasets. The 2007 Fortune Global 200 dataset is a large dataset and was selected for the test of random thirds. It is also the dataset with sufficient women to have a women-only network as a subset.

To randomly assign the directors to either a half or a third of the dataset, random numbers were assigned to each director. These were a sequence of random numbers equal to the number of directors in the dataset, generated from the random sequence generator of www.random.org. As the dataset was in two mode matrix format

(director by company) in a Microsoft Excel spreadsheet, the director names were sorted into sequential random numbers using a column sort while keeping the row data intact, that is the links to each company, and through those links keeping links to other directors intact. The dataset was then divided numerically into halves.
Another set of random numbers was generated from www.random.org and again assigned to the directors of the Fortune Global 200 dataset in their original order. Following sorting into number sequence the dataset was divided numerically into thirds.

Individual halves or thirds were then extracted without destroying the network structure and analysed in the same way as the original dataset. The seven director networks were converted into affiliation networks with UCINET software, the network components determined and the largest component extracted for further analysis in the same manner as the actual director networks.

This process of random allocation to smaller segments does allow for iterative repetitions such as those conducted by Robins and Alexander (2001), but requires computer programming to reduce to manageable proportions the large volume of calculations required to analyse the resulting networks.

4.5.3 Wilcoxon matched pairs signed ranks test

To test for significant differences in degree and betweenness in longitudinal director networks, a nonparametric statistical procedure that was appropriate for ordinal, discrete and related data was selected. This was the Wilcoxon matched pairs signed ranks test (Siegal, 1956). The software used was the PAST statistical program (Hammer, Harper & Ryan, 2001). The directors in the 2004 and 2007 Fortune Global 200 and NZX datasets were matched by name and sorted by presence or absence of a degree score. A gender analysis was not done.

It became apparent that the statistical test could be done two ways, namely on the first set of directors who were present in both data sets and had a degree value or a betweenness value greater that one in both years and a second set comprising all directors with those who were only present once in either 2004 or 2007 coded zero for the missing year. It should be noted that, depending on changes in board appointments over time, directors could lose or gain a betweenness greater than zero. The data did not differentiate between those who never had a betweenness score greater than zero and those whose betweenness over time dropped or rose above zero.

The null hypothesis for the Wilcoxon test is that there is no median shift or difference in the median values.

4.6 Women-only director networks

Once the full director networks had been constructed and then coded by gender, the women director networks were extracted. Using only the women to women links, Microsoft Excel spreadsheets of two mode networks (director by company) were constructed for the Fortune Global 200 datasets, the New Zealand Stock exchange datasets. A stored Microsoft SQL procedure was used to extract the 1999 Fortune US 1000 women director network in DL format. The women director networks were converted into affiliation networks with UCINET software, the network components determined and the largest component extracted for further analysis.

Only the largest component of the 1999 Fortune 1000 and 2007 Fortune Global 200 women-only director networks were large enough to permit further analysis.

4.7 Data Preparation

The director datasets were analysed and validated using various Microsoft Excel functions, UCINET 6 (Borgatti et al., 2002) and Netminer 3. (Cyram, 2009).

Input to the various software programs was by copying or importing Microsoft Excel spreadsheets or by importing files in DL format extracted from Microsoft SQL databases. The data were imported as two-mode networks, director by company, and converted in UCINET to a one-mode affiliation network, director by director. The data was dichotomized to remove lobby links as required by most of the calculations to avoid over-counting. The removal of lobby connections in the data reduces the connectedness of the network. The largest connected component was extracted and only director data in this large or giant component was utilized for the data analyses.

Once the main network components had been extracted in UCINET, the data was exported in DL format from UCINET for import into Netminer 3 for the Assortativity analyses. Netminer 3 also was used to validate the UCINET results.

In addition, a sample network was constructed that contained all the likely elements, that is multiple companies with main and subsidiary components, directors of both genders in all companies and two companies with lobby directors who sat on two boards together. This was used for validation purposes and to draw up a user guide for future studies duplicating this thesis. This is available on request from the author.

4.8 Comparative methodology

In considering the best methodology to be used for the data analysis, the prediction from Glass Network theory that director network data will not be normally distributed precludes the use of parametric statistics. The data is not independent and not continuous with multiple ties. Mean values are, however, used in the Small-world Quotient calculations and are therefore calculated and included. The network data is best represented in graphical form as conventional representation in terms of means or averages will not do full justice to the data, especially where a few nodes have large values and many nodes have small values.

Following the graphical approach used by Watts, Newman and Barabási in early small-world and scale-free network research, a methodology was developed using the popular business software Microsoft Excel's advanced graphical function. This facility provides a means to easily compare disparate director networks and present them visually together on one graph. In addition, the methodology can be readily applied to future research and permits predictions to be made. It can be used to monitor the consequences of future affirmative action, as this initial research sets baselines for gendered director networks. If diversity activists are successful, change should be readily apparent with this methodology.

As Glass Network theory predicts that director network data will be self-similar by scale and gender, the comparative methodology permits comparisons by gender over time, country and at differing scales. In addition, the methodology can be used with a variety of director attributes such as age or ethnicity or network attributes such as director degree or betweenness. As the presence of power laws in director networks has been established by Barabási (2003a) and confirmed by Newman (2003c), this underlying organising principle will determine the structure and functioning of a director network. It is these derived patterns of organization that this method uses to compare director networks so that the social and business implications may be understood, particularly if attempts are made to change the diversity of director networks.

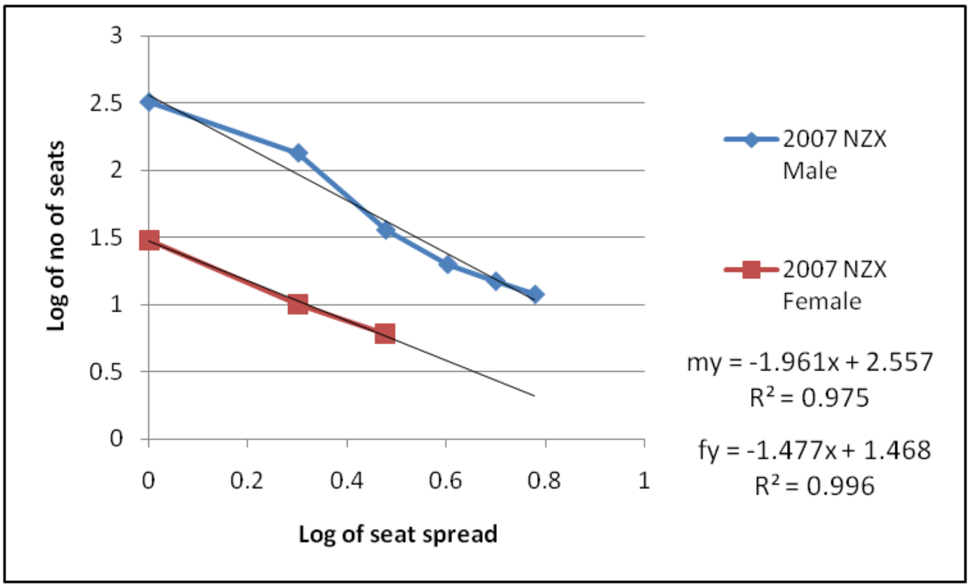
4.8.1 Fitting trend lines and deriving linear equations from log-log plots

Firstly, the data was plotted using a scatter plot and the power law trend line fitted. This equation is derived from regression analysis, which also gives R^2 values. The closer the R^2 value to 1.0, the better the fit. This confirms that the observed right-curving graph does conform to a mathematically significant pattern.

Secondly, the logarithms of this same data to base 10 were then calculated and plotted in the same scatter plot form as a log-log graph. Using Microsoft Excel 2007 the linear trend line was selected and the equation and R^2 value shown on the graph. The differing attributes being measured were thus reduced to a linear equation in the format $y=mx+c$ with the associated R^2 value for each director network at a specific point in time. This gives an easily compared slope m and y intercept. Parallel lines have the same slope and thus the underlying data follows a similar structure and can be compared.

To illustrate the plotting and fitting of trend lines, the log-log plot of the 2007 NZX spread of director seats by gender for the largest connected component only is given in Figure 22, which also shows the resulting linear equation.

Figure 22.
Log-log plot of 2007 NZX seat spreads by gender with linear trend line equation and R^2 value.



These equations were then plotted for a range of *x* variables from -5 to +5 and the resulting y values plotted on a third scatter plot to show the clustering of lines with similar slopes and intercepts. The more similar the data, the more the lines will cluster into clearly defined groups. If the data are not similar, the lines will diverge in slope and intercept. Anomalous data was thus easily identified, as illustrated in Figure 21 (page 126) using the historical data from other network studies and summarised in Table 7 (page 125).

4.8.2 High and low range predictive equations.

The comparative methodology described above allows different director networks to be compared to each other and to themselves over time. In this form it is limited to comparisons between the datasets measured in this thesis. To enable comparisons to be made in future network research and to set baseline values against which to measure other datasets , predictive linear equations were developed. These predictive equations are simple models that form an integral part of Glass Network theory, which predicts that director networks are self-similar. These can be added to a plot of actual values with non-conforming networks easily identified. Where there has been no governance or affirmative action, it is predicted that director networks will fall between the high and low ranges for each variable derived from the predictive equation.

The predictive equations for each variable were derived from the results obtained in the comparative analysis of the six datasets used in this thesis, and then tested against longitudinal and random datasets. They were not adjusted after this testing, indicating confidence in the ranges that were initially established.

To derive these high and low ranges, the equation with the largest slope value and intercept value was identified, frequently from the 1999 Fortune US 1000 dataset, and the value of its slope was used for the range slope value. Its intercept value was used as the starting value for the high range value with a small incremental value, ranging from 0.5 to 3.00, added to it in a trial and error process. This was done to visually distinguish the resulting predictive line from the plotted data lines and to incorporate their larger values within the predictive line, but at the same time to ensure that the predictive line was as visually close to actual data as possible. The low range was determined by using the same slope value and deducting an amount from the high range intercept in a trial and error process, until the plotted low range line fell below the data, and could be visually distinguished. To do this, predictive equations were plotted for a range of values from -5 to +5. The resulting values from the predictive equations give a high and low range line, within which the values for the attribute being measured in a director network are expected to fall. The smaller the range, the more precise the prediction will be.

To give an example, to develop the high and low ranges for the variable ‘degree’, the degree equations by gender from Table 45 (page 209) were examined and the male equation with the highest slope selected, in this case -0.53. A value of 2.5 was added or deducted from the intercept to create the high and low range after a trial and error process to determine the smallest value needed. It should be noted that this is not a difficult process and the predictive equations did not need to be forced to fit the data. This indicates an underlying order that is easy to tease out with this methodology. This process produced two equations of a high range of $y = -0.53x + 3$ and a low range of $y = -0.53x +1.5$. These equations were then plotted for values of +5 to -5 and compared to the plot of the equations from the six originating networks. The intercept value was tuned to make the range as small as possible while still accommodating the existing data within its boundaries.

The summary table of the predictive equations is given in Table 9. To show the interrelationship between the equations these are plotted in Figures 23 and 24. The high range equation for the seat spreads and degree are the same and overlap in Figure 23, where the low range of the seat spreads is wider than the degree range. In addition, the intercept value for the high range of degree, seat spreads and betweenness is the same value, namely 8. This was not deliberately derived but may be an artefact of this data. Figure 24 is included to show the narrow range from the high and low equations for components against the wider seat spread range.

Table 9.
Summary of predictive equations used to set high and low ranges to compare director networks by seat spreads, degree, betweenness and component

Attribute	High	Low
Seat spreads	y = -3.087x+8	y = -3.087x-2
Degree	y = -3.087x+8	y = -3.087x+3
Betweenness	y = -1.099x+8	y = -1.099x+4
Component	y = -0.57x+2.8	y = -0.57x-0.5

Figure 23.
Comparison of plotted predictive equation showing high and low range lines, (identical for seat spread and degree high range).

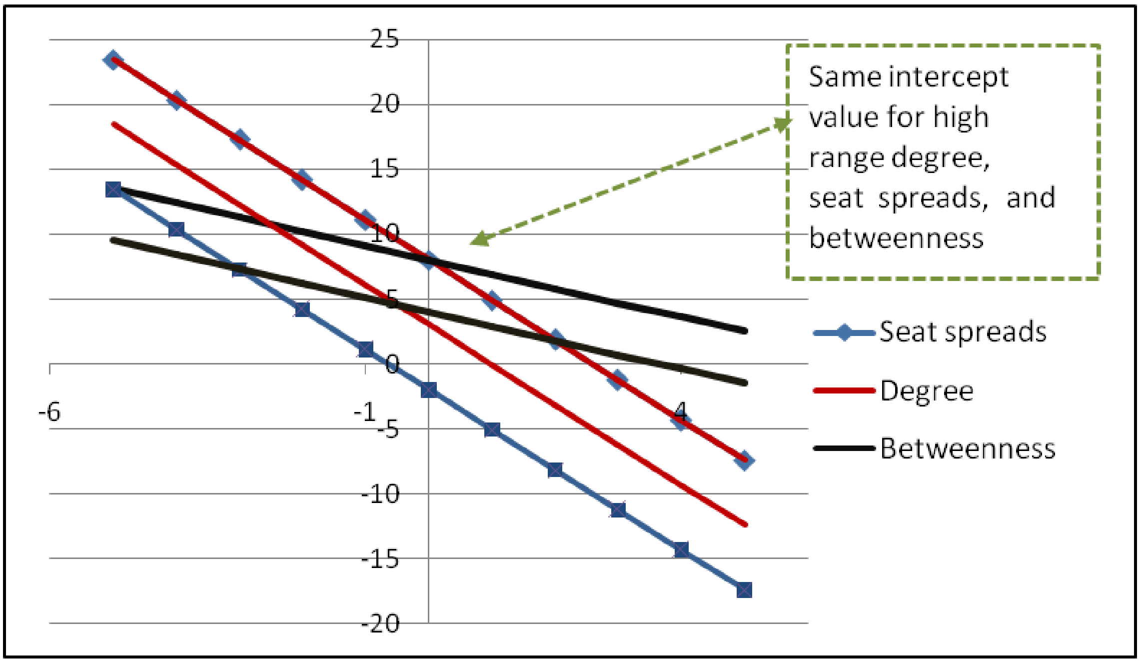
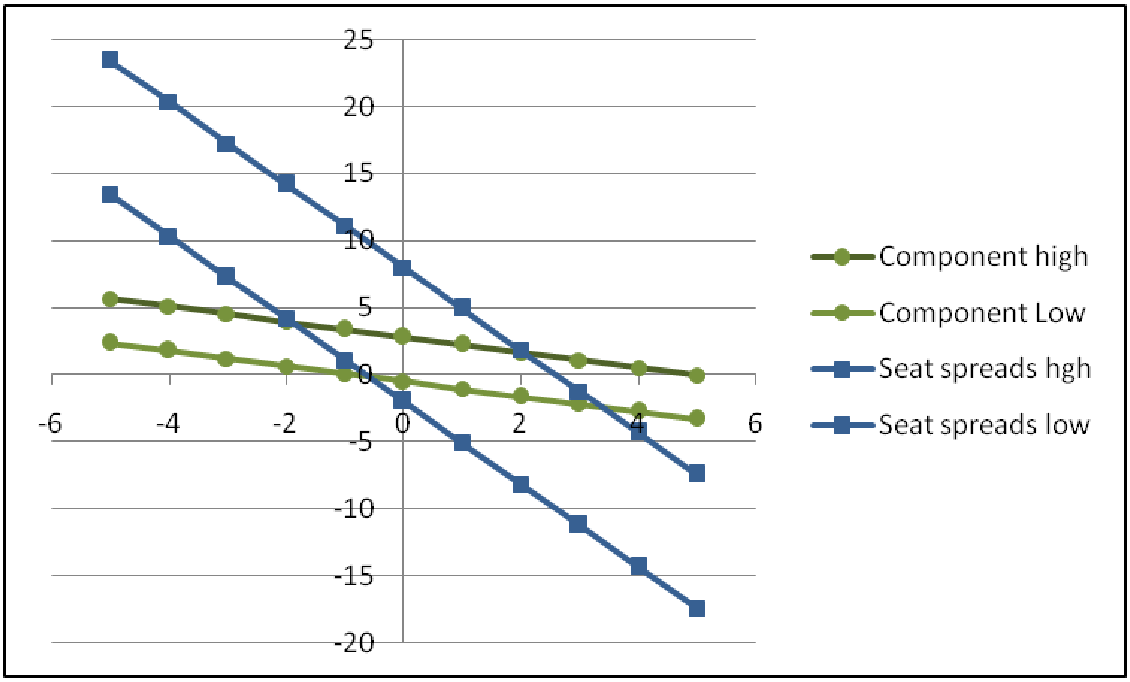


Figure 24.
Comparison of plotted predictive equation showing high and low range lines for the component and seat spread equations.



4.9 Assortativity

To measure assortativity, director degree has to be calculated first. Once the director degree is known a Pearson product moment correlation coefficient, *r*, is calculated for each pair of directors by degree (Newman, 2002). Assortativity is defined as:

> Assortative mixing measures the degree at which the nodes that have high (low) attribute value (in default, degree) tend to be connected to other nodes with high (low) attribute value, respectively. A given network is assortative if $r > 0$, disassortative if $r < 0$ and has no assortative mixing if $r = 0$ (Netminer Version 3.3.2.090304).

Degree was calculated in UCINET and again in Netminer 3 and validated against each program. In addition, Netminer 3 provides a significance test that uses a Quadratic Assignment Procedure (QAP). The algorithm underlying the QAP procedure creates new and random networks by changing rows and columns within the same constraints as the observed network and computes expected values for that network. The 'Iteration' option controls how many random networks are made each time. The resulting expected *r* values are averaged over the number of iterations selected.

QAP procedures are computer resource intensive and depending on the size of the network and available computer memory, may take considerable time to calculate. After some email correspondence with the Netminer 3 developers regarding processing speed, the following procedure was adopted to give representative results. The number of iterations selected was initially set at 10, then 100, then 1000 and then 10,000. If the QAP results for the expected values did not change for three iterations of increasing size the expected r value was accepted. Netminer 3 also outputs a table giving the two arrays of director pairs by degree and the results were manually validated using Microsoft's Excel @Pearson function.

Chapter Four Summary

Chapter Four presents the research methodology. It clarifies the terminology used, then details the determination of director gender and the software programs used. There are no ethical issues as the information is all in the public domain and conventions in the director literature are followed. The data preparation and validation are outlined and the unique characteristics of each dataset described. Construction of the women-only, longitudinal and random datasets is described. The comparative methodology is also outlined and the resulting predictive equations described. The calculation of assortativity is also described.

Chapter Five. Results

5.1 Introduction

The results follow in the same sequence as the research question set. Each question is re-stated with the corresponding results. Descriptive statistics are given in the first section with the results from the component analysis, and the further gender analysis of the components. The section also includes the results for the seat spread analysis using the comparative methodology and the generating function which compares the actual and expected seat spreads. The second section gives the results from the social network analysis and includes the small-world and assortativity results. Additional degree and betweenness analysis using the comparative methodology follows in the next section. The final section gives the results from the testing of Glass Network theory against the random and longitudinal datasets using the same measures.

5.2. Network description and component analysis

5.2.1 Descriptive statistics

What does a gendered director network look like? Where are the women directors in the mixed gender and women-only networks?

Detailed descriptive statistics of each network were prepared. The results are presented in Tables 10 and 11.

Table 10.
Descriptive statistics for the mixed gender 1999 Fortune US 1000;
2004 and 2007 Fortune Global 200;
2004, 2005 and 2007 New Zealand Stock Exchange (NZX) director networks.

Mixed gender	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
No. of companies	916	200	200	184	197	185
Average board size	8.3	13.6	13.8	6.4	6.1	5.8
No. of directors	7644	2479	2538	965	958	899
Number of connector directors (%)	1068 (13.9)	198 (8.0)	190 (7.5)	144 (14.9)	157 (16.3)	117 (13.0)
Male directors (%)	6985 (91.4)	2223 (89.7)	2263 (89.2)	908 (95.1)	891 (93.0)	832 (92.5)
Female directors (%)	659 (8.6)	256 (10.3)	275 (10.8)	57 (5.9)	67 (6.7)	67 (7.5)
Gender ratio	10.6	8.6	8.2	16	13.3	12.4
No. of seats	10090	2725	2754	1176	1197	1059
Mean seats	1.4	1.1	1.1	1.2	1.2	1.2
No. of male Seats (%)	9141 (90.6)	2439 (89.5)	2446 (88.8)	1106 (94.0)	1115 (93.1)	985 (93.0)
No. of female seats (%)	949 (9.4)	286 (10.5)	308 (11.2)	70 (6.0)	82 (6.9)	74 (7.0)

Table 11.
Descriptive Statistics for the female only 1999 Fortune US 1000;
2004 and 2007 Fortune Global 200;
and 2004, 2005 and 2007 NZX director networks.

Female Only	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
No. of companies	631	146	155	58	63	54
% companies with female directors	68.9	73.0	77.5	31.5	32.0	29.2
No. of female directors	659	256	286	57	67	65
No. of connector directors (%)	176 (26.7)	28 (10.9)	30 (10.9)	11 (19.3)	11 (16.4)	7 (10.8)
Mean seats	1.4	1.1	1.1	1.3	1.2	1.1

5.2.2 Component analysis

How many components does a network break into and what is the size of the largest component? Does the size of the unconnected components follow a specific distribution, assuming the data is not normally distributed?

Using UCINET, the components of each network were determined and the largest component extracted. The results for the mixed gender and female only networks are presented in Table 12. This gives the number of components in each network and the number of directors in the largest connected component and the unconnected components.

Table 12.
Component analysis for the mixed gender and female only 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX director networks.

Mixed Gender	**1999 Fortune US 1000**	**2004 Fortune Global 200**	**2007 Fortune Global 200**	**2004 NZX**	**2005 NZX**	**2007 NZX**
No. of components	96	62	67	55	53	66
No. of directors in largest components (%)	6705 (87.7)	1573 (63.5)	1582 (62.3)	639 (66.2)	676 (70.6)	446 (49.6)
No. of directors in unconnected components (%)	939 (12.3)	906 (36.5)	956 (37.7)	326 (33.8)	282 (29.4)	453 (50.4)
Female Only						
No. of components	342	117	122	45	52	46
No. of directors in largest components (% directors)	88 (13.4)	2 groups of 8	15 +11	2 groups of 3	4	3 groups of 3
No. of directors in unconnected components (% directors)	571 (86.6)	240 (93.8)	260 (94.5)	51 (89.5)	63 (94.0)	56 (86.1)

To confirm the expectation that network data is not normally distributed, the component data was grouped by size and the group distribution plotted for each data set. This was done for the mixed gender network and for the women-only networks once these had been extracted from the source network. The male-only director network was not extracted, as it does not differ substantially from the mixed gender network components given the dominating role of the men in the director network.

No networks conformed to a normal distribution, being either right-tailed or power law distributions (particularly the women-only director networks). Four examples are presented in Appendix One, namely, the 1999 Fortune US 1000 data, the 2007 Fortune Global 200 data, the 2007 NZX data and the 1999 Fortune US 1000 female only network data.

The components were ranked individually by size for each of the mixed gender networks. This data was then plotted using Microsoft Excel 2007 and the power law trend line fitted with the corresponding equation and R^2 value, checking that this was the best fitting trend line. The number of directors in the largest component and the second largest component are also given, as the size discrepancy is noteworthy. These results are presented in Table 13.

Table 13.
Director network component analysis with best trend line equation, includes largest component.

Mixed gender director network components	No of directors in largest component	No of directors in 2nd largest component	Power law equation	R^2
Fortune US 1000	6705	34	$y = 106.4x^{-0.66}$	0.614
2004 Fortune Global 200	1573	56	$y = 186.0x^{-0.81}$	0.837
2007 Fortune Global 200	1582	57	$y = 135.6x^{-0.70}$	0.768
2004 NZX	639	21	$y = 58.52x^{-0.74}$	0.748
2005 NZX	676	16	$y = 51.71x^{-0.74}$	0.705
2007 NZX	449	37	$y = 63.70x^{-0.70}$	0.825

The best fitting trend line in all networks was a power law. The R^2 values for the networks ranged from 0.614 to 0.837.

The exercise was repeated with the largest component excluded. Overall the resulting R^2 values were higher, ranging from 0.927 to 0.972 for the mixed gender networks, indicating a better fit to the data when the largest component was excluded.

The log-log values were calculated and also plotted. The equation for the best linear trend line was determined, with its associated R^2 value. These results are presented in Table 14 for both the mixed gender and women-only networks, where there was sufficient data to do this analysis.

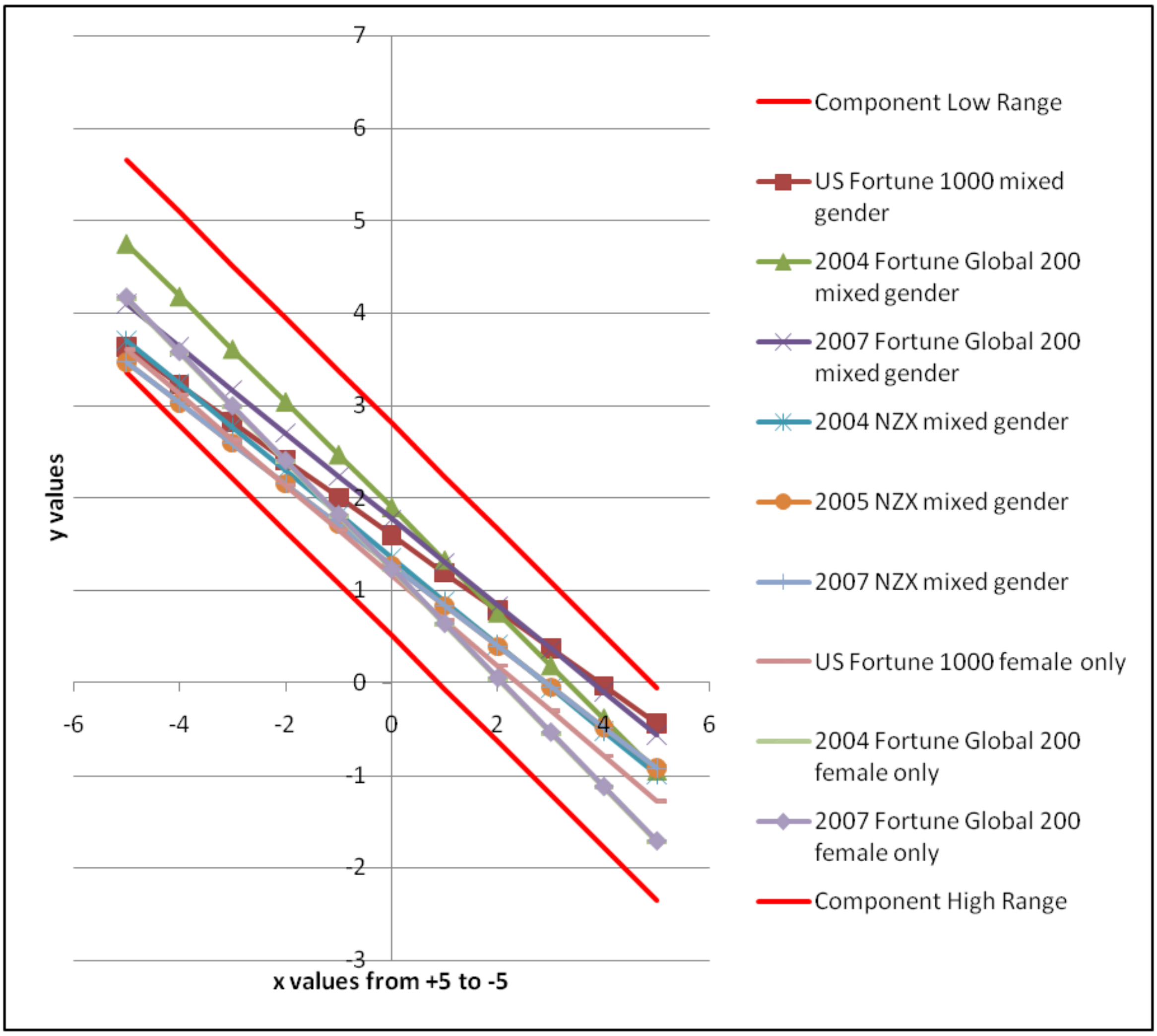
Mixed gender director network components. Largest component excluded.						
Year	Director Network	No of Directors	Trend line equation excluding largest components	R^2 Value	Linear trend line equation from log-log plot of component ranked by size excluding largest components	R^2 Value of linear trend line equation from log-log plot
1999	Fortune US 1000	7644	$y = 39.17x^{-0.40}$	0.861	y = -0.407x + 1.593	0.861
2004	Fortune Global 200	2479	$y = 77.87x^{-0.57}$	0.951	y = -0.570x + 1.891	0.951
2007	Fortune Global 200	2538	$y = 58.60x^{-0.46}$	0.972	y = -0.466x + 1.768	0.972
2004	NZX	965	$y = 22.68x^{-0.46}$	0.927	y = -0.469x + 1.355	0.927
2005	NZX	958	$y = 18.60x^{-0.44}$	0.882	y = -0.439x + 1.269	0.882
2007	NZX	904	$y = 30.98x^{-0.50}$	0.932	y = -0.508x + 1.491	0.932

Women-only director network components. Largest component excluded.						
1999	Fortune US 1000	659	$y = 14.65x^{-0.48}$	0.885	y = -0.488x + 1.166	0.885
2004	Fortune Global 200	256	$y = 15.02x^{-0.56}$	0.860	y = -0.587x + 1.214	0.872
2007	Fortune Global 200	275	$y = 16.86x^{-0.58}$	0.895	y = -0.588x + 1.227	0.895

Table 14. Director network component analysis with power law trend line equation and linear trend line from log-log plot for mixed gender and women-only director networks (largest component excluded).

The linear equations derived from the component analysis were plotted for a range of x values from -5 to +5. The results are presented in Figure 25. The high and low ranges derived from the predictive equations based on these results are also included as red lines. For the components, these are high: *y = -0.57x+2.8* and low: *y = -0.57x-0.5.*

Figure 25.
Component plot of linear trend line equations for values of +5 to -5 from log-log plot ranked by size excluding the largest component for mixed gender and female only director networks with low and high ranges from predictive equations.



5.2.3 Component analysis by gender

Where are the women directors in the network components of the mixed gender networks? Are they in the largest connected component or in the unconnected components?

Glass Network theory predicts that more women will be found in the largest connected component than the unconnected components in mixed gender networks. This means that the ratio of male to female directors in the largest connected component will be greater than the total gender ratio of the combined largest and the unconnected components. As this is categorical data, chi-squared analysis with Yates correction and one degree of freedom, was selected to test the hypothesis that:

> *Male and female directors are found in the largest connected component in the same ratio as the total gender ratio for the director network of the 1999 Fortune US 1000 directors; the 2004 and 2007 Fortune Global 200 directors; the 2004, 2005 and 2007 NZX directors.*

The results are presented in Tables 15 and 16.

Table 15.
Director Component Analysis by Gender for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200.

	1999 Fortune US 1000			**2004 Fortune Global 200**			**2007 Fortune Global 200**		
	Male (%)	**Female (%)**	**Gender Ratio**	**Male (%)**	**Female (%)**	**Gender Ratio**	**Male (%)**	**Female (%)**	**Gender Ratio**
Total	6985	659	10.6	2223	256	8.6	2263	275	8.2
Largest connected component	6107 (87.4)	598 (90.7)	10.2	1377 (62)	196 (76.6)	7.0	1366 (60.4)	216 (78.5)	6.3
Remainder unconnected components	878 (12.6)	61 (9.3)	14.4	846 (38)	60 (23.4)	14.0	897 (39.6)	59 (21.5)	15.2
x^2	5.9*			20.4**			33.7**		
** p<.001 and p<.05* with Yates correction for one degree of freedom									

Table 16.
Director Component Analysis by Gender for2004, 2005 and 2007 NZX.

	2004 NZX Directors			2005 NZX Directors			2007 NZX Directors		
	Male (%)	Female (%)	Gender Ratio	Male (%)	Female (%)	Gender Ratio	Male (%)	Female (%)	Gender Ratio
Total	908	57	16.0	891	67	13.3	832	67	12.4
Largest connected component	597 (65.8)	42 (73.2)	14.0	622 (69)	54 (80.6)	11.5	409 (49.2)	37 (55.2)	11.0
Remainder unconnected components	311 (34.2)	15 (26.8)	20.7	269 (30.2)	13 (19.4)	20.7	423 (50.8)	30 (44.8)	14.1
x^2	1.19			2.98			0.65		

5.2.4 Seat spreads

In the largest connected component of the mixed gender director networks, who are the connector directors, that is directors with more than one seat, and what is their gender? Does the spread of seats held by connector directors to single seat directors follow a specific pattern? Do they conform to the expected seat spreads derived from the non-symmetrical generating function?

5.2.4.1 Seat spreads analysed using the comparative methodology

The spread of seats of connector directors to single seat directors by gender was calculated and the results presented in tabular form by directors and by seats for all directors as well as the largest connected component. The results are shown in Appendix Two.

The summary results giving the derived equations for male and female directors' spread of seats for the largest connected component of each director network are presented in Table 17. Seat totals by gender and percentage of connector directors to the single seat directors by gender are also given.

Year	Director network Largest components only	No of male seats	No of female seats	% Male director connector seats to total male seats	% Female director connector seats to total female seats	Male linear trend line equation from log-log plot of distribution of multiple seats	R^2 Value	Female linear trend line equation from log-log plot of distribution of multiple seats	R^2 Value
1999	Fortune US 1000	8248	882	43.2	51.8	y = -3.087x + 4.110	0.899	y = -2.201x + 2.889	0.845
2004	Fortune Global 200	1582	223	23.1	23.3	y = -2.930x + 3.154	0.941	y = -2.663x + 2.338	0.943
2007	Fortune Global 200	1540	248	21.2	24.6	y = -2.886x + 3.077	0.945	y = -2.924x + 2.316	0.926
2004	NZX	787	54	40.0	43.6	y = -2.251x + 2.823	0.925	y = -1.418x + 1.542	0.887
2005	NZX	837	69	42.1	37.7	y = -2.193x + 2.833	0.925	y = -1.756x + 1.660	0.987
2007	NZX	536	46	40.5	34.8	y = -1.961x + 2.557	0.975	y = -1.477x + 1.468	0.996

Table 17. Seat spread by gender with linear trend line equation from log-log plot (largest components only) for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX.

The linear equations from Table 17 were plotted for a range from -5 to +5 and the combined gender results presented in Figure 26 and the female directors only in Figure 27. The female director results are presented separately to show that the plotted lines only fall outside the predictive ranges in the smaller NZX network. The high and low ranges derived from the predictive equations based on these results are also included as red lines. These are high: $y = -3.087x+8$ and low: $y = -3.087x-2$.

Figure 26.
Seat spreads combined plot of linear equations from log-log plot for male and female directors in mixed gender networks for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; 2004, 2005 and 2007 NZX with low and high ranges from predictive equations.

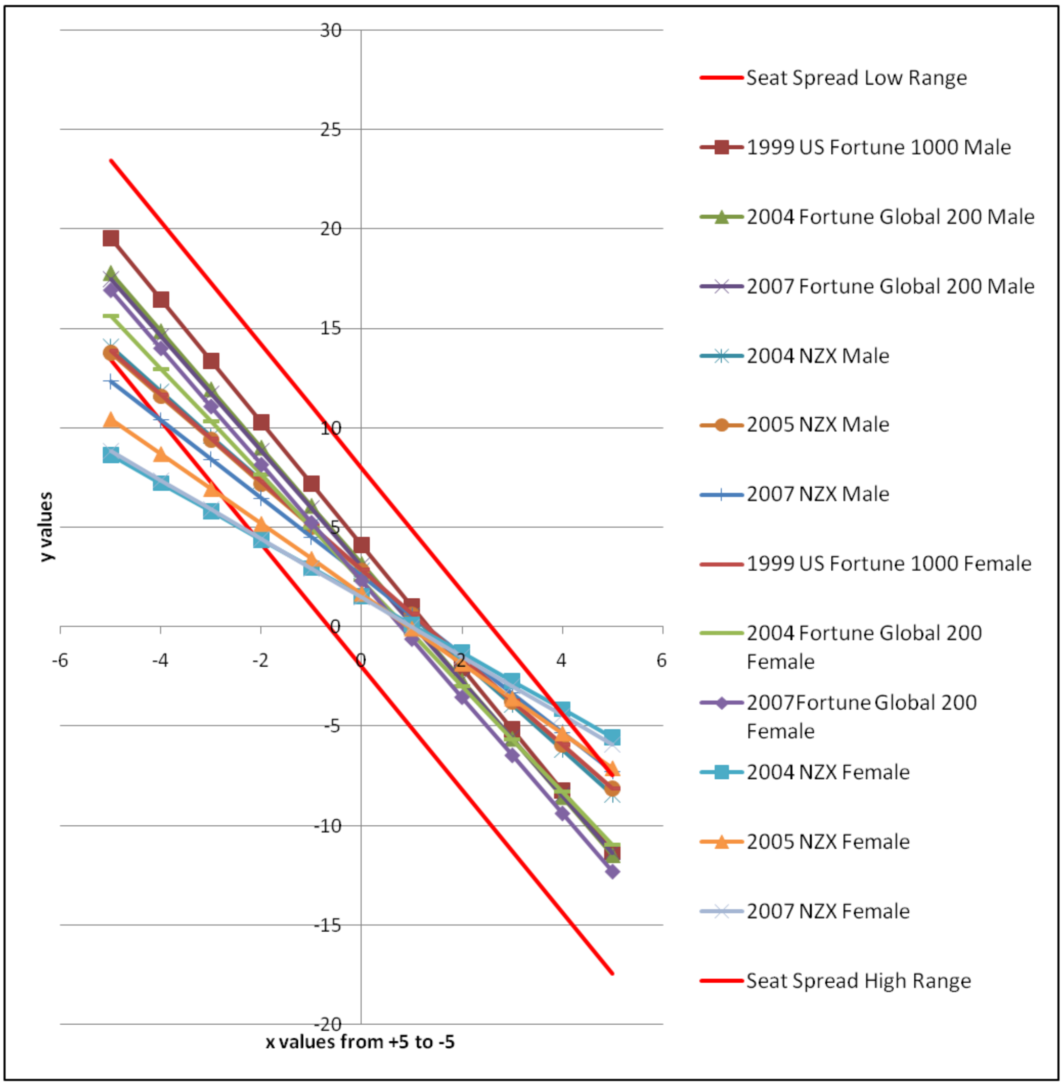
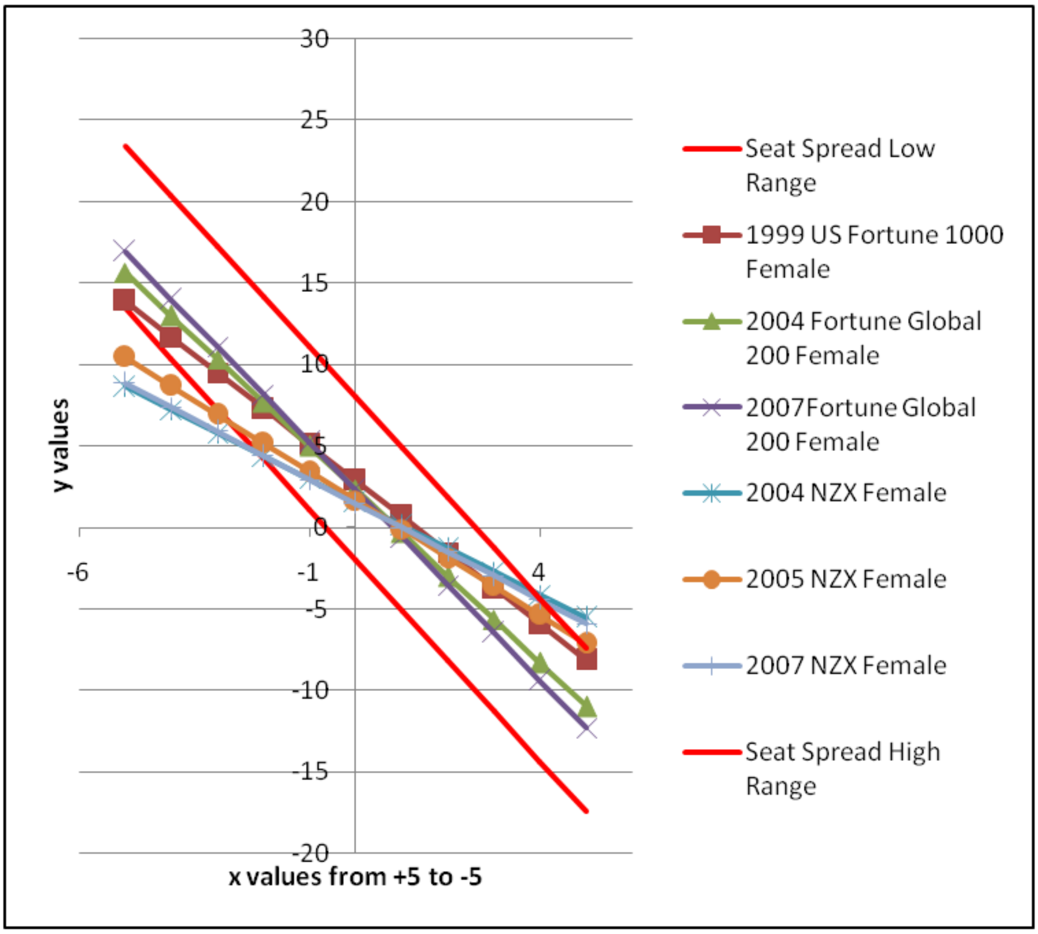


Figure 27.
Seat spread plot of linear equations from log-log plot for female directors only in mixed gender networks for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX with low and high ranges from predictive equations.



5.2.4.2 Generating seat spreads

To test actual networks against the theoretical model from the generating function, expected seat spreads by gender were calculated for the 1999 Fortune US 1000 directors; the 2004 and 2007 Fortune Global 200 directors; the 2004, 2005 and 2007 NZX directors with a seat spread parameter of 2. The gender breakdown for the expected seat spreads used the same ratios as the actual seat spread for each seat category. These results are presented in Appendix Five.

The expected and actual seat spreads were plotted on a log-log graph with the US Fortune 1000, the 2007 Fortune Global 200 and the 2007 NZX plot presented in Figures 28, 29 and 30. The remaining plots are presented in Appendix Six.

In addition chi-squared tests were performed against the total values for the actual and expected seat spreads. Any statistically significant data was further investigated by performing chi-squared tests by gender against actual and expected values. These results are presented in Table 18 for the full data sets and the continuing directors from these datasets.

Figure 28.
Log-log plot of actual and expected seat spread for the 1999 Fortune US 1000 director network for the largest component. Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

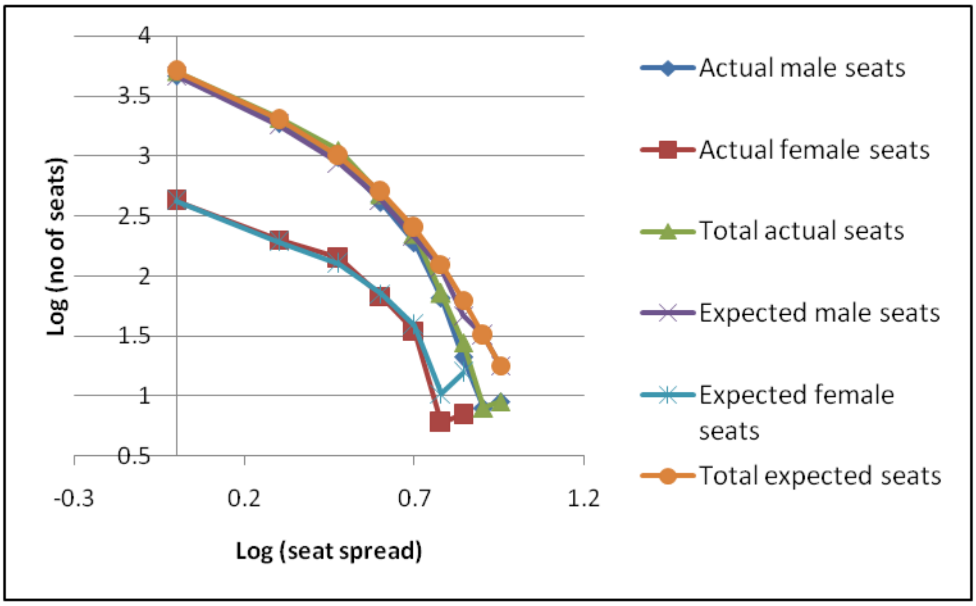


Figure 29.
Log-log plot of actual and expected seat spread for the 2007 Fortune Global 200 director network for the largest component. Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

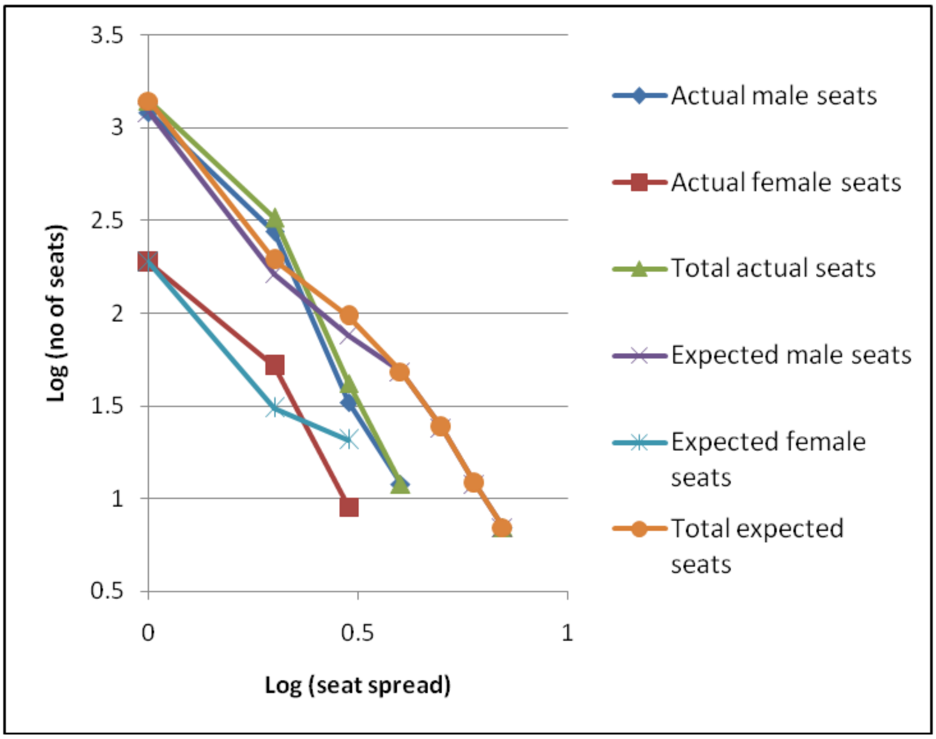
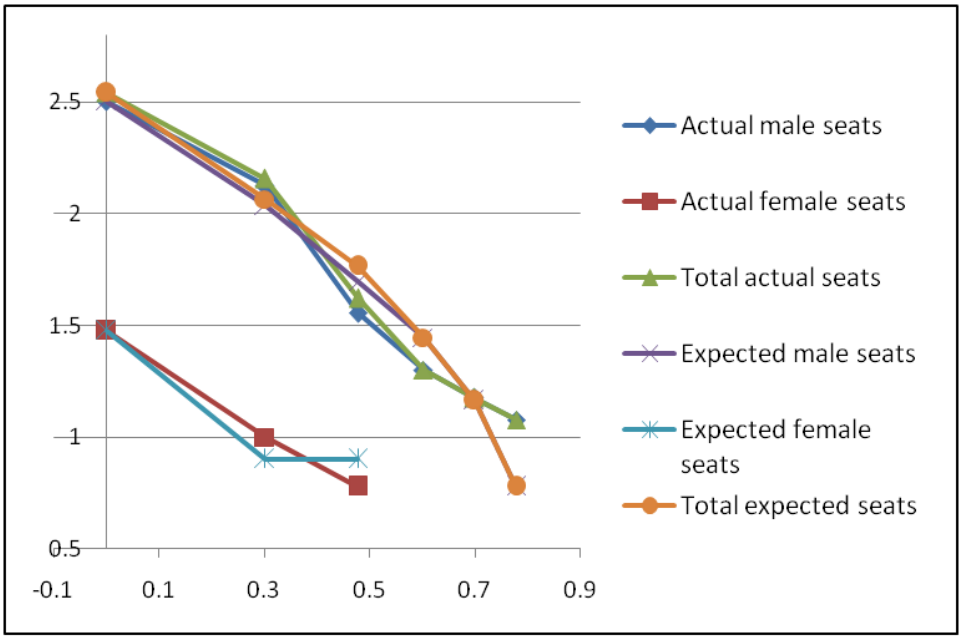


Figure 30.
Log-log plot of actual and expected seat spread for the 2007 NZX director network for the largest component. Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.



Largest component		Total expected to actual			Male expected to actual			Female expected to actual		
Year	**Dataset**	x^2	p	df	x^2	p	df	x^2	p	df
1999	Fortune US 1000	53.2	p <.001	9	46.9	p <.001	9	5.7	Not significant	7
2004	Fortune Global 200	58.5	p <.001	7	55.0	p <.001	7	3.6	Not significant	3
2007	Fortune Global 200	112.9	p <.001	7	102.8	p <.001	7	10.0	p< .05	3
2004	NZX	6.5	p >.95	7	NA			NA		
2005	NZX	9.4	p >.95	7	NA			NA		
2007	NZX	8.3	p >.95	6	NA			NA		

Largest component		Total expected to actual			Male expected to actual			Female expected to actual		
Year	**Dataset**	x^2	p	df	x^2	p	df	x^2	p	df
2004	Fortune Global 200 continuing	46.4	p <.001	7	43.4	p <.001	7	2.7	Not significant	3
2007	Fortune Global 200 continuing	80.2	p <.001	7	72.2	p <.001	7	6.9	Not significant	3
2004	NZX continuing	6.7	p >.95	7	NA			NA		
2007	NZX continuing	2.3	p >.95	6	NA			NA		

Table 18. Chi-squared analysis of seat spreads for total actual and expected values with further chi-squared analysis by gender if significant for full director network and continuing directors. Largest component only.

5.2.4.3 Female connector directors as preferred director

Are female directors with more than one seat, namely connector directors, being appointed to more boards than their equivalent male connector directors in the largest connected components of the mixed gender networks?

To ensure comparable data the seat spreads from Appendix Two were grouped into two categories, single seat directors' seats and connector directors' seats with two or more seats for the mixed gender networks only. Chi-squared analysis using the male to female ratio for the expected values was performed as this is categorical data to test the null hypothesis that:

> *The ratio of male to female connector directors seats in the largest connected components of the mixed gender networks is equal to the total ratio of male to female director seats in the 1999 Fortune 1000 directors; the 2004 and 2007 Fortune Global 200 directors; the 2004, 2005 and 2007 NZX directors.*

The summary results from the chi-squared analysis are presented in Table 19. As significant data was found in the largest connected component this analysis was repeated for the full seat count which included the directors in the unconnected components to determine if this pattern applied to the networks as a whole. The results from the continuing director analysis are also presented here for ease of comparison.

Total network seats	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Single seats	5553	483	2053	228	2103	304	775	46	745	56	722	60
2+ Seats	3588	466	386	58	343	63	331	24	370	26	261	16
x^2	34.3**		3.4		8.5*		0.4		0.02		0.8	

Largest components seats	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Single seats	4685	425	1217	171	1214	187	472	30	485	43	319	30
2+ Seats	3563	457	365	52	326	61	315	24	352	26	217	16
x^2	23.6**		0.006		1.2		0.2		0.3		0.4	

Largest components seats	Continuing 2004 Fortune Global 200		Continuing 2007 Fortune Global 200		Continuing 2004 NZX		Continuing 2007 NZX	
	Male	Female	Male	Female	Male	Female	Male	Female
Single seats	579	100	618	110	196	13	160	9
2+ Seats	283	39	260	45	260	20	198	11
x^2	0.53		0.02		0.16		0.0007	
**p <.001 and *p <.01 with Yates correction and one degree of freedom								

Table 19 Chi-squared analysis of connector directors with 2+ seats to single seat directors in the total networks and the largest connected components only for 1999 Fortune US 1000; and the 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX, including the 2004 and 2007 continuing directors of these networks.

5.3 Network metrics and small-world quotient

5.3.1 Social network analysis of the largest component in the director networks

What is the social network structure of the largest component of the mixed gender and women-only director networks in terms of the density, reach, clustering coefficient, degree, geodesic distance and subsidiary measures derived from these calculations? How do they differ from each other?

Using UCINET the values for density, reach, the clustering coefficient, degree, geodesic distance and their standard deviations as well as the minimum and maximum degree were calculated for the mixed gender director networks and the results presented in Table 20.

The results for the women-only 1999 Fortune 1000 directors and the 2007 Fortune Global 200 directors are presented in Table 21. Only these networks had enough women directors in the largest component to permit this analysis.

5.3.2 Small-world networks

Are mixed gender and women-only director networks small-world networks at a global and national level?

Using the Watts and Strogatz formula as used in Davis et al. (2003) and Stablein et al. (2005), the Small-world quotient was calculated as follows:

Small-world Quotient = $[C_{actual}/L_{actual}] * [L_{random}/C_{random}]$

The results for the mixed gender networks are presented in Table 20. The results for the female only 1999 Fortune 1000 directors and the 2007 Fortune Global 200 directors are presented in Table 21.

Table 20.
Measures of cohesion, centrality, Small-world Quotient and other network metrics for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200;and 2004, 2005 and 2007 NZX.

Largest Components Only	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
Density	0.002	0.01	0.01	0.013	0.012	0.017
Density Standard Deviation	0.05	0.10	0.01	0.12	0.12	0.13
Reach (Normalised Reach)	1564.65 (0.23)	341.09 (0.22)	327.53 (0.21)	145.65 (0.23)	163.47 (0.36)	93.40 (0.21)
Reach Standard Deviation	214.01	59.60	43.23	22.39	27.24	17.15
Clustering Coefficient	0.87	0.93	0.94	0.89	0.89	0.89
Mean Geodesic Distance	4.59	5.46	5.64	5.13	5.22	5.99
Mean Degree (Normalised Degree)	15.12 (0.23)	16.52 (1.05)	15.83 (1.0)	8.56 (1.34)	8.21 (1.22)	7.55 (1.69)
Degree Standard Deviation	9.82	8.50	8.51	5.0	5.14	5.06
Minimum Degree	3	6	6	2	2	2
Maximum Degree	106	121	103	38	39	35
Clustering Coefficient Random	0.002	0.01	0.01	0.01	0.01	0.01
Geodesic Random	3.24	2.62	2.67	3.01	3.10	3.36
Small-world Quotient	271.66	42.56	44.43	38.97	43.45	26.49

Table 21.
Measures of cohesion, centrality, Small-world Quotient and other network metrics for the 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200 female directors only.

Largest Components Female Directors Only	1999 Fortune US 1000	2007 Fortune Global 200
Density	0.03	0.26
Density Standard Deviation	0.17	0.44
Reach (Normalised reach)	18.88 (0.21)	8.54 (0.57)
Reach Standard Deviation	3.91	1.46
Clustering Coefficient	0.50	0.81
Mean Geodesic Distance	7.01	2.51
Mean Degree (Normalised degree)	2.73 (3.14)	3.60 (25.2)
Degree Standard Deviation	1.7	1.86
Minimum Degree	1	2
Maximum Degree	7	10
Clustering Coefficient Random	0.03	0.24
Geodesic Random	4.46	2.11
Small-world Quotient	10.29	2.84

5.4 Assortative mixing

Do mixed gender and women-only director networks show positive assortative mixing?

To measure assortativity, director degree was calculated first, followed by the calculation of the Pearson product moment correlation coefficient, *r*, for each pair of directors. To test for significance the QAP procedure was applied to the results with increasing iterations, until there were no further changes to the significance levels.

The results are presented in Tables 22 and 23.

In addition the 1999 Fortune US 1000 and the 2007 Fortune Global 200 two largest components of the women-only director networks were plotted using UCINET's Netdraw facility and are presented in Figure 31, 32 and 33. The assortativity results become clearer when these diagrams are examined.

Table 22.
Assortativity Analysis for 1999 Fortune US 1000 directors;
2004 and 2007 Fortune Global 200 directors; and 2004, 2005 and 2007 NZX directors.

Largest Components Only	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
Observed Assortativity	0.238	0.187	0.127	0.247	0.208	0.399
Expected Assortativity	-0.001	-0.001	-0.001	-0.001	-0.002	-0.003
Standard Deviation	0.005	0.009	0.008	0.017	0.18	0.023
***P>= Observed Assortativity**	0	0	0	0	0	0
***P = Observed Assortativity**	0	0	0	0	0	0
***P <= Observed Assortativity**	1	1	1	1	1	1

*Probability = [Number of networks which have larger assortativity value than observed network] / [the number of iterations]

Table 23.
Assortativity Analysis for 1999 Fortune US 1000 and 2007 Fortune Global 200 directors female directors only.

Largest Components Only	1999 Fortune US 1000	2007 Fortune Global 200
Observed Assortativity	0.276	-0.126
Expected Assortativity	0.259	-0.081
Standard Deviation	0.68	0.101
Probability >= Observed Assortativity	0.39	0.64
Probability = Observed Assortativity	0	0
Probability <= Observed Assortativity	0.61	0.36

Figure 31.
1999 Fortune US 1000 Women Directors Network Largest Component.

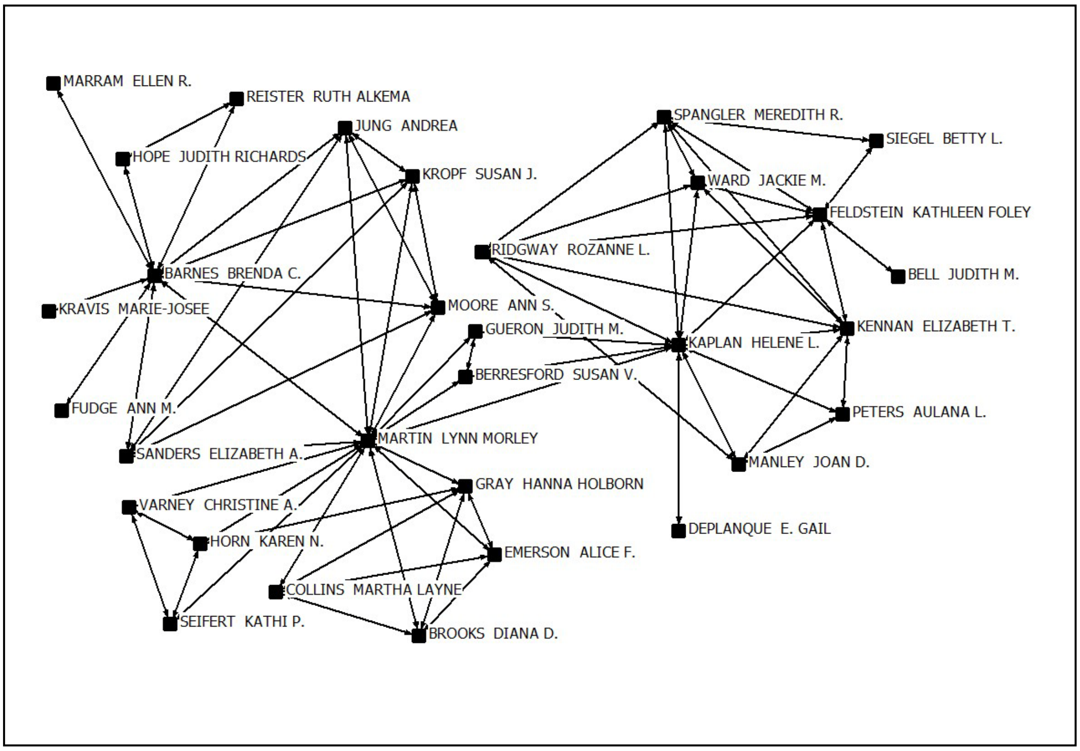


Figure 32.
2007 Fortune Global 200 Women Directors Network Largest Component.

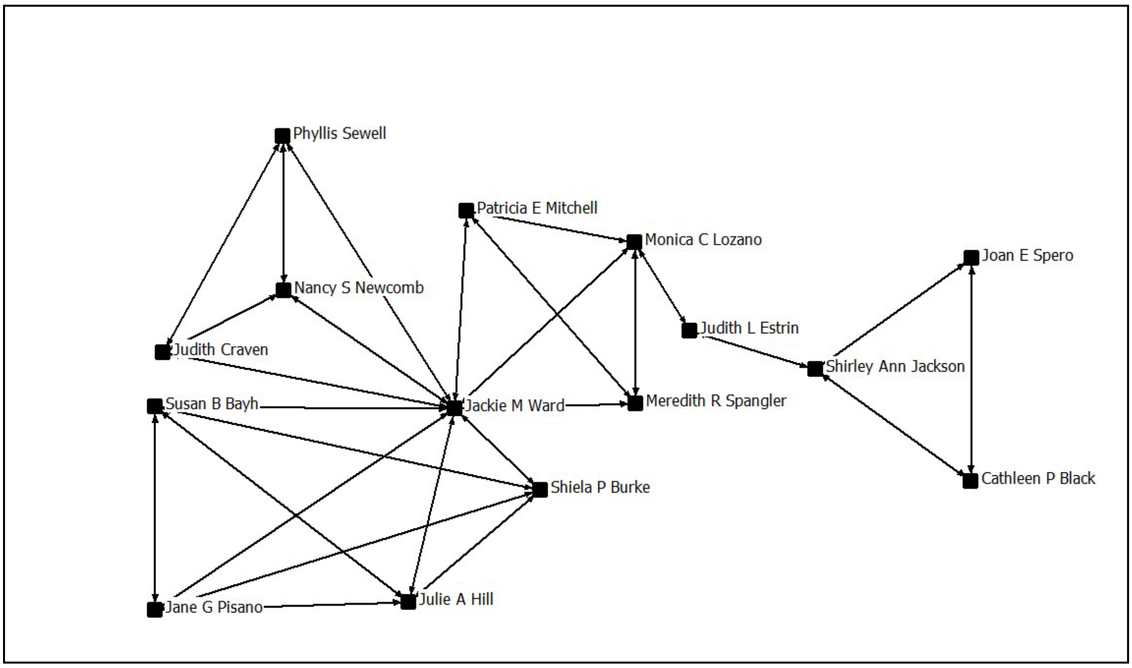
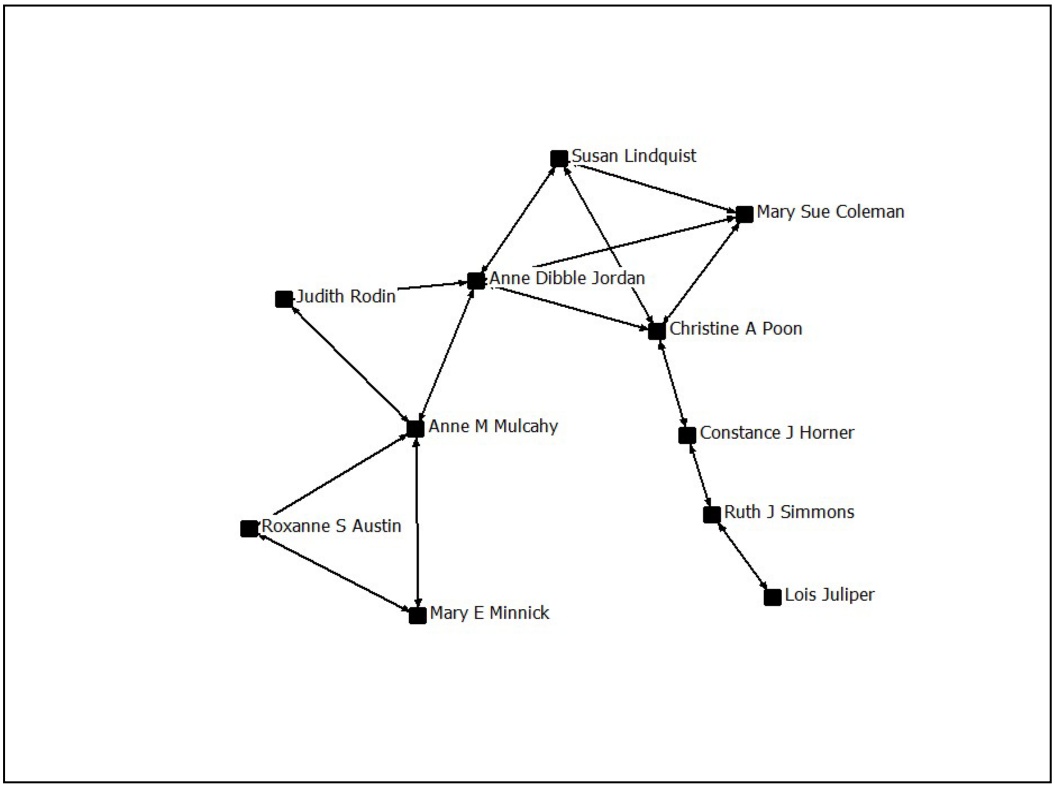


Figure 33.
2007 Fortune Global 200 Women Directors Network Second Largest Component.



5.5 Degree analysis

Does the distribution of the degree, or number of links between a director and adjacent directors, in the largest component of the mixed gender networks follow a specific pattern?

The mean degree for the mixed gender 1999 Fortune 1000 directors; the 2004 and 2007 Fortune Global 200 directors; and the 2004, 2005 and 2007 NZX directors is presented in Table 20 (page 174). The mean degree for the 1999 Fortune 1000 female directors and the 2007 Fortune Global 200 directors of the women-only networks is presented in Table 21 (page 175).

Following the comparative analysis methodology, the summary results giving the power law trend line equations and derived linear equations from the log-log plot of male and female directors' degree for the largest connected component of each director network for the 1999 Fortune 1000 directors; the 2004 and 2007 Fortune Global 200 directors; the 2004, 2005 and 2007 NZX directors are presented in Table 24, and the two women-only networks are presented in Table 25.

The plotted linear equations for male directors are presented in Figure 34, while Figure 35 presents the female directors from the mixed gender and women-only networks. The high and low ranges derived from the predictive equations are included as red lines. These are high: $y = -3.087x+8$ and low: $y = -3.087x+3$.

Mixed Gender. Largest connected component only.		Degree power law trend line equations				Degree linear trend line from log-log plot			
Year	Director network	Male	R^2	Female	R^2	Male	R^2	Female	R^2
1999	US Fortune 1000	$y = 574.7x^{-0.49}$	0.925	$y = 266.8x^{-0.54}$	0.988	y = -0.491x + 2.759	0.922	y = -0.545x + 2.426	0.922
2007	Fortune Global 200	$y = 109.5x^{-0.32}$	0.893	$y = 59.64x^{-0.31}$	0.910	y = -0.320x + 2.039	0.893	y = -0.316x + 1.775	0.910
2004	Fortune Global 200	$y = 180.6x^{-0.39}$	0.932	$y = 64.96x^{-0.34}$	0.851	y = -0.397x + 2.256	0.910	y = -0.349x + 1.812	0.851
2007	New Zealand Stock Exchange	$y = 92.70x^{-0.53}$	0.909	$y = 24.83x^{-0.50}$	0.943	y = -0.530x + 1.967	0.909	y = -0.508x + 1.395	0.943
2005	New Zealand Stock Exchange	$y = 115.3x^{-0.51}$	0.890	$y = 38.45x^{-0.55}$	0.875	y = -0.513x + 2.062	0.890	y = -0.557x + 1.585	0.875
2004	New Zealand Stock Exchange	$y = 102.9x^{-0.48}$	0.887	$y = 31.85x^{-0.50}$	0.797	y = -0.486x + 2.012	0.887	y = -0.501x + 1.503	0.797

Table 24. Degree analysis with power law trend line equation and linear trend line from log-log plot for mixed gender director networks.

Female only. Largest connected component only.					
Year	Director network	Degree power law trend line equations	R^2	Degree linear trend line from log-log plot	R^2
1999	US Fortune 1000	$y = 19.35x^{-0.61}$	0.806	y = -0.612x + 1.286	0.806
2007	Fortune Global 200	$y = 7.812x^{-0.46}$	0.827	y = -0.463x + 0.892	0.827

Table 25. Degree analysis with power law trend line equation and linear trend line from log-log plot for women-only director networks.

Figure 34.
Degree plot from log-log plot of equations for male directors in mixed gender networks for 1999 Fortune US 1000;
2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX
with low and high ranges from predictive equations.

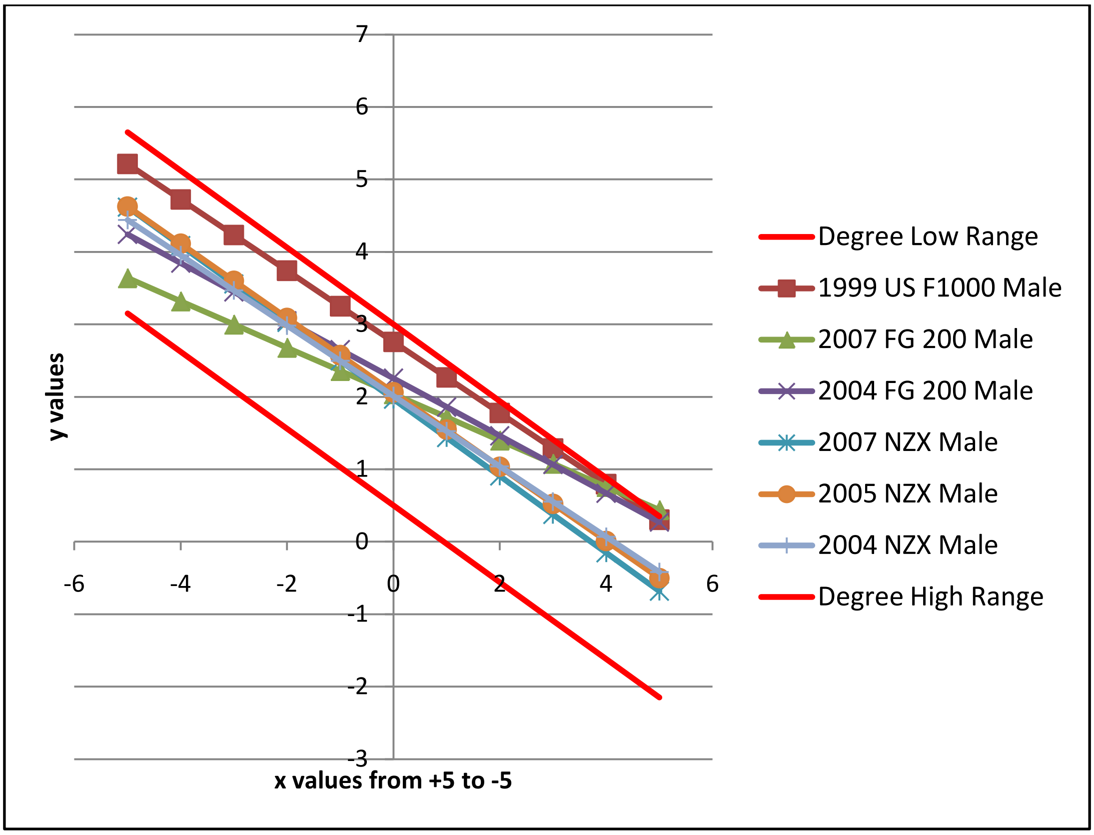
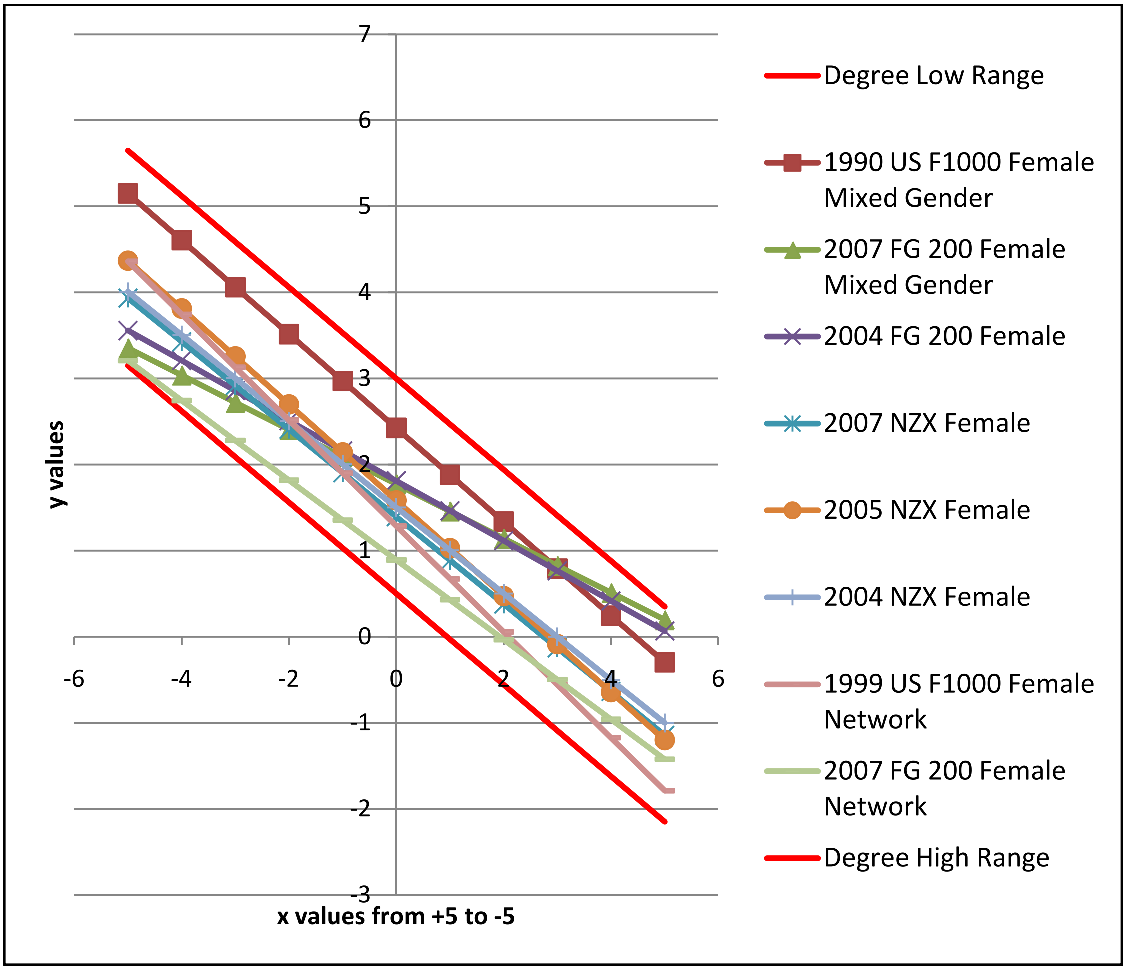


Figure 35.
Degree plot from log-log plot of equations for female directors in mixed gender networks for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX: and 1999 Fortune US 1000 and 2007 Fortune Global 200 women-only networks.



5.6 Betweenness analysis

On the Freeman betweenness measure, or the number of times a director is found on a geodesic path between two other directors, what percentage of male and female directors in the mixed gender and women-only networks have a betweenness score of greater than zero. Are these in a specific proportion to male and female directors respectively who have a zero betweenness score?

Does the distribution of betweenness scores in the largest component of the mixed gender networks follow a specific pattern, namely a power law?

Who are the top fifteen directors by betweenness and what is their gender?

The mean raw scores of the Freeman betweenness measure for the largest connected component of the 1999 Fortune 1000 directors; the 2004 and 2007 Fortune Global 200 directors; and the 2004, 2005 and 2007 NZX directors are presented in Table 26. As only a proportion of directors have a betweenness score, the percentages of directors with betweenness scores greater than zero, in relation to directors of the same gender with a betweenness score of zero, were calculated for all the datasets. These results are presented in Table 27.

The mean raw scores for the largest connected component of women-only networks, is presented in Table 31 with the percentage of women directors with a betweenness score of greater than zero.

As these results from the mixed gender networks indicate that the same percentage of male or female directors with a betweenness of greater than zero to total male or female directors respectively, are proportionally similar, further analysis was done.

From Glass Network theory's rule of self-similarity the following null hypothesis can be derived:

> *There is no difference between the proportion of female directors with betweenness scores of greater than zero compared to the male directors with a betweenness scores of greater than zero, in the largest connected component of the mixed gender director networks.*

In other words, even though the numbers of women directors with a betweenness score of greater than zero is much less than those of the men, in relation to the remaining women directors with a zero betweenness score, these percentages will follow the same proportions as the male directors with a betweenness score of greater than zero to the remaining male directors with a zero betweenness score. This is a similar test to the seat spread hypothesis as the directors with a betweenness score are connector directors and those zero scores are single seat directors.

The data was grouped into four categories by gender and by betweenness score greater or equal to zero. As this is categorical data, chi-squared analysis was performed for the 1999 Fortune 1000 directors; the 2004 and 2007 Fortune Global 200 directors; and the 2004, 2005 and 2007 NZX directors. The results are presented in Tables 28 and 29.

Following the comparative methodology, the summary results giving the power law trend line equations and derived linear equations from the log-log plot for male and female directors' betweenness for the largest connected component of the mixed gender and women-only networks are presented in Tables 30 and 31 respectively.

Table 26.
Mean raw score measures of Freeman Betweenness centrality for 1999 Fortune US 1000, 2004 and 2007 Fortune Global 200; 2004, 2005 and 2007 NZX.

Largest Connected Component Only	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
Mean Betweenness	12,017.7 (0.53)	3512.6 (0.28)	3669.3 (0.29)	1316.0 (0.65)	1425.3 (0.63)	1110.6 (1.12)
Betweenness Standard Deviation	34,193.4	15,358.7	15,114.4	4091.8	4449.2	3436.4

Table 27.
Percentage of male and female directors in the largest component with a Freeman Betweenness value of greater than zero for 1999 Fortune US 1000; 2004 and 2007 Fortune Global 200; 2004, 2005 and 2007 NZX.

	1999 Fortune US 1000	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2005 NZX	2007 NZX
% Male Directors with betweenness greater than zero/ Largest component male directors	23.3	11.9	11.3	20.1	20.3	22.7
% Female Directors with betweenness greater than zero/ Largest component female directors	29.9	10.2	12.5	23.8	18.5	13.5

Table 28.
Analysis by gender of directors in the largest component with Freeman Betweenness values of greater than zero for 1999 Fortune US 1000, 2004 and 2007 Fortune Global 200.

Largest Component Only	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200	
	Male	Female	Male	Female	Male	Female
Total	6107	598	1377	196	1366	275
Betweenness > 0	1424	179	165	20	154	27
Betweenness = 0	4683	419	1212	176	1212	248
x^2	12.74**		0.37		0.36	

** p<.001 with Yates correction for one degree of freedom

Table 29.
Analysis by gender of directors in the largest component with Freeman Betweenness values of greater than zero for 2004, 2005 and 2007 NZX.

Largest Component Only	**2004 NZX**		**2005 NZX**		**2007 NZX**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Total	597	42	622	54	409	37
Betweenness > 0	283	25	126	10	93	5
Betweenness = 0	314	17	496	44	316	32
x^2	1.85		0.01		1.18	

The linear equations for the mixed gender networks were plotted and are presented for the male directors only in Figure 36, and the female directors only in Figure 37. There were only five women directors in the 2007 NZX dataset with betweenness scores of greater than zero and these have been included in the results and also in Figure 37.

Only the 1999 Fortune US 1000 women-only network has sufficient numbers of women directors in the largest connected component with a betweenness score of greater than zero, to permit a comparative analysis. The Fortune Global 200 women-only network had only four women directors with a betweenness score of greater than zero. This network and that of the 2007 NZX women is included to show how sensitive a measure this can be. Anomalous results are easily differentiated.

The high and low ranges derived from the predictive equations are included as red lines. These are high: $y = -1.099x+8$ and low: $y = -1.099x+4$.

Mixed gender networks. Largest components only		Betweenness power law trend line equations				Betweenness linear trend line from log-log plot			
Year	Director network	Male	R^2	Female	R^2	Male	R^2	Female	R^2
1999	US Fortune 1000	$y = 6E+06x^{-0.83}$	0.820	$y = 2E+06x^{-0.88}$	0.854	y = -0.836x + 6.792	0.820	y = -0.883x + 6.181	0.854
2007	Fortune Global 200	$y = 87731x^{-0.91}$	0.698	$y = 13137x^{-0.84}$	0.657	y = -0.932x + 5.973	0.672	y = -0.844x + 5.118	0.657
2004	Fortune Global 200	$y = 1E+06x^{-0.99}$	0.848	$y = 20484x^{-1.21}$	0.708	y = -0.996x + 6.043	0.848	y = -1.216x + 5.311	0.708
2007	New Zealand Stock Exchange	$y = 13098x^{-1.06}$	0.818	$y = 17875x^{-2.12}$	0.991	y = -1.061x + 5.117	0.818	y = -2.126x + 4.252	0.991
2005	New Zealand Stock Exchange	$y = 27253x^{-1.09}$	0.750	$y = 35896x^{-1.22}$	0.892	y = -1.099x + 5.435	0.750	y = -1.226x + 4.555	0.892
2004	New Zealand Stock Exchange	$y = 18600x^{-1.02}$	0.774	$y = 50827x^{-1.62}$	0.846	y = -1.021x + 5.269	0.774	y = -1.627x + 4.706	0.846

Table 30. Betweenness analysis with power law trend line equation and linear trend line from log-log plot for 1999 Fortune US 1000, 2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX mixed gender director networks.

Women-only networks. Largest components only		Betweenness power law trend line equations		Betweenness linear trend line from log-log plot		Betweenness mean, std deviations & %		
Year	Director network	Female	R^2	Female	R^2	Mean (normalised)	Std Dev	% >0
1999	US Fortune 1000	$y = 9343.x^{-1.23}$	0.843	y = -1.234x + 3.970	0.843	261.6 (6.9)	494.4	47.7
2007	Fortune Global 200	$y = 62.09x^{-0.64}$	0.979	y = -0.642x + 1.793	0.979	10.5 (11.5)	18.8	26.6

Table 31. Betweenness analysis with power law trend line equation and linear trend line from log-log plot for 1999 Fortune US 1000 and 2007 Fortune Global 200 female only director network.

Figure 36.
Betweenness plot of linear equations from log-log plot
for male directors only in mixed gender networks 1999 Fortune US 1000:
2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX.

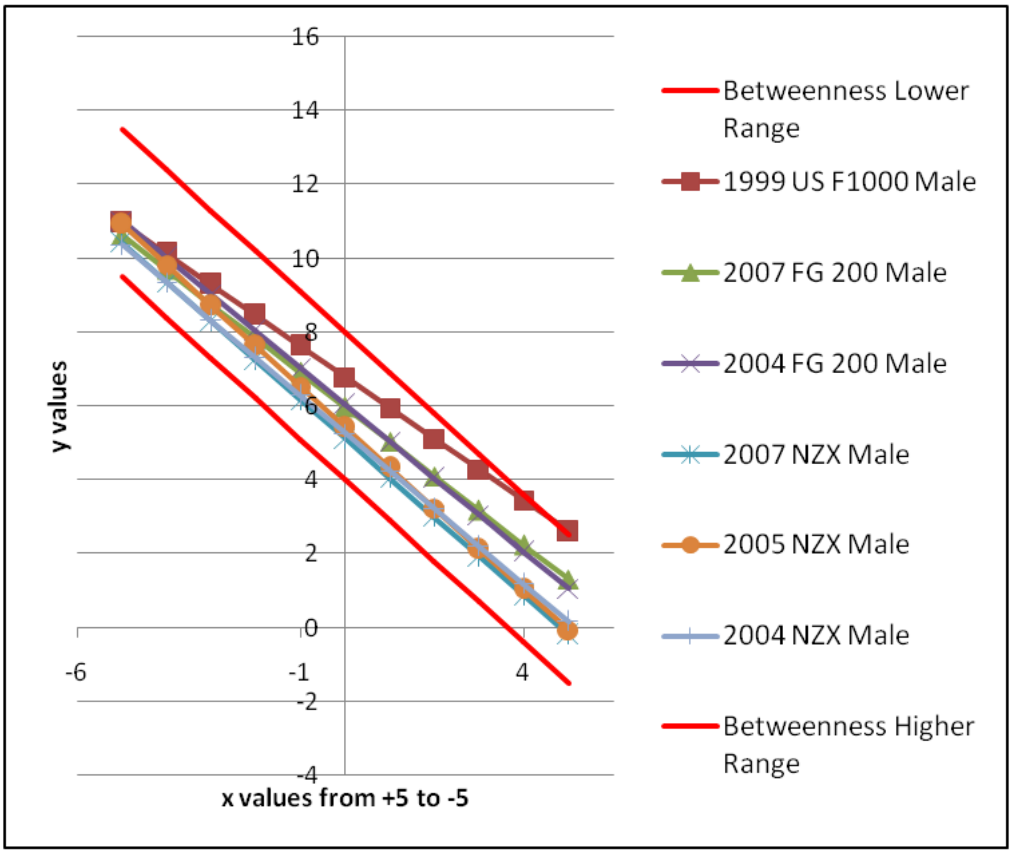
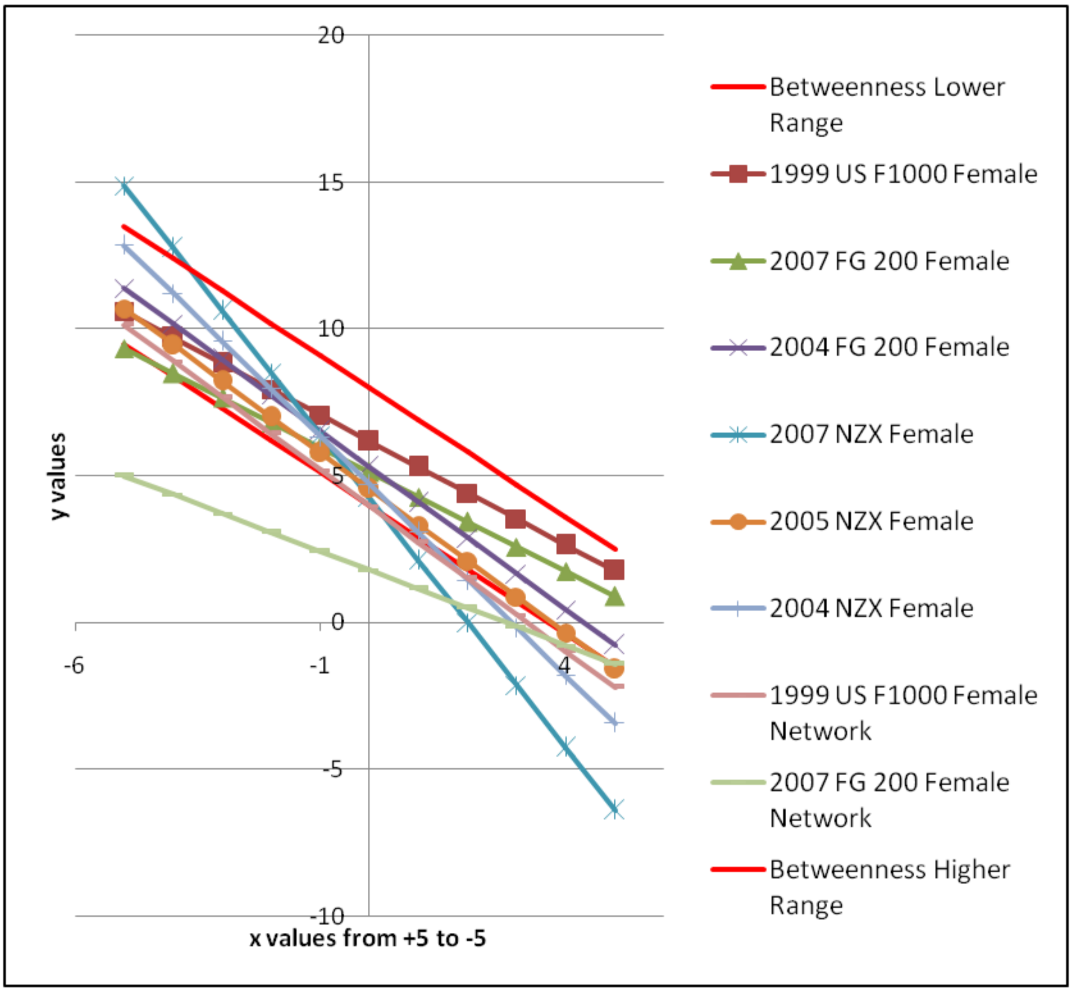


Figure 37.
Betweenness plot of linear equations from log-log plot
for female directors only in mixed gender networks 1999 Fortune US 1000:
2004 and 2007 Fortune Global 200; and 2004, 2005 and 2007 NZX;
with 1999 Fortune US 1000 and 2007 Fortune Global 200 female only networks



The Top Fifteen directors by normalised betweenness for the 2004 and 2007 Fortune Global 200 are presented in Table 32 and that of the 2004, 2005 and 2007 NZX networks in Table 33.

Table 32.
Fortune Global 200 Top Fifteen Directors
by normalised Betweenness for 2004 and 2007

Fortune Global 200 Top Fifteen Directors by Betweenness (Normalised)				
Rank	2004		2007	
1	Burgmans, Antony	21.8	Castell, William	28.5
2	Cromme, Gerhard	18.3	Burgmans, Antony	27.6
3	Knight, Charles	17.3	Simon, David	23.6
4	Price, Hugh	17.1	Cromme, Gerhard	22.7
5	Miles, Michael	16.2	Lane, Robert	15.7
6	Collomb, Bertrand	16.1	Lafley, Alan	10.7
7	Vasella, Daniel	12.4	Martin, Lynn *	10.2
8	Lee, Charles	12.2	Job, Peter	9.5
9	Neubauer, Joseph	10.8	Neubauer, Joseph	9.3
10	Lehner, Ulrich	9.9	Von Pierer, Heinrich	9.3
11	Ghosn, Carlos	9.2	Ollila, Jorma	9.1
12	Martin, Lynn *	8.8	Lee, Charles	9.0
13	Reinemund, Steven	8.2	Shipley, Walter	8.9
14	Dibble Jordan, Ann *	7.6	Cash, James Jr	8.7
15	Popoff, Frank	7.3	Bethune, Gordon	8.6
	Mean	**12.9**		**14.1**
*** = Female Director**				
Four maledirectors appear twice. ***One woman director appears twice.***				

Table 33.
New Zealand Stock Exchange Top Fifteen Directors
by normalised Betweenness for 2004, 2005, 2007

New Zealand Stock Exchange Top Fifteen Directors by Betweenness (Normalised)						
Rank	2004		2005		2007	
1	Fletcher, Hugh	17.4	Saunders, Timothy	20.1	Smith, Keith	33.9
2	Wilson, Peter David	16.5	Fletcher, Hugh	13.7	Pryke, Phillip	22.1
3	Smith, P. Michael	16.3	Gibbs, Anthony	13.4	Beeren, Bruce	20.2
4	Weiss, Gary	13.3	Barton, Ronald	13.3	Maasland, John	19.3
5	Maiden, Colin	12.8	Withers, Joan*	12.2	Jackson, David	19.1
6	Withers, Joan*	12.6	Wilson, Peter David	11.5	Carter, Ronald	17.5
7	Meo, Rosanne*	10.5	Morrison, Hugh	11.2	Freeman, Jane*	17.1
8	Falconer, William	9.2	Falconer, William	9.9	Baylis, William	14.4
9	Boyd, Wayne	9.2	Morschel, John	9.9	Spring, Dryden	14.1
10	Scott, Trevor	8.9	Deane, Roderick	9.7	McLay, James	13.5
11	King, John	8.4	Fisher, Rodger	8.2	Loughlin, John	13.4
12	Rolleston, Humphrey	8.2	Smith, Keith	7.8	Cushing, Selwyn	12.6
13	Gattung, Theresa*	8.1	Rolleston, Humphrey	7.7	Walker, Gavin	12.4
14	Saunders, Timothy	8.0	Smith, P. Michael	7.6	Frankham, Anthony	10.4
15	Barton, Ronald	7.2	Capp, William	7.5	Maiden, Colin	9.9
	Mean	**11.1**		**10.9**		**16.7**

*** = Female Director**

5 male directors appear twice. One woman director appears twice.
No director appears in all three years.

5.7 Testing Glass Network theory against random and longitudinal networks.

5.7.1 Continuing director descriptive statistics and continuation rates

The same analyses were performed for the continuing director and random director networks, where appropriate. Detailed descriptive statistics for the 2004 and 2007 Fortune Global 200 and NZX networks are presented in Table 34. The continuation rates are included.

Table 34.
Descriptive statistics for the 2004 and 2007 Fortune Global 200; and the 2004 and 2007 NZX continuing directors.

	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2007 NZX
No. of Companies	195	193	159	167
No. of continuing directors	1384	1384	476	476
Male continuing directors (%)	1215 (87.8)		451 (94.7)	
Female continuing directors (%)	169 (12.2)		25 (5.3)	
Gender Ratio	7.1		18 .0	
No. of Seats	1582	1557	653	621
Mean Seats	1.14	1.12	1.4	1.3
No. of Male Seats (%)	1388 (87.7)	1363 (87.5)	617 (94.5)	588 (94.7)
No. of Female Seats (%)	194 (12.3)	194 (12.5)	36 (5.5)	33 (5.3)
% total director continuation rate	55.8	54.5	49.3	52.9
% male director continuation rate	54.7	53.7	49.7	54.2
% female director continuation rate	66.0	61.5	43.9	37.3

5.7.2 Component Analysis for continuing and random directors

The results of the component analysis are presented in Table 35 for the continuing directors and Table 36 for the random director datasets.

Table 35.
Component Analysis for the 2004 and 2007 Fortune Global 200;
2004 and 2007 New Zealand Stock Exchange (NZX) continuing directors.

	2004 Fortune Global 200	**2007 Fortune Global 200**	**2004 NZX**	**2007 NZX**
No. of Components	68	69	40	55
No. of Directors in Largest Component (%)	820 (59.2)	869 (62.8)	317 (66.6)	251 (52.7)

Table 36.
Component Analysis for the 2007 Fortune Global 200
random network thirds and halves; and the 2007 NZX random network halves.

Largest components only	**2007 Fortune Global 200 Random 1st Third**	**2007 Fortune Global 200 Random 2nd Third**	**2007 Fortune Global 200 Random 3rd Third**	**2007 Fortune Global 200 Random 1st Half**	**2007 Fortune Global 200 Random 2 nd Half**	**2007 NZX Random 1st Half**	**2007 NZX Random 2nd Half**
No of directors	**846**			**1269**		**449**	
No. of Components	**124**	**147**	**123**	**106**	**106**	**117**	**104**
No. of Directors in Largest Components (%)	**99 (11.7)**	**46 (5.4)**	**103 (12.1)**	**295 (23.2)**	**597 (47.0)**	**45 (10.0)**	**57 (12.7)**

In the continuing director networks the Glass Network theory predicts that more women will be found in the largest connected component than the unconnected components in mixed gender networks. Chi-squared analysis with Yates correction and one degree of freedom, was selected to test the null hypothesis that:

> *Male and female directors are found in the largest connected component in the same ratio as the total gender ratio for the continuing director network of the 2004 and 2007 Fortune Global 200 and NZX directors.*

The results presented in Tables 37 and 38.

Table 37.
Director component analysis by gender for the
2004 and 2007 Fortune Global 200 continuing directors.

	2004 Fortune Global 200		2007 Fortune Global 200	
	Male	**Female**	**Male**	**Female**
Total	1215	169	1215	169
Largest Connected Component (%)	701 (57.7)	119 (70.4)	738 (60.7)	131 (77.5)
Remainder Unconnected Components	514	50	477	38
x^2	9.4*		17.2**	

**** p <.001**
*** p <.01 with Yates correction for one degree of freedom**

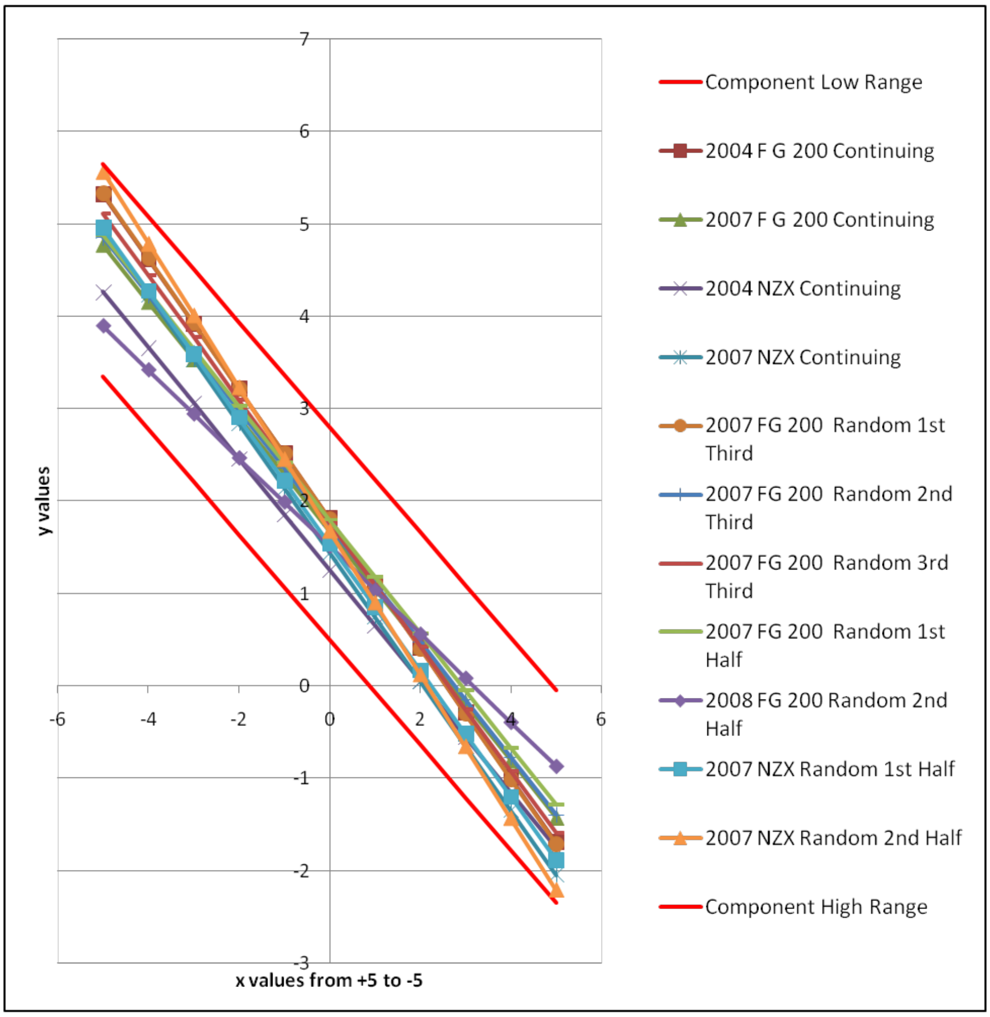
Table 38.
Director component analysis by gender
for 2004 and 2007 NZX continuing directors.

	2004 NZX		2007 NZX	
	Male	**Female**	**Male**	**Female**
Total	452	24	452	24
Largest Connected Component	295	22	238	13
Remainder Unconnected Components	157	2	213	11
x^2	6.0*		0.00	

***P <.05 with Yates correction for one degree of freedom**

Using the comparative methodology, the component predictive equations were tested against the continuing directors and the random director networks. Figure 38 shows how the derived equations for these networks for the components fall comfortably with the high and low ranges.

Figure 38.
Ranked component plot of linear trend line equations from log-log plot excluding the largest component for mixed gender male 2004 and 2007 Fortune Global 200 and NZX continuing director networks; random 2007 Fortune Global 200 thirds and halves networks; and 2007 NZX random halves networks.



5.7.3 Seat spreads for continuing and random directors

5.7.3.1 Seat spreads analysed with the comparative methodology

The seat spreads of the 2004 and 2007 Fortune Global 200 and NZX continuing directors were calculated by gender for directors and for seats for the largest component. These are included in Appendix Two. In the same appendix are seat spreads from the 2007 Fortune Global 200 and 2007 NZX networks divided into random halves for the largest component.

The seat totals by gender and percentage of connector directors to the single seat directors for the 2004 and 2007 Fortune Global 200 and NZX continuing directors by gender is given in Table 39.

Using the comparative methodology, the seat spread predictive equations were tested against the continuing directors and the random director networks and the results presented in Table 39. These were plotted and are presented in Figure 39 and 40. The high and low ranges derived from the predictive equations based on these results are also included as red lines. These are high: $y = -3.087x+8$ and low: $y = -3.087x-2$.

Year	Director Network Largest Connected Component Only	No of Male Seats	No of Female Seats	% Male Director Connector Seats to Total Male Seats	% Female Director Connector Seats to Total Female Seats	Male Linear Trend Line Equation from log-log plot of distribution of multiple seats	R^2 Value	Female Linear Trend Line Equation from log-log plot of distribution of multiple seats	R^2 Value
2007	Fortune Global 200	878	155	29.6	29.0	y = -2.532x + 2.822	0.934	y = -2.206x + 2.089	0.955
2004	Fortune Global 200	852	139	32.8	26.0	y = -2.550x + 2.860	0.922	y = -3.006x + 2.124	0.857
2007	NZX	358	20	55.3	55.0	y = -1.573x + 2.322	0.944	y = -0.233x + 0.797	0.022
2004	NZX	456	33	57.0	60.6	y = -1.751x + 2.489	0.831	y = -0.616x + 1.172	0.532

Table 39. Continuing director seat spreads by gender with linear trend line equation from log-log plot (largest component only)

Figure 39.
Seat spread plot of linear equations from log-log plot of continuing directors for male and female directors in mixed gender networks (largest component only).

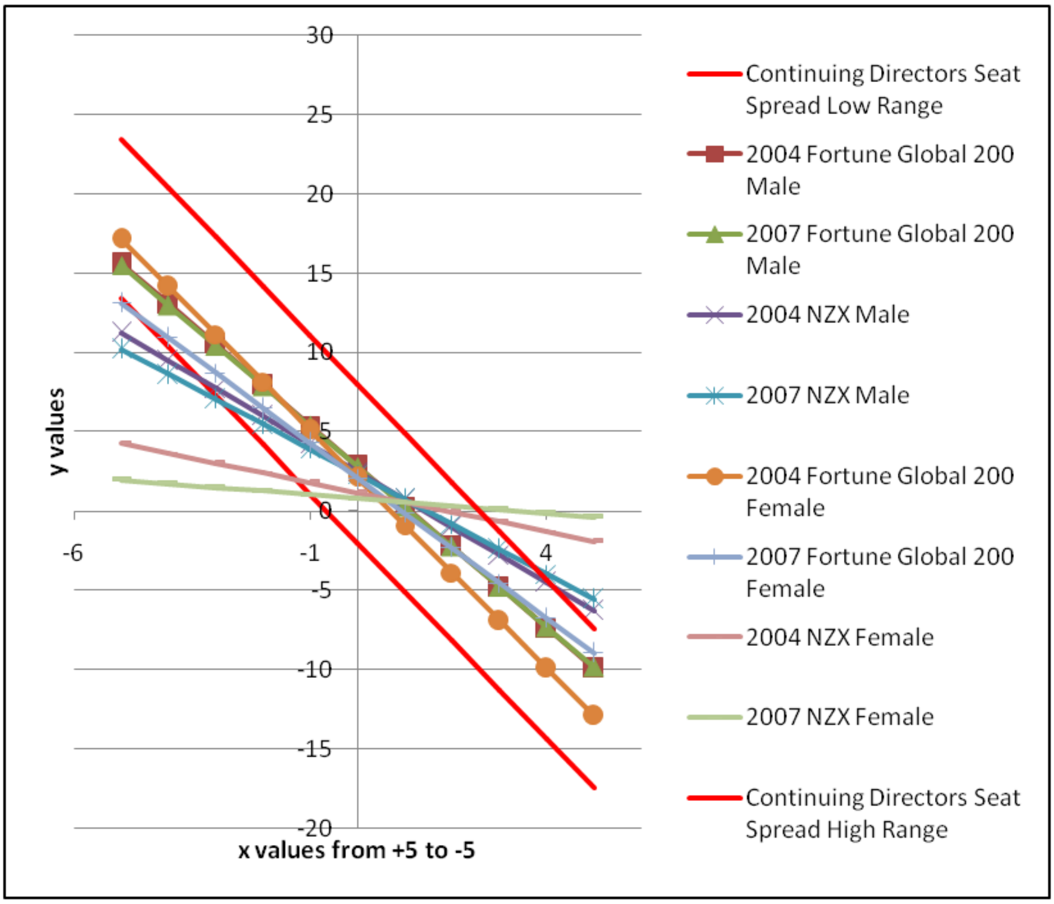
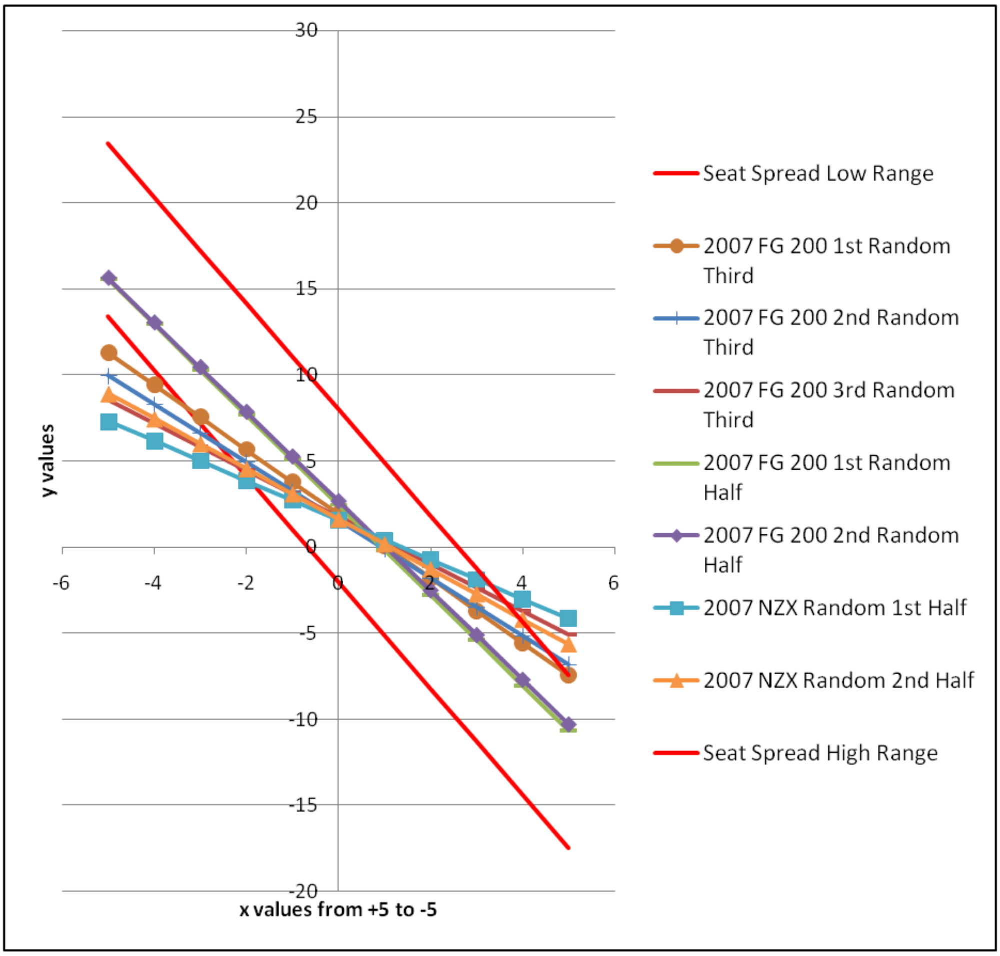


Figure 40.
Seat spread plot of linear equations from log-log plot of directors in the random 2007 Fortune Global 200 thirds and halves networks; and the 2007 NZX random halves networks. Largest component only.



5.7.3.2 Generating seat spreads

To test the non-symmetrical generating function expected seat spreads by gender were calculated for the 2004 and 2007 Fortune Global 200 continuing directors; and the 2004 and 2007 NZX directors with a seat spread parameter of 2. This was also done for the 2007 Fortune Global 200 and NZX random halves.

The gender breakdown for the expected seat spreads used the same ratios as the actual seat spread for each seat category. These results are presented in Appendix Five. The expected and actual seat spreads were plotted on a log-log graph and are presented in Figures 41 and 42 for the continuing directors and Figures 43 and 44 for random directors.

In addition chi-squared tests were performed against the total values for the actual and expected seat spreads. The continuing director chi-squared analyses were presented earlier in Table 18 (page 170) and the same analysis for random networks is presented in Table 40.

Table 40.
Chi-squared analysis of seat spreads for total actual and expected values for random director networks. Largest component only

Largest component		Total expected to actual		
Year		x^2	p	df
2007	Fortune Global 200 random 1st half	33.6	p <.001	6
2007	Fortune Global 200 random 2nd half	53.5	p <.001	6
2007	NZX random 1st half	3.5	Not significant	5
2007	NZX random 2nd half	2.7	Not significant	5

Figure 41.
Log-log plot of actual and expected seat spread for the 2004 and 2007 Fortune Global 200 continuing director networks for the largest component. Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

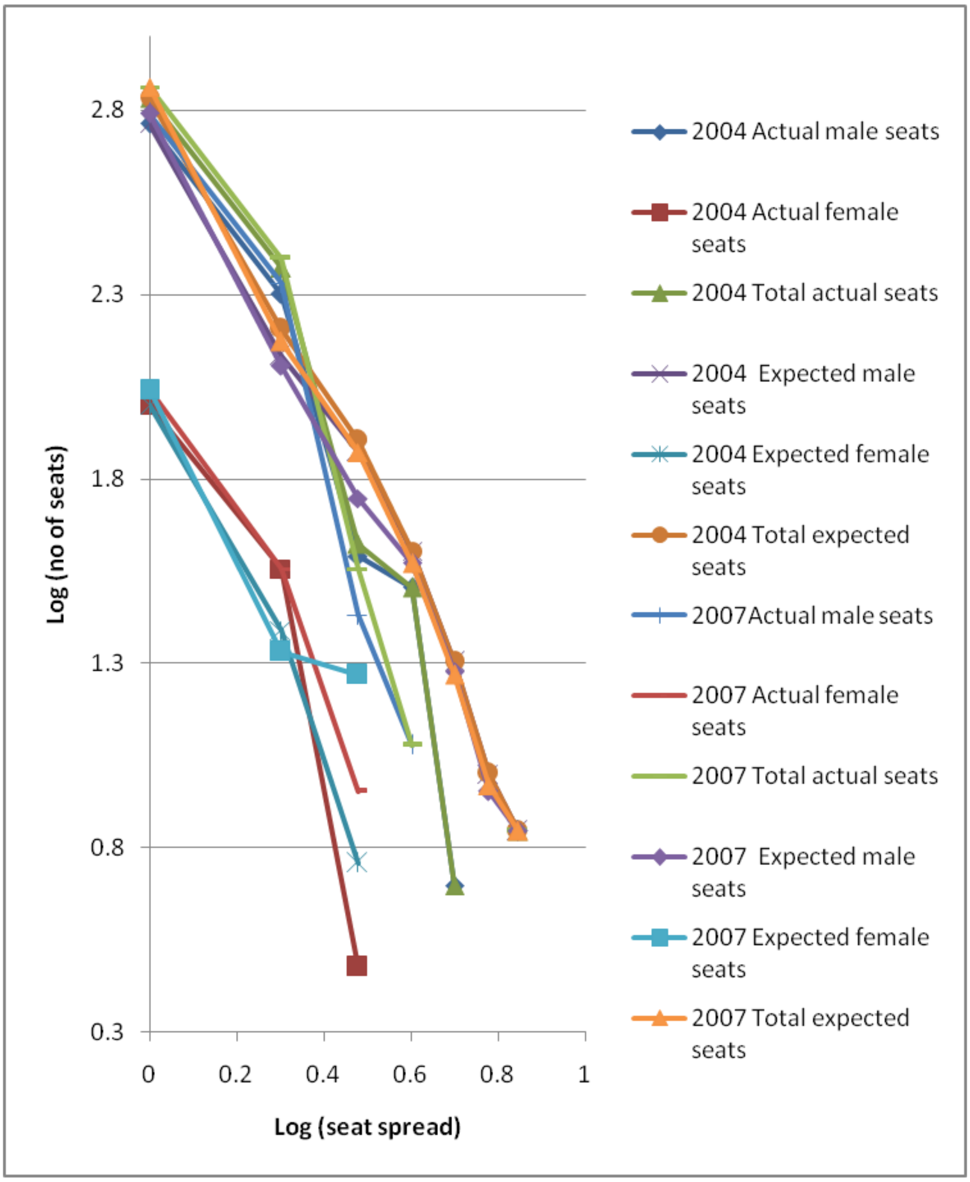


Figure 42.
Log-log plot of actual and expected seat spread for the 2004 and 2007 NZX continuing director networks for the largest component.
Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

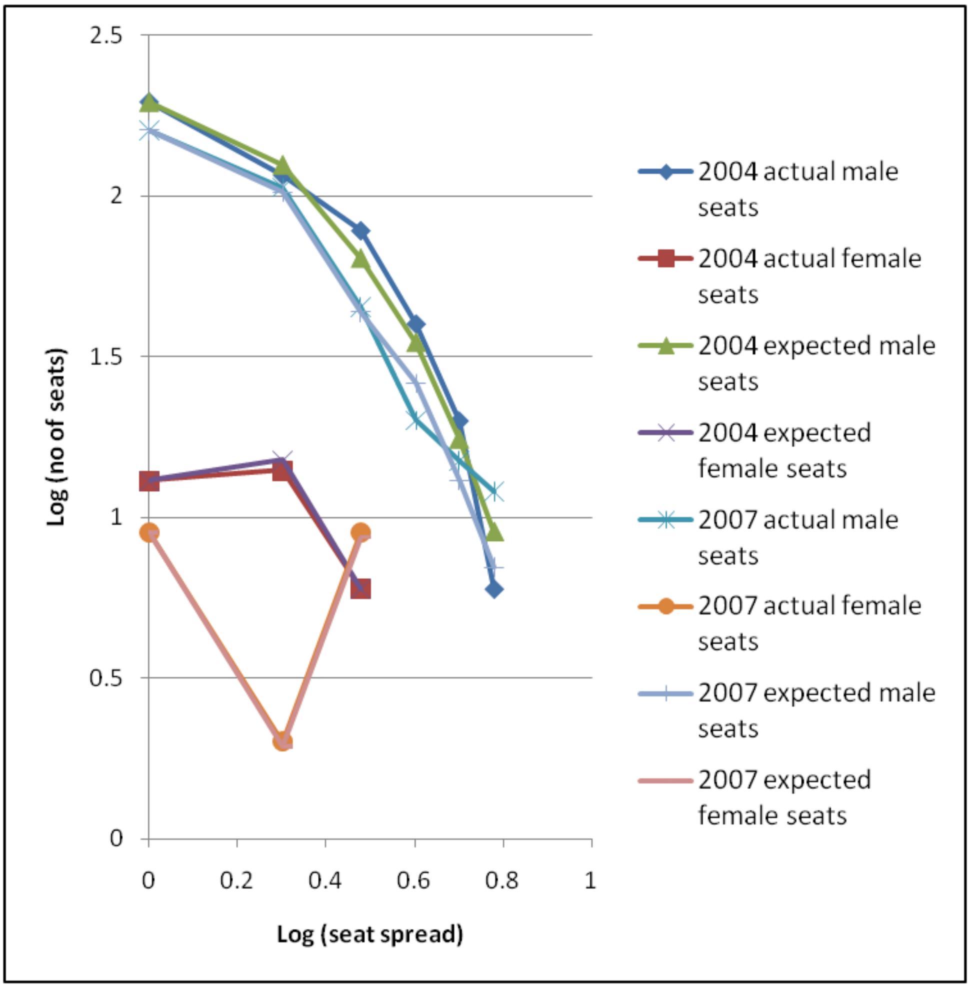


Figure 43.
Log-log plot of actual and expected seat spreads for the 2007 Fortune Global 200 random halves for the largest component. Seat spread parameter = 2.

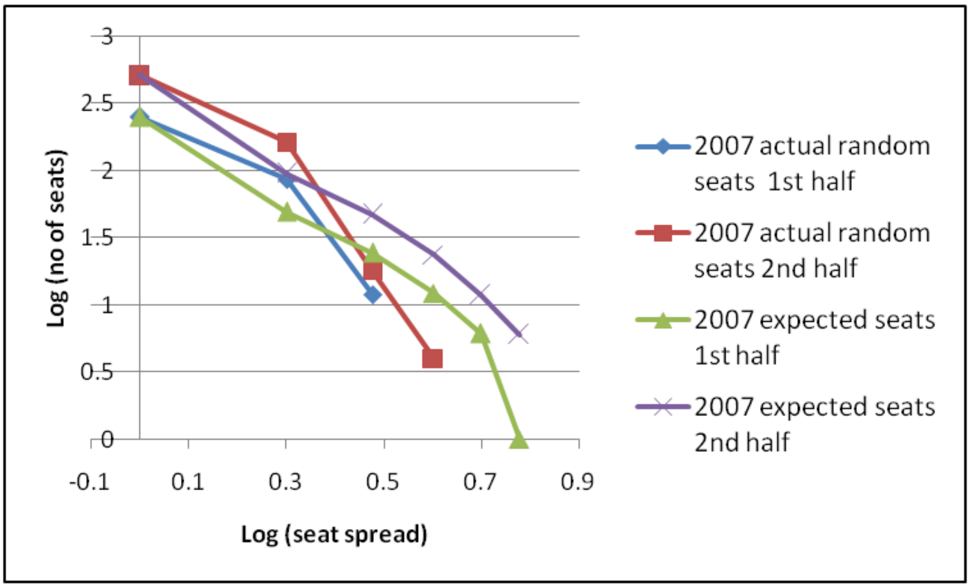
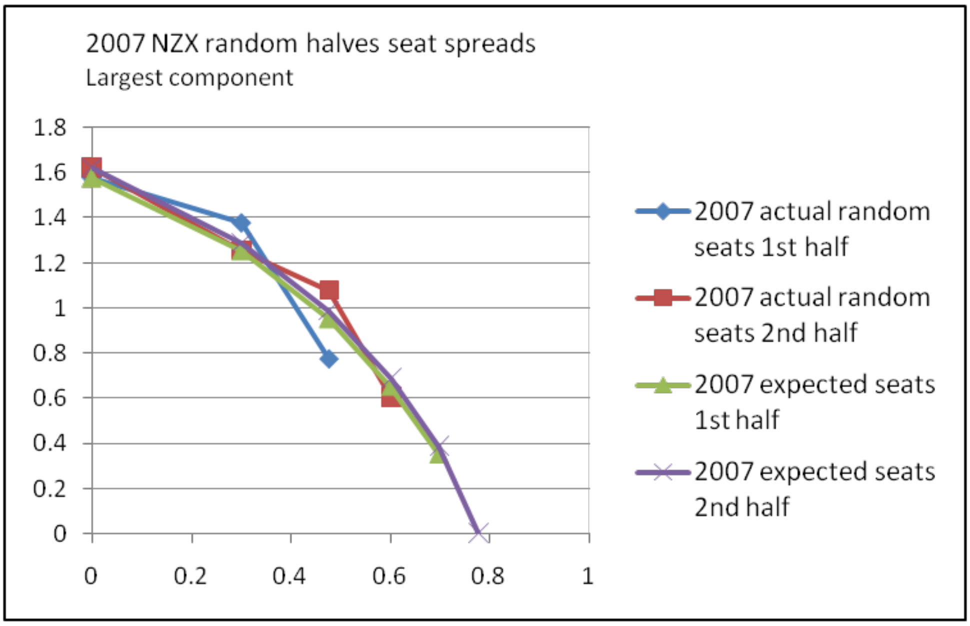


Figure 44.
Log-log plot of actual and expected seat spreads for the 2007 NZX random halves for the largest component. Spread parameter = 2.



5.7.4 Network metrics and small-world quotient

The same network metrics were calculated for the 2004 and 2007 Fortune Global 200 and NZX continuing directors as well as the 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves. The results are presented in Tables 41 and 42. To test whether the continuing directors and the random director networks were small-world networks, the SW quotient was calculated and these results are included in the same tables.

Table 41.
Measures of cohesion, centrality and Small-world Quotient for the 2004 and 2007 Fortune Global 200 and NZX continuing directors.

Largest Connected Component Directors Only	2004 Fortune Global 200	2007 Fortune Global 200	NZX 2004	NZX 2007
Density	0.01	0.01	0.019	0.02
Density Standard Deviation	0.12	0.11	0.13	0.15
Reach	175.27	171.45	73.90	54.54
Reach Standard Deviation	32.71	25.12	13.13	11.86
Clustering Coefficient	0.92	0.92	0.82	0.84
Mean Geodesic Distance	5.73	6.23	5.20	6.49
Mean Degree (Normalised)	11.03 (1.34)	10.86 (1.25)	5.79 (1.8)	5.63 (2.25)
Degree Standard Deviation	5.75	4.85	3.41	3.19
Minimum Degree	2	1	1	1
Maximum Degree	68	57	21	24
Clustering Coefficient Random	0.008	0.008	0.01	0.01
Geodesic Random	3.01	3.03	3.51	3.59
Small-world quotient	33.4	33.5	28.3	18.5

Table 42.
Measures of cohesion, centrality and small-world quotient for the 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves.

Largest components only	2007 Fortune Global 200 Random 1st Third	2007 Fortune Global 200 Random 2nd Third	2007 Fortune Global 200 Random 3rd Third	2007 Fortune Global 200 Random 1st Half	2007 Fortune Global 200 Random 2nd Half	2007 NZX Random 1st Half	2007 NZX Random 2nd Half
No of directors	846			1269		449	
Density	0.05	0.13	0.05	0.02	0.01	0.09	0.10
Density Standard Deviation	0.23	0.34	0.22	0.16	0.12	0.29	0.31
Reach (Normalised Reach)	25.70 (0.26)	20.14 (0.44)	32.32 (0.29)	65.27 (0.22)	98.21 (0.16)	17.55 (0.33)	22.93 (0.40)
Reach Standard Deviation	3.94	3.12	6.84	11.46	18.91	3.60	4.55
Clustering Coefficient	0.88	0.91	0.86	0.91	0.92	0.84	0.85
Mean Geodesic Distance	5.91	3.03	4.63	5.98	8.95	4.78	3.26
Mean Degree (Normalised Degree)	5.35 (5.46)	6.04 (13.43)	5.96 (5.47)	7.94 (2.70)	8.92 (1.50)	5.19 (9.78)	5.86 (10.46)
Degree Standard Deviation	2.20	2.71	2.99	3.21	4.37	2.78	4.09
Minimum Degree	1	2	1	1	2	2	1
Maximum Degree	12	14	16	22	60	15	20
Clustering Coefficient Random	0.006	0.007	0.007	0.006	0.007	0.012	0.013
Geodesic Random	4.02	3.78	3.78	3.45	3.27	3.71	3.45
Small-world quotient	94.60	157.53	99.02	84.59	47.93	56.78	69.57

In addition a further 16 sets (8 sets of two halves) of measures of cohesion, centrality and small-world quotient were performed for the 2007 Fortune Global 200 and NZX random directors. These are presented in Appendix Seven.

5.7.5 Assortative Mixing

To test whether continuing director networks are positively assortative, the same methodology was followed for the full networks. The results for the 2004 and 2007 Fortune Global 200 and NZX continuing directors are presented in Table 43. Assortative mixing was not performed against the random networks as the QAP procedure tested the results against random pairing of directors by degree.

Table 43.
Assortativity Analysis for 2004 and 2007 Fortune Global 200 and NZX continuing directors

Largest Components Only	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2007 NZX
Observed Assortativity	0.267	0.271	0.245	0.199
Expected Assortativity	-0.001	-0.001	-0.003	-0.002
Standard Deviation	0.012	0.012	0.029	0.029
***P>= Observed Assortativity**	0	0	0	0
***P = Observed Assortativity**	0	0	0	0
***P <= Observed Assortativity**	1	1	1	1

*P = [Number of networks which have larger assortativity value than observed network]/[the number of iterations]

5.7.6 Degree Analysis

The mean degree for the 2004 and 2007 Fortune Global 200 and NZX directors continuing directors and the random director networks is presented in Table 41 (page 204).

Following the comparative analysis methodology, the power law trend line equations and derived linear equations from the log-log plot of male and female directors' degree for the largest connected component are presented in Table 45.

The linear equations were plotted and are presented for the male and female continuing directors in Figure 44 and the 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves for the largest components only in Figure 46. The high and low ranges derived from the predictive equations are included as red lines.

These are high: $y = -3.087x+8$ and low: $y = -3.087x+3$.

The results from the Wilcoxon matched pairs signed ranks test are presented in Table 45.

Table 44.
Degree analysis with power law trend line equation and linear trend line from log-log plot for mixed gender continuing director networks for 2004 and 2007 Fortune Global 200 and NZX directors.

Mixed gender networks. Largest components only		**Degree power law trend line equations**				**Degree linear trend line from log-log plot**			
Year	**Continuing Director network**	**Male**	**R^2**	**Female**	**R^2**	**Male**	**R^2**	**Female**	**R^2**
2007	Fortune Global 200	$y = 84.31x^{-0.38}$	0.794	$y = 43.47x^{-0.37}$	0.723	y = -0.381x + 1.925	0.794	y = -0.372x + 1.638	0.723
2004	Fortune Global 200	$y = 105.7x^{-0.42}$	0.836	$y = 36.54x^{-0.33}$	0.767	y = -0.425x + 2.024	0.836	y = -0.338x + 1.562	0.767
2007	NZX	$y = 46.03x^{-0.5}$	0.811	$y = 12.36x^{-0.50}$	0.727	y = -0.499x + 1.663	0.811	y = -0.505x + 1.092	0.727
2004	NZX	$y = 60.48x^{-0.53}$	0.8	$y = 19.36x^{-0.58}$	0.811	y = -0.534x + 1.781	0.8	y = -0.582x + 1.287	0.811

Table 45.
Wilcoxon matched pairs signed rank test by degree for 2004 and 2007 Fortune Global 200 and NZX directors.

Wilcoxon matched pairs signed rank test by degree	Median 2004	Median 2007	z score	p(same)
Fortune Global 200 matched directors present in both years	10	10	2.03	0.042
Fortune Global 200 including directors present in one year only	9	10	0.63	0.154
NZX matched directors present in both years	5	5	1.91	0.056
NZX including directors present in one year only	5	4	5.96	0.000

Figure 45.
Degree plot of linear equations from log-log plot for male and female continuing directors for 2004 and 2007 Fortune Global 200 and NZX directors (largest components only).

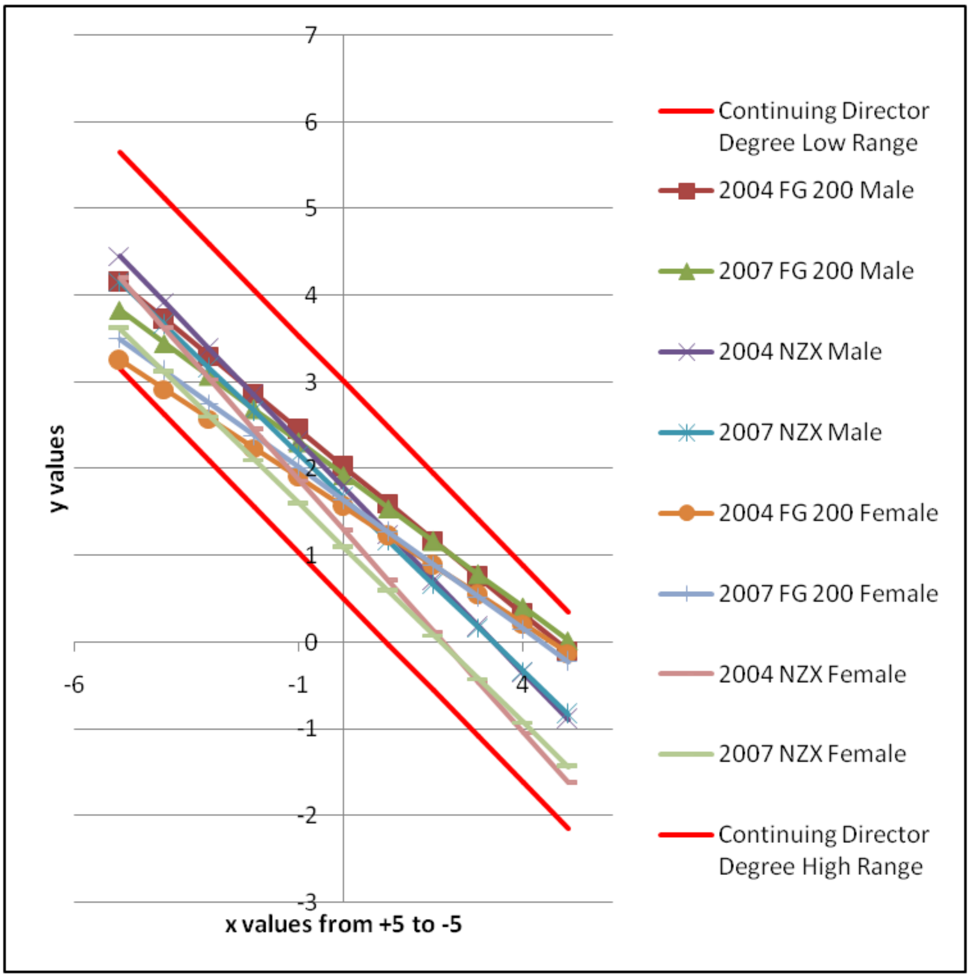
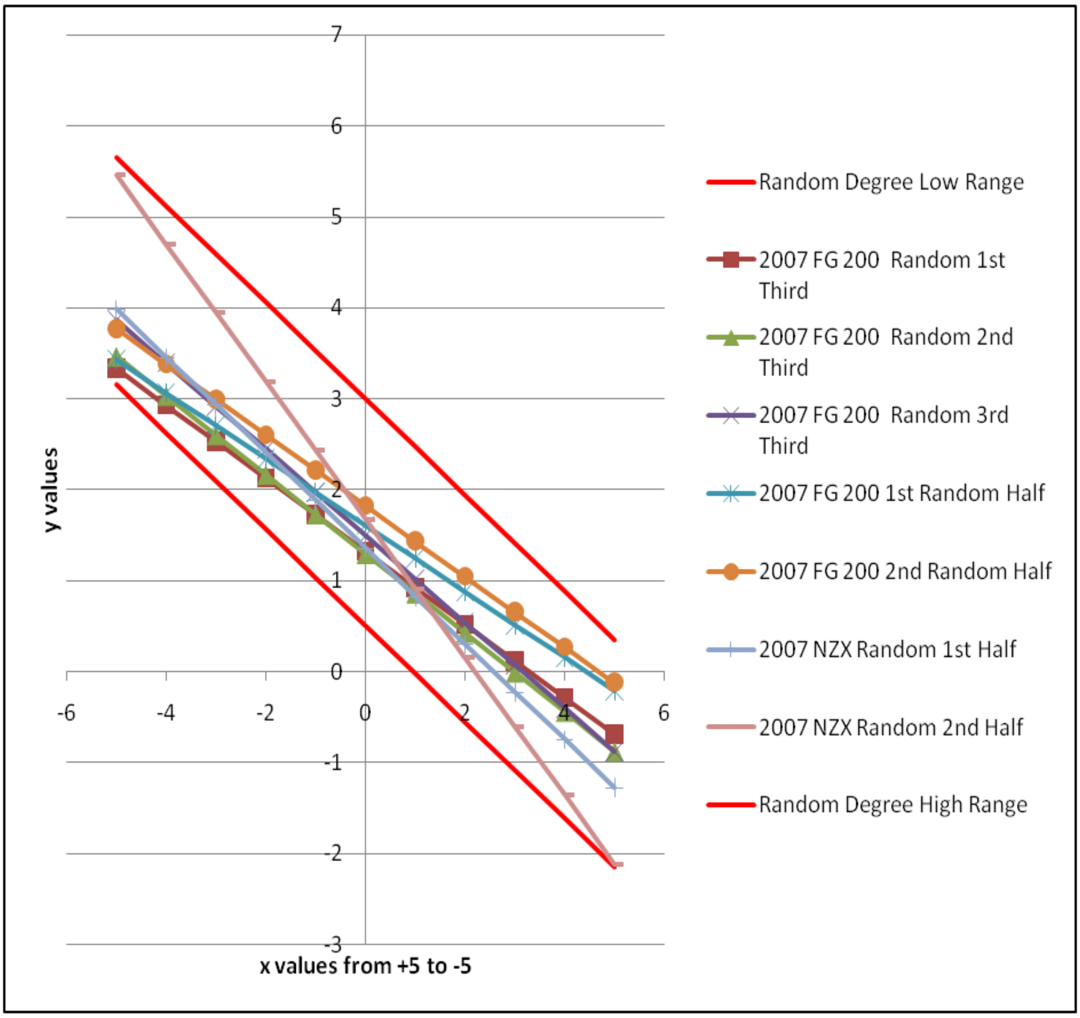


Figure 46.
Degree plot of linear equations from log-log plot for directors of 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves (largest components only).



5.7.7 Betweenness Analysis

The mean betweenness for the 2004 and 2007 Fortune Global 200 and NZX continuing directors and the random director networks is presented in Table 46 and Table 47.

As the results in Table 48 indicate that the percentage of male or female continuing directors with a betweenness of greater than zero to total male or female directors respectively, are proportionally similar, further analysis was done. From Glass Network theory's rule of self-similarity the following null hypothesis can be derived:

There is no difference between the proportion of female continuing directors with betweenness scores of greater than zero compared to the male continuing directors with a betweenness scores of greater than zero, in the largest connected component.

The data was grouped into four categories by gender and by betweenness score greater or equal to zero. As this is categorical data, chi-squared analysis was performed. The results are presented in Table 49.

Following the comparative analysis methodology, the summary results giving the power law trend line equations and derived linear equations from the log-log plot of male and female directors' betweenness for the largest connected component of the 2004 and 2007 Fortune Global 200 and the NZX continuing directors are presented in Table 51.

The linear equations for betweenness were plotted and are presented for the male and female continuing directors in Figure 47 and the 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves for the largest components only in Figure 48. The high and low ranges derived from the predictive equations are included as red lines. These are: high: $y = -1.099x+8$
and low: $y = -1.099x+4$.

The results from the Wilcoxon matched pairs signed ranks test are presented in Table 50.

Table 46.
Mean raw score measures of Freeman betweenness centrality for 2004 and 2007 Fortune Global 200; 2004 and 2007 NZX continuing directors.

Largest Components Only	**2004 Fortune Global 200**	**2007 Fortune Global 200**	**2004 NZX**	**2007 NZX**
Mean Betweenness (normalised)	1938.2 (0.58)	2268.1 (0.6)	663.4 (1.3)	685.7 (2.2)
Betweenness Standard Deviation	7002.7	8778. 0	1661.8	1847.3

Table 47
Mean raw score measures of Freeman Betweenness centrality for 2007 Fortune Global 200 random network thirds and halves; and the 2007 NZX random network halves.

Largest Connected Component Directors Only	2007 Fortune Global 200 Random 1st Third	2007 Fortune Global 200 Random 2nd Third	2007 Fortune Global 200 Random 3rd Third	2007 Fortune Global 200 1st Half	2007 Fortune Global 200 2nd Half	2007 NZX Rando m 1st Half	2007 NZX Random 2nd Half
Mean Betweenness	240.3	45.7	198.0	731.6	2367.7	100.2	63.4
Betweenness Standard Deviation	570.3	121.8	447.3	2270.5	10129.4	178.0	156.3

Table 48.
Percentage of male and female continuing directors with a Freeman Betweenness value of greater than zero for 2004 and 2007 Fortune Global 200; 2004 and 2007 NZX.

Largest Components Only	2004 Fortune Global 200	2007 Fortune Global 200	2004 NZX	2007 NZX
% Male Directors with betweenness greater than zero/ Largest component male directors	17.4	15.9	31.2	29.8
% Female Directors with betweenness greater than zero/ Largest component female directors	16.8	16.0	36.4	30.8

Table 49.
Analysis by gender of continuing directors in the largest component with Freeman Betweenness values of greater than zero for 2004 and 2007 Fortune Global 200 and for 2004 and 2007 New Zealand Stock Exchange NZX.

Largest Component Only	**2004 Fortune Global 200**		**2007 Fortune Global 200**		**2004 NZX**		**2007 NZX**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Total	701	119	738	131	295	22	238	13
Betweenness > 0	122	20	117	21	92	8	71	4
Betweenness = 0	579	99	621	110	203	14	167	9
x^2	0		0		0.071		0.071	

Figure 47.
Betweenness plot of linear equations from log-log plot for male and female continuing directors for 2004 and 2007 Fortune Global 200; and NZX mixed gender networks (largest components only).

Figure 48.
Betweenness plot of linear equations from log-log plot for 2007 Fortune Global 200 random director network thirds and halves; and the 2007 NZX random network halves (largest components only).

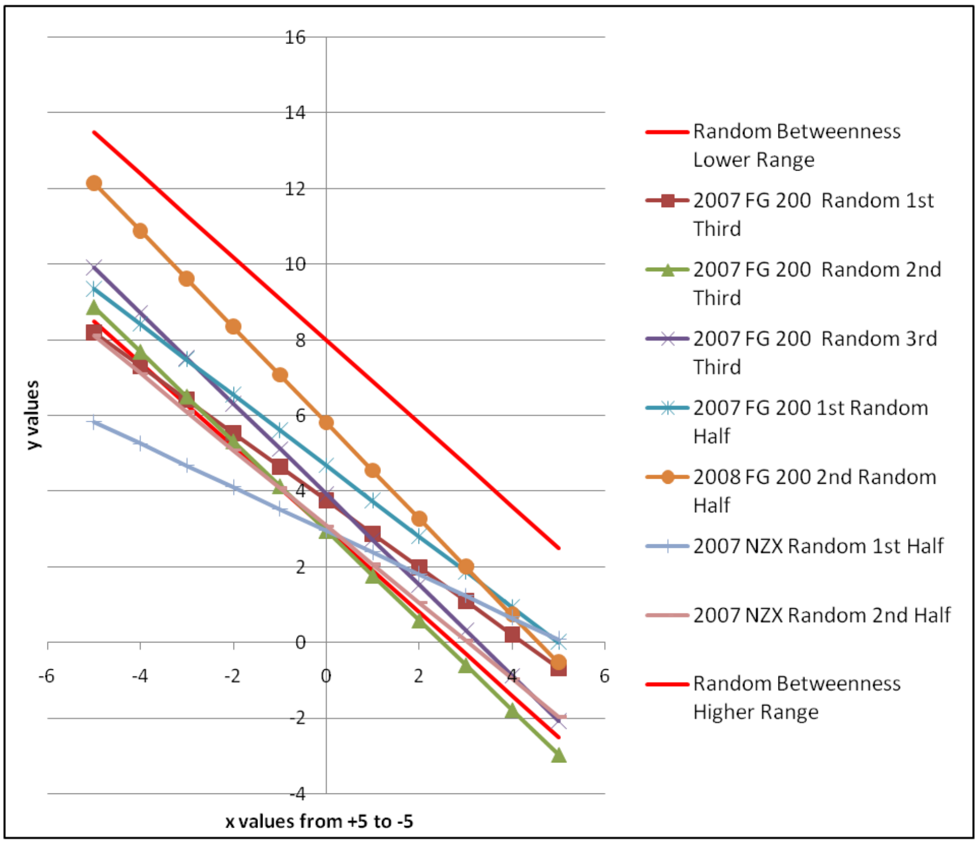


Table 50.
Wilcoxon matched pairs signed rank test by betweenness for 2004 and 2007 Fortune Global 200 and NZX directors.

Wilcoxon matched pairs signed rank test by betweenness	Median 2004	Median 2007	z score	p(same):
Fortune Global 200 matched directors present in both years	7826.9	7968.1	0.73	0.47
Fortune Global 200 including directors present one year only	4251.1	5172.0	0.34	0.74
NZX matched directors present in both years	1488.4	1265.6	0.38	0.71
NZX including directors present one year only	1103.8	414.2	2.57	0.01

Mixed gender networks. Largest components only			Betweenness power law trend line equations			Betweenness linear trend line from log-log plot			
Year	Director network	Male	R^2	Female	R^2	Male	R^2	Female	R^2
2007	Fortune Global 200	$y = 51873x^{-1.10}$	0.713	$y = 60754x^{-0.85}$	0.902	y = -1.101x + 5.714	0.713	y = -0.854x + 4.783	0.902
2004	Fortune Global 200	$y = 52736x^{-1.16}$	0.797	$y = 67910x^{-1.20}$	0.759	y = -1.166x + 5.722	0.797	y = -1.204x + 4.831	0.759
2007	NZX	$y = 86656x^{-1.32}$	0.798	$y = 2144.x^{-1.05}$	0.970	y = -1.319x + 4.937	0.798	y = -1.059x + 3.331	0.970
2004	NZX	$y = 52966x^{-1.06}$	0.770	$y = 13869x^{-1.72}$	0.935	y = -1.065x + 4.724	0.770	y = -1.722x + 4.146	0.935

Table 51. Betweenness analysis with power law trend line equation and linear trend line from log-log plot for 2004 and 2007 Fortune Global 200; and NZX mixed gender continuing director networks.

Chapter Five Summary

In the first section, descriptive statistics describe the structure of mixed gender director networks, and for the first time women-only director networks. Continuation rates for mixed gender networks at two points in time are given. The component analysis shows that the sub-components in the network when ranked by size fall within the predicted ranges. Further gender analysis of the components found that there were significantly more women in the largest connected component of the Fortune US 1000 and Fortune Global 200 networks.

Using the comparative methodology the seats spreads of all networks fell within the predicted ranges. Using the generating function with a parameter of two, actual male seat spreads differed significantly from the expected seat spreads but female seat spreads did not.

Mixed results were obtained for the test of the hypothesis that female directors with more than one seat were being appointed to more boards than their equivalent male connector directors in the largest connected components of the networks.

The second section gives the metrics from the social network analysis. All networks were found to have a small-world quotient greater than one. Except for the 2007 Fortune Global 200 women-only network, all networks were positively assortative. Using the comparative methodology, the degree and betweenness results fell within the predicted ranges.

The final section tested Glass Network theory against the random and longitudinal datasets using the same measures. Similar significant results by gender were found for the component analysis and the actual to expected seats spreads. More variability in the fitting of the seat spreads, degree and betweenness measures into the predictive ranges was observed for the continuing directors, probably due to small sample sizes. All continuing director networks were found to have a small-world quotient greater than one and were positively assortative.

Chapter Six. Discussion

6.1 Introduction

The discussion first considers statistical and methodological issues followed by the detailed results from each question in the research set. The results from the testing of Glass Network theory against longitudinal and random datasets are presented. A summary discussion then draws the results together, considers the limitations and discusses the role and relevance of each of the major concepts for Glass Network theory in the light of the major findings, that:

- male and female director networks are similar in structure
- are self-similar across time and location
- are all small-worlds
- are positively assortative
- show the characteristics of scale-free networks

Glass network theory is extended to include geographic proximity and research into city and company size.

6.2 Statistical and methodological issues

New methodologies have been developed in this thesis to demonstrate similarities between director networks at different scales and at different times. The 1999 Fortune US 1000 data, although ten years old, has stood out in this research as significantly different to the more recent Fortune Global 200 and the NZX data on a number of measures. This benchmark data has been useful as I have been able to highlight aspects of glass networks that could be seen as merely statistical artifacts in the other networks. These differences may be a function of the larger numbers of directors, but may also reflect the response of the US director networks to governance and affirmative action initiatives. The very obvious next step is to run the same analyses through a current US data set to determine the persistence of these trends in the USA economy. This is currently precluded by the lack of such a dataset.

Director networks are dynamic systems in a constant state of flux, and the challenge is to take snapshot measures of the network that have sufficient precision to reveal the underlying structure. The methodology developed here of predictive ranges accommodates fluctuating networks while at the same time quickly identifying anomalous data, whether due to data collection errors or underlying trends. Derived from actual data, these ranges for each of the measures analysed have a number of advantages. They can be refined further in the light of new data, are independent of the size, location and time frame of the data collected and are best viewed graphically, encompassing in one figure the large volumes of underlying data.

Given that much small-world and scale-free research has been driven by physicists and mathematicians using probability distributions, one of the challenges has been to develop a methodology that is accessible and reproducible by WOB and governance researchers. Interpreting probability distributions requires a sophisticated level of understanding (Bohorquez, 2009) and an appreciation of the findings may be lost in the complexity of the interpretation. However, the rigorous research by Newman, Watts and Barabási and many others does lend a great deal of confidence to the findings of this research.

Dynamic systems also pose problems of data accuracy, director networks being a case in point. Data provided by stock exchanges and other agencies legally required to collect such information is not necessarily validated by the organizations tasked with this duty. Although the internet has made the job of researchers in verifying names and checking attributes like gender much easier, an ongoing problem is the high level of error in the raw data. Both CWDI reports of the Fortune Global 200 had several discrepancies between the raw data in the appendices to the totals in the text. Insufficient proof-reading appeared to be an issue and was perpetuated in the 2007 version despite correspondence with CWDI on the matter. Longitudinal studies smooth out some of this variability while capturing the fluctuating nature of director networks.

In measuring director turnover rates, shown here to range from 40% to 60% in a three year period, this research has indicated how quickly the identity of individuals in the network change. This research provides an indication of the proportions of the two genders being replaced. It also indicates whether connector directors as a population are more stable than single seat directors, with the results indicating that they do stay marginally longer, but it does depend to some extent on the network.

In addition, the statistical analyses of the continuing directors indicate that their personal circumstances also change significantly. This brings its own problems with teasing out abnormal change from 'normal' change in the network. This study, contrary to most research, looked for similarities not differences in the data.

This research has also highlighted the necessity of appreciating the underlying distribution of the data and thinking beyond statistical measures for normal distributions. The reworking of the historical data indicates that earlier research must be reconsidered in the light of the power law distributions in director data.

The limited nonparametric tests available make statistical comparisons difficult and are of weak statistical power (Siegel, 1956; Kazmier, 1976). The Wilcoxon matched pairs signed ranks test most closely met the criteria for ordinal, related and discrete data that are not normally distributed, but it can only be used with longitudinal data where it is possible to match directors. The Wilcoxon test is itself very sensitive to errors in the data. In double checking the data, the inadvertent exclusion of one matched pair with a degree of 7 in 2004 dropping to 2 in 2007 moved the results of the degree analysis from non-significant to significant. This experience highlights issues over the usefulness of statistical tests except in verifying results obtained from the methodology developed here with predictive ranges.

This research also highlighted the importance of understanding randomness in director network data and the necessity for researchers not to be, in the words of Taleb (2004), fooled by randomness. Differences in networks are not necessarily indicative of randomness, while order and similarity in complex networks may be the end result of random processes in a dynamic equilibrium (Ball, 2004; Buchanan, 2002; Taylor, 2001). Researchers have varied in how they dealt with randomness in director networks ranging from boot-strapping procedures to the use of generating functions (Conyon & Muldoon, 2006, 2008; Newman et al., 2001).

The use of generating functions in the literature to create theoretical structures to test against actual data also stimulated the search for mathematical regularities in the gendered seat spreads. The resulting finding that a non-symmetrical bifurcation generating function with a parameter of 2 fits director seat spreads with some accuracy has allowed a theoretical model to be developed that can readily be appreciated by WOB and other diversity researchers.

In addition, the use of random number sequences to create artificial director attributes and assign directors to networks on the basis of those attributes was productive when comparing patterns created by random networks to those extracted on the basis of gender. The results indicate that random director networks where the links between companies and directors are preserved are difficult to distinguish from actual networks as they fall comfortably and more reliably into the predictive ranges. This supports arguments for self-similarity across director networks however the network is apportioned.

6.3 Detailed Discussion of results

6.3.1 Network description and component analysis

6.3.1.1 Network description

Women directors were found in low proportions in all networks, but interestingly the highest percentage (10%) was found in the 2004 and 2007 Fortune Global 200 director network, which may be due to the larger board size - an average of 13.7 members compared to 8.3 for US boards and 6.1 for NZX boards. Table 10 (page 157) shows the gender ratio varied from 8.6 to 1 (1999 Fortune US 1000) to 10 to 1 in the Fortune Global 200 and ranging from 16 to 1 to 12.4 to 1 in the NZX network.

The mean number of seats per director for all networks did not exceed 1.5 and the percentage of female seats closely followed the director percentages namely, 9.4% for the 1999 Fortune US 1000, and an average of 10.8% in the 2004 and 2007 Fortune Global 200. A reduction of seats in the 2007 NZX saw female seat percentages remaining static at 6.6% as numbers of male seats fell. These statistics illustrate the importance of disclosing both director and seat percentages, as false impressions may be created if only one is reported.

In the mixed gender networks, the percentage of connector directors, that is, directors with more than one seat, was below 17%; 14% in the 1999 Fortune US 1000 network, an average of 7.7% in the Fortune Global 200 network and an average of 14.7% in the NZX director network. The 2007 NZX also saw a decline in connector directors from 16.3% to 13%.

Table 11 (page 158) compares the female only networks that were extracted from the mixed gender networks. The percentage of companies with women directors ranges from an average of 75.3% in the Fortune Global 200 network, 68.9% in the 1999 Fortune US 1000 network and a low average of 30.9% in the NZX director network.

The mean seat values rose marginally for the women director networks, while the percentage of female connector directors to total female directors was higher than the percentage of connector directors to single seat directors in the mixed gender networks; 26.7 % (12.7% difference) in the 1999 Fortune US 1000 network, an average of 10.9% (3.2% difference) in the Fortune Global 200 network and an average of 15.5% (0.8% difference) in the NZX female only director network. Although not tested for significance, this does suggest a preference for female connector directors over single seat directors, which is explored further in the component analyses of the largest network components.

In terms of Glass Network theory, as expected the percentages of women directors was below 20% with higher percentages of women connector directors in the women-only networks indicating a preference for women directors through the glass net.

6.3.1.2 Network components

How many components does a network break into and what is the size of the largest component? Do the unconnected components ranked by size follow a specific distribution, assuming the data is not normally distributed?

Table 12 (page 159) lists the numbers of components in each director network, which range from 96 in the 1999 Fortune US 1000 network, an average of 64.8 in the Fortune Global 200 networks and an average of 55 in the NZX director networks.

The largest component in each mixed gender network ranges from a giant component in the 1999 Fortune US 1000 with 87.7% of the directors and an average of 62% of the directors in the Fortune Global 200 and similarly in the NZX networks. In 2007 the NZX network contracted by 6%, with the number of directors in the largest component reduced from 70% to 50%, evidence that there was significant change in the connector director cadre, with an associated fracturing of the director network into more components.

When the female only director networks were extracted, similarly fractured and mostly unconnected director groups were observed as outlined in Table 12. The 1999 Fortune US 1000 women-only network was the only network with a large component big enough to analyse. This consists of 88 women and contains 13.4% of the women directors. The remaining 86.6% of the women directors are distributed through the unconnected components. The Fortune Global 200 women-only networks broke into two bigger components of 8 women each in 2004 and 15 and 11 in 2007. In both the Fortune Global 200 networks and the NZX networks, 90% of women directors were in the unconnected components of the women-only networks. From this it can be concluded that the appointment of additional female connector directors would rapidly cause the formation of a large connected component and that most female directors are not linked through the director network to other women directors.

Before commencing the analysis it was confirmed that the component distributions when ranked by size did not conform to a normal distribution and were either right tailed distributions or followed a power law distribution (particularly the women-only director networks). This is illustrated with four examples in Appendix One. The results of the comparative analysis are presented in Tables 13 and 14 (pages 160 and 161), and Figure 25 (page 162). The best fitting trend line was a power law both with the largest component included and excluded. The R^2 values were greater than 0.8 and improved further when the largest component was excluded. The R^2 values are a good fit to the mixed gender data. The R^2 values for the trend lines in the women-only networks (especially the NZX data) are less reliable, probably due to the smaller sample sizes.

Similarly, the equations for the linear trend lines from the log-log plot of the component size ranking data also have R^2 values greater than 0.85, indicating a good fit to the data. Again, the reliability declines in the smaller women-only networks. Examination of the slope exponent and intercepts in the linear equations from the mixed gender networks shows marked similarity with limited ranges between networks and over time, in the case of the slope from -0.5 to -0.4 while the intercept ranges from 1.2 to 1.8. These ranges are wider for the female only networks, but do overlap the mixed gender networks.

Examination of Figure 25 showing the plot of the linear equations indicates a very tight clustering of the mixed gender networks, indicating a similar component structure despite being of different sizes. The women-only network values range wider, but overlap with the mixed gender networks, indicating that their structure is also similar to the mixed gender networks. The NZX women-only networks for 2005 and 2007 exhibit the most divergence, but being based on small numbers of directors these lines should be treated with caution.

The evidence provides support for the Glass Network theory proposition that in relation to each other, the ranked size of the unconnected component, both with and without the largest component in mixed gender director networks, is not random or normally distributed, but follows a power law. This suggests that changes in one network component will affect others and induce a re-arranging of the network until the power law pattern prevails again. If a connector director of high degree is, for whatever reason, removed from the network, another connector director will emerge to take his or her place with a subsequent re-arranging of the network components. The NZX dataset contained two examples where the death of high profile director and the collapse of a large manufacturing company impacted the number of seats held by directors of that board in subsequent years. Although this evidence is anecdotal, it suggests an avenue for future research into the waxing and waning of components at one level and specific incidents at the director level. The preference of boards for women directors in times of crisis suggests that gendered component structures may vary in economic downturns.

6.3.1.3 Location of women directors in network components

Where are the women directors in the network components of the mixed gender networks? Are they in the largest connected component or in the unconnected components?

From the results presented in Tables 15 and 16 (p. 163 and 164), the null hypothesis that male and female directors are found in the largest connected component in the same ratio as the total gender ratio for the director network is rejected for the 1999 Fortune US 1000 directors with a x^2 value of 5.9 significant for p<.05 and the 2004 and 2007 Fortune Global 200 directors with x^2 values of 20.4 and 33.7, significant for p<.001. Examination of Table 15 indicates that the ratio of men to women directors in the largest connected components of these two networks is significantly less than the total gender ratio indicating that more women directors are to be found in the largest connected components than in the unconnected components.

The null hypothesis was accepted for the 2004, 2005 and 2007 NZX directors but visual examination reveals a similar trend in these networks. The lack of significant data in the NZX network may be a function of the small size of the network and the contraction of the NZX network in 2007.

These mixed results do support Glass Network hypotheses that women directors will be found in the largest connected component of the network but network size and the possibility of effective affirmative action enhancing this tendency must also be considered as explanations for the obtained results.

6.3.2 Seat spreads

In the largest connected component of the mixed gender director networks, who are the connector directors, that is directors with more than one seat, and what is their gender? Does the spread of seats held by connector directors to single seat directors follow a specific pattern? Do they conform to the expected seat spreads derived from a generating function?

The spread of directors and seats of connector directors to single seat directors by gender was calculated and the results presented in tabular form for all directors as well as the largest connected component in Appendix Two. In all cases, including by gender, the seat spreads follow the pattern predicted by Glass Network theory following the underlying power law. Most directors have one seat, with connector directors having decreasing numbers of multiple seats.

6.3.2.1 Seat spreads from a non-symmetrical generating function

The expected seat spreads by gender for all the networks, using the generating function with a parameter of 2 are presented in Appendix Five. The transformed logarithmically transformed plots of these seat spreads are presented in Appendix Six. From the log-log plots in Figures 28 (page 168), 29 and 30 (page 169), it can be seen that the total expected network plot followed closely that of the actual male plot, given that in most networks male directors constitute approximately 90% of directors. Connector directors with two or three seats conformed remarkably well to the predicted pattern, although in general there are more connector directors with two seats than predicted.

Variation from the predicted seats emerged in the tail of the distribution, with fewer connector directors at higher levels than expected. The plot of the 2007 and 2004 Fortune Global 200 directors showed the greatest variability from the expected values and the NZX networks the least. This is supported by the results from the chi-squared analysis presented in Table 18 (page 170). The NZX seat spread analysis showed no significant differences between the total expected and actual seat distributions, whereas the 1999 Fortune US 1000 and the Fortune Global 200 networks were significant at $p < .001$. Further analysis of these networks by gender found significant differences in the male expected to actual results, but not for female directors.

As the gender breakdown followed the same ratios as the actual seat spread for each seat category, the male and female director curves can be expected to be very similar to the actual curves. If there is variability in the total actual to total expected numbers of seats in a category then the male and female curves can be expected to diverge, as seen most clearly in the 2007 and 2004 Fortune Global 200 plots. Supporting other findings that women connector directors with two or more seats are preferred in the US and global networks, this category has more women directors than expected. This is also true for women connector directors with three or more seats in the US Fortune 1000 network, but in the four plus seat categories the actual numbers of women directors are fewer than expected. The expected seat spread for women directors of the NZX networks follows the actual figures closely, although these numbers are relatively small.

The close convergence of actual and expected seats in all networks in this analysis supports the Glass Network hypothesis that the theoretical non-symmetrical bifurcation process is a good fit for the observed seat spreads and resulting power law pattern to the distribution. The NXZ networks closely follow this pattern whereas the US and global male director networks may be responding to affirmative action and the logistics of an international career requiring extensive travel. Pressures for governance improvement may also be reflected in the trends for US connector directors as well as directors of global companies to reduce the numbers of board seats they hold.

6.3.2.2 Seat spreads analysed using the comparative methodology

The summary seat spread results for the largest connected component of each director network are presented in Table 17 (page 165). This gives the number of male and female seats and for each gender the percentage connector directors to total directors, the derived linear equations and associated R^2 from the log-log plot of the male and female directors' spread of seats. The plotted linear equations are presented in Figure 26 (page 166) for males and females, while Figure 27 (page 167) shows how the female directors' trend lines span the predictive range. The 1999 Fortune US 1000 trend line sets the upper boundary, closely paralleled by the Fortune Global 200 networks with the NZX trend lines showing more variability in slope. This may reflect the smaller numbers in the NZX network, with the contracting 2007 network being the most divergent.

From Table 17 it can be seen that the percentage of connector director seats to total seats by gender are remarkably similar and only vary between genders by less than 10%. Inspection of Table 17 shows that overall there is a higher percentage of female connector directors to total directors except for the NZX in 2005 and 2007, where this trend reversed as the director network contracted.

This similarity is further evident if the linear equation slope exponents and intercepts are examined. The slope value ranges for male directors from -1.9 to -3.0 and for female directors from -1.4 to -2.9, while the intercepts range from 2.5 to 4.1 for males and 1.4 to 2.8 for females. The R^2 values range from 0.85 to 0.99 indicating an excellent fit to the linear trend line. The results by gender thus overlap and the tight clustering is clear if Figures 26 and 27 are examined.

These results support the Glass Network proposition that the seat spreads of single seat and connector directors follow a power law pattern across networks that is constant over time and similar by gender. While most male and female directors only ever have one board appointment, connector directors are appointed to multiple boards in proportion to the power law prevailing in their network. The number of connector director seats can be predicted and from the gender perspective is proportional to the total gender ratio in the director network concerned.

6.3.2.3 Preference for female connector directors

Are female directors with more than one seat, (namely connector directors), being appointed to more boards than their equivalent male connector directors in the largest connected components of the mixed gender networks?

The summary results from the chi-squared analysis are presented in Table 19 (page 172) based on the seat spreads in Appendix Two. The null hypothesis is that *the ratio of male to female connector directors' seats in the largest connected components of the mixed gender networks is equal to the total ratio of male to female director seats*. This is rejected for the 1999 Fortune US 1000 directors. This has a x^2 value of 23.6 significant for p<.001 with Yates correction and one degree of freedom. However, the null hypothesis was accepted for the Fortune Global 200 and NZX director networks. This indicates that as early as 1999 US female directors with two or more seats in the largest connected component of the Fortune 1000 director network were preferred over male directors for additional board appointments. This was not a significant trend in the global director network or the smaller network of New Zealand.

As significant data was found in the largest connected component this analysis was repeated for the total network, which included the directors in the unconnected components, in order to determine if this pattern applied to the networks as a whole.
The summary results of the chi-square analysis are presented in Table 13 (page 160) based on the director seat spread in Appendix Two. The null hypothesis is that *the ratio male to female connector directors' seats in the total mixed gender networks is equal to the total ratio of male to female director seats.* This is rejected for the 1999 Fortune US 1000 directors with a x^2 value of 34.3 significant for p<.001 and the 2007 Fortune Global 200 network with a x^2 value of 8.5 for p<.01 with Yates correction and two degrees of freedom. It was accepted for the 2004 Fortune Global 200 and NZX director networks.

These findings support early evidence that female connector directors with two or more seats are being preferred for board appointments in the Fortune US 1000 companies. This preference is a possible emerging trend in the Fortune Global 200, but it is absent in the NZX networks. This is not a significant trend in the New Zealand director networks, indicating that diversity interventions are not having an impact on New Zealand listed companies.

The results support Glass Network theory by showing that a preference for women directors with two or more seats is emerging in some director networks. This trend is shown in both the largest connected component as well as the network as a whole. This trend may indicate a response to diversity interventions where the director networks are responding by appointing more women directors but prefer to appoint the known women directors already above the initial glass net, that is, already have a seat on a substantial board.

6.3.3 Social network analysis of the largest components

6.3.3.1 Social network analysis of mixed gender networks

What is the social network structure of the largest component of the mixed gender director networks in terms of the density, reach, clustering coefficient, degree, geodesic distance and subsidiary measures derived from these calculations?

In terms of the density of the network, very low levels are reported, with the smaller networks being denser than the larger networks. The NZX network average density is 0.014, the Fortune Global 200 is 0.01 with the 1999 Fortune US 1000 at 0.002. These are similar to the company-company levels reported by Kogut and Walker (2001), who were surprised by how few ties were required to generate a network structure. The paradox of the small-world is confirmed here at the director-director level that a network “presents far more order and stability than that suggested intuitively by network sparseness” (Kogut & Walker, 2001, p.318).

Reach, or the average number of nodes each node can reach in *k* or less steps, is presented for director-director networks for the first time. Reach is a function of the network size with the smaller networks limited in their reach. However, the normalised reach scores present a remarkable uniformity across the three director networks. With the raw scores in parentheses, the normalised reach was 0.23 (1564.5) in the 1999 Fortune US 1000 network, an average of 0.22 (334.3) in the Fortune Global 200 network and an average of 0.27(134.1) in the NZX director network. This result provides support for the self-similarity of director networks across different scales, and is consistent over time.

The clustering coefficients for the three networks were, as expected from the literature, over 0.8, confirming the high level of correlation that is inherent in director networks (Newman, 2001; Watts, 2003). In the 1999 Fortune US 1000 network the clustering coefficient was 0.87, an average of 0.93 in the Fortune Global 200 networks and an average of 0.89 in the NZX director networks. The clustering coefficient for the 2004 NZX network is different to that computed for the same data by Stablein et al. (2005) who found a clustering coefficient of 0.95, which supports the suggestion that their data was not dichotomised. The clustering coefficient data is also remarkably similar across the three networks, lending support for self-similarity at different scales and consistent over time.

The mean geodesic distance or measure of the shortest distance between nodes is the average number of edges that must be traversed in the shortest path connecting any two nodes. In the 1999 Fortune US 1000 network the mean geodesic distance is 4.59, an average of 5.55 in the Fortune Global 200 networks and an average of 5.45 in the NZX director networks. Some variability is reflected in 1999 Fortune US 1000 when compared to the historical results. Battiston and Catanzaro (2004) reported a geodesic distance of 3.7, whereas Davis et al. (2003) reported an average of 4.33 for the same data. Although not large, this variability may be the result of scrubbing stringency in the dataset. In this thesis a conservative approach was followed where uncertain director data was retained rather than dropped or ambiguous names were retained as separate individuals. The effect is to dilute the network links and the geodesic measure does appear to be sensitive to this. The geodesic distance calculated for the 2004 NZX (5.13) is similar to the result of 5.04 by Stablein et al. (2005).

Analysis of the degree or the number of edges or links into a node finds a mean degree of 15.12 for the 1999 Fortune US 1000 network, an average degree of 16.18 in the Fortune Global 200 network and an average of 8.11 in the NZX director network. Examining the normalised degree results of 0.23 for the 1999 Fortune US 1000 network, an average normalised degree of 1.0 in the Fortune Global 200 network and 1.42 in the NZX director networks, mild divergence is shown in the networks that follows the density results. The degree of the 1999 Fortune US 1000 network is the highest, but it is the largest network with the lowest density; the Fortune Global 200 network is also less dense with larger boards, while the NZX network is the smallest, but most dense and has more links between directors. These results are more conservative than Davis et al. (2003), who found a degree of 16.0 for the 1999 data and an average degree of 17.3 for the continuing directors present in 1982 and 1999. Conversely the degree result of 8.56 from the 2004 NZX dataset is higher than that of 7.61 reported by Stablein et al. (2005).

The minimum and maximum degree figures were included to illustrate the wide range of degree in the networks with the 1999 Fortune US 1000 and Fortune Global 200 directors having two thirds more links to other directors than the NZX directors. These partly reflect the varying board sizes in the network, but as the reach results suggest, this does not imply that the US and global networks are more influential. Within their local network the ability to contact other directors through links created by serving on multiple boards is the same at all scales of the director network.

These results support earlier director network analyses and extend social network analysis into global director networks and an additional national network, namely the New Zealand director network.

6.3.3.2 Social network analysis of women-only networks

What is the structure of the largest component of the female director networks, providing there are sufficient women directors to form a large component? Do they differ from mixed gender director networks in terms of the density, reach, clustering coefficient, degree, geodesic distance, degree, and subsidiary measures derived from these calculations?

This is a qualified question reflecting the emergence of the first women-to-women director networks and can only be answered if there are enough connector women sitting on boards together to form such a network. Only the 1999 Fortune US 1000 network of 659 women with 88 women directors in the largest component, and the 2007 Fortune Global 200 with 286 women of whom 15 formed the largest connected component, could be analysed. Figures 31 and 32 (pages 177 and 178) display these two networks and the trophy connector directors are very obvious. In these linchpin roles are three women in the 1999 Fortune US 1000 and one in the 2007 Fortune Global 200. However, over 85% of the women were in unconnected components, indicating that most women directors never meet another woman around the boardroom table.

Table 21 (page 175) gives the results from the social network analysis. The women-only networks have a slightly higher density than the mixed gender networks at 0.03 in the 1999 Fortune US 1000 and 0.26 in the 2007 Fortune Global 200, while the network reach of 18.88 and 8.54 are considerably lower than those of the mixed gender networks. The normalized reach of the 1999 Fortune US 1000 at 0.21 is similar to the mixed gender networks. An anomalous normalized reach of 0.57 for the 2007 Fortune Global 200 reflects the small sample in this component of the network.

The clustering coefficient at 0.5 in the 1999 Fortune US 1000 and 0.81 in the 2007 Fortune Global 200 women-only network reflects the scarcity of women co-directors. The mean geodesic distance of 7.01 in the 1999 Fortune US 1000 and 2.51 in the 2007 Fortune Global 200 women-only network represent extreme values when contrasted to the mixed gender networks. The low degree of 2.73 in the 1999 Fortune US 1000 and 3.6 in the 2007 Fortune Global 200 women-only network, with normalized values of 3.14 and 25.2 respectively, similarly reflects the limited links between women directors. Women directors in the largest connected components are within a few handshakes of each other, and contactable should they wish to make this effort.

Overall, the women-only director network measures represent the early stages of network formation. Even at this early stage the values tend to be close to those of the mixed gender networks. These findings support Glass Network theory that female-only director networks do not differ from male director networks except in size.

6.3.4 Small-world Networks

6.3.4.1 Mixed gender small-world networks

Are mixed gender director networks small-worlds at a global and national level?

Small-worlds, as described by Watts and Strogatz (1998), are characterised by a low average geodesic distance and a high clustering coefficient. Characteristically, the degree or number of interlocks or links to a director, is low. The Small-world Quotient (SWQ) combines these elements into a null model that takes the size of the network into account, in determining whether the network described meets these criteria. A value greater than one indicates that the network is a small-world.

As Table 20 (page 174) indicates, in all cases in the mixed gender networks, the SWQ was higher than 1 and all networks are thus self evidently small-worlds. The 1999 Fortune US 1000 network had a small-world quotient of 271.66 in contrast to Davis et al. (2003) who reported a value of 183.03 for the same data. The Fortune Global 200 had an average SWQ of 43.5 and in the NZX networks the average was 36.3

These result duplicate earlier director network analyses and confirm that global director networks are also small-worlds.

6.3.4.2 Women-only small-world networks

Are women-only networks small-worlds at a global and national level, providing there are sufficient female directors to form the women-to-women networks?

As Table 21 (page 175) indicates, for both the women-only networks, the small-world quotient was higher than 1 and both networks are also small-worlds. The 1999 Fortune US 1000 women-only network had a small-world quotient of 10.29 while the 2007 Fortune Global 200 women-only network had a much lower SWQ of 2.84. This indicates that women-only director networks show the same pattern of high clustering and short path lengths between nodes as the mixed gender networks. The smaller absolute values reflect the smaller network sizes.

These findings support Glass Network theory that female-only director networks are also small-worlds.

6.3.5 Assortative mixing

6.3.5.1 Assortative mixing in mixed gender networks

Do mixed gender director networks show positive assortative mixing or assortativity?

As Table 22 (page 176) indicates, the largest component of all the director networks is positively assortative with the 2007 NZX the highest at 0.399, with an average for the NZX of 0.284. The 1999 Fortune US 1000 assortativity is 0.238, which corresponds well to the 0.276 reported by Newman (2002). The Fortune Global 200 reported an average assortativity of 0.157, the lowest for the networks. In all networks the Quadratic Assignment Procedure (QAP) found strongly that the observed assortativity was significantly less than the expected assortativity with p <= to 1. This result indicates a strong preference in director networks for directors of similar degree around the boardroom table.

These result duplicate earlier research in the US Fortune 1000 network and confirm that global and other national director networks are positively assortative with directors preferring to sit on boards with other directors of similar degree.

6.3.5.2 Assortative mixing in women-only networks

Do female director only networks show positive assortative mixing or assortativity?

As Table 23 (page 177) indicates, only the largest component of the 1999 Fortune US 1000 female only network is positively assortative, with a slightly higher assortativity of 0.276, identical to Newman's (2002) results. The Quadratic Assignment Procedure (QAP) found a weaker significant probability of $p <= 0.61$. Inspection of the network plot in Figure 31 (page 177) of the 1999 Fortune US 1000 women-only largest component shows clearly that the nine women connector directors with degrees of 7 and 8 link to each other and create this component.

An insignificant negative assortativity of -0.126 was found for the largest connected component of the Fortune Global 200 women-only network. This result may reflect the small number of 15 women directors in this group, as seen in the network plot in Figure 32 (page 178) compared to the second largest component of 11 women directors of the same network in Figure 33 (page 178). One linking directorship to a woman director in each component would create a comparable large component to the 1999 Fortune US 1000 women-only network.

This result, as predicted by Glass Network theory, indicates a preference in US women-only director networks for women directors of similar degree around the boardroom table. The smaller numbers in the Fortune Global 200 women-only network explains the lack of supporting results in this network.

6.3.6 Degree Analysis

6.3.6.1 Degree analysis in mixed gender networks

Does the distribution of the degree or number of links between a director and adjacent directors in the largest component of the mixed gender networks follow a specific pattern?

The results for mean degree of the largest connected components of the mixed gender director networks are presented in Table 20 (page 174). With normalised degree in parentheses, these range from 15.12 (0.23) in the 1999 Fortune US 1000 network, an average of 16.17 (1.0) in the Fortune Global 200 network and 8.1 (1.4) in the NZX network.

Following the comparative methodology, Table 24 (page 180) gives the derived linear equations and associated R^2 from the log-log plot of the male and female directors' degree. The plotted linear equations are presented for the male directors in Figure 34 and the female directors in Figure 35.

Examining the linear equation slope exponents and intercepts in Table 24, the slope value ranges for male directors from -0.32 to -0.53 and for female directors from -0.316 to -0.55, very similar ranges. The intercepts range from 1.9 to 2.7 for males and 1.39 to 2.42 for females, with the female range overlapping the male range but shifted down in value, a pattern also observed with other measure such as betweenness. The R^2 values range from 0.95 to 0.98 for males, indicating an excellent fit to the linear trend line. The female results are less reliable ranging from an R^2 value of 0.79 to 0.94, but still represent a reasonable fit to the data. The results by gender thus overlap and the tight clustering is clear if Figures 34 and 35 (pages 181 and 182) are examined. Within the high and low ranges of the predictive equations, the male values cluster at the top of the range with the women's values more widely spread across the range. The 1999 Fortune US 1000 trend line sets the upper boundary, with more variability in the slope of the Fortune Global 200 networks with the NZX trend lines closely parallel.

These results support the Glass Network proposition that the degree of directors follows the known power law pattern across networks that is constant over time and similar by gender.

6.3.6.2 Degree analysis in women-only networks

Does the distribution of the degree or number of links between a director and adjacent directors, in the largest component of women-only director networks follow a specific pattern?

The results for mean degree of the largest connected component of the two women-only director networks are presented in Table 21 (page 175). With normalised degree in parentheses, these range from 2.73 (3.14) in the 1999 Fortune US 1000 network of 88 women directors and an average of 3.60 (25.2) in the Fortune Global 200 network of 15 women directors.

Following the comparative methodology, Table 25 (page 180) gives the derived linear equations and associated R^2 from the log-log plot of the male and female directors' degree. The plotted linear equations are included with the female directors in mixed gender networks in Figure 35 (page 182).

Examining the linear equation slope exponents and intercepts in Table 25, the slope values are -0.612 (1999 Fortune US 1000) and -0.463 (2007 Fortune Global 200), very similar to the mixed gender ranges. The intercepts range from 1.286 (1999 Fortune US 1000) and 0.892 (2007 Fortune Global 200), lower than the mixed gender female ranges, but still within the ranges derived from the predictive equations. The R^2 values are 0.8 in both women-only networks, indicating a good fit to the linear trend lines.

Within the high and low ranges of the predictive equations, the values from the women-only networks cluster at the bottom of the range with the 1999 Fortune US 1000 trend line overlapping the NZX female trend lines.

These results support the Glass Network proposition that the degree of directors in women-only networks follows the known power law pattern across networks, although the small size of these networks, particularly the 2007 Fortune Global 200 largest component of 15 women means that these results must be treated with caution.

6.3.7 Betweenness Analysis

6.3.7.1 Betweenness in mixed gender networks

On the Freeman betweenness measure (the number of times a director is found on a geodesic path between two other directors), what percentage of male and female directors in the mixed gender networks have a betweenness score of greater than zero and are these in a specific proportion to male and female directors respectively who have a zero betweenness score?

Does the distribution of betweenness scores in the largest component of the mixed gender networks follow a specific pattern, namely a power law?

Inspection of the mean raw scores (normalised scores in parentheses) of the Freeman betweenness measure for the largest connected component of the mixed gender networks presented in Table 26 (page 184) indicates that these reflect the network size, with larger networks having larger values. The normalised scores do not confirm this relationship with the NZX networks having the highest scores indicating a more closely linked network with higher percentages of connector directors, as shown in Table 10 (page 157).

The percentages of directors with betweenness scores greater than zero, in relation to directors of the same gender with a betweenness score of zero are presented in Table 27 (page 185), where the 1999 Fortune US 1000, the 2007 Fortune Global 200 and the 2004 NZX women have a higher percentage of directors with betweenness scores relative to their gender than male directors. The percentages differ at most by 6.6% in the 1999 Fortune US 1000 with the lowest difference in the 2007 Fortune Global 200 of 1.2%.

Table 27 also presents the chi-squared results of the testing of the null hypothesis that, *there is no difference between the proportion of female directors with betweenness scores of greater than zero compared to the male directors with a betweenness scores of greater than zero, in the largest connected component of the mixed gender director networks.* The null hypothesis is accepted for all the networks except for the 1999 Fortune US 1000 with a x^2 value of 12.74, significant at $p<.001$ with Yates correction and one degree of freedom.

These results support Glass Network theory's prediction of self-similarity, which proposes that gender ratios between connector directors and single seat directors in the largest connected component will be similar. Female directors with betweenness scores greater than zero will not differ from the total ratio of male to female directors in the largest connected component as a whole. These results also show that connector women directors have a higher betweenness percentage in relation to single seat directors in the 1999 Fortune US 1000 mixed gender network. Both results support the Glass Network proposition that women connector directors already through the glass net will be preferred over single seat directors where there is pressure to appoint more women to boards of directors.

Following the comparative methodology, Table 30 (page 187) gives the derived linear equations and associated R^2 from the log-log plot of the male and female directors' betweenness. The plotted linear equations are presented for the male directors in Figure 36 (page 188) and the female directors in Figure 37 (page 189), with ranges of predictive equations in red.

Examining the linear equation slope exponents and intercepts in Table 30, the slope values for male directors (-0.83 to -1.09) and female directors (-0.84 to -2.12) exhibit very similar ranges. The intercepts range from 5.1 to 6.7 for males and 4.2 to 6.1 for females, with the female range being wider. The R^2 values range from 0.67 to 0.84 for males with a wider range for females from 0.65 to 0.99. The R^2 values by gender within a dataset tend to be close in value. For example, the R^2 value for the 2007 Fortune Global 200 dataset is 0.67 for male directors and 0.65 for females. The male results indicate a tight clustering of trend lines in the middle of the predictive range in Figure 36 with much great variability in the female trend lines in Figures 37.

The 2007 NZX female betweenness is highly anomalous and falls outside the predictive ranges. As only five women directors in this network have a betweenness score greater than zero these results must be treated with caution. There were ten women in the 2004 and 2005 NZX data. They are included to show how sensitive a measure of connector director numbers and links to other directors this measure can be when compared to other networks and time frames.

6.3.7.2 Betweenness in women-only networks

Does the distribution of the betweenness scores in the largest component of the women-only director networks follow a specific pattern?

Only the 1999 Fortune US 1000 women-only network has sufficient numbers of women directors in the largest connected component with a betweenness score greater than zero to permit a comparative analysis. As indicated in Table 25 (page 180), this percentage was very high: 47.4% for the 1999 Fortune US 1000 female directors compared to 26.6% in the 2007 Fortune Global 200 women-only network. As the Fortune Global 200 network only has four women directors with a betweenness score greater than zero these results must be treated with caution.

Following the comparative methodology, Table 31 (page 187) gives the derived linear equations and associated R^2 from the log-log plot female directors' betweenness. The plotted linear equations, with ranges of predictive equations in red, are included in Figure 37 (page 189).

Examining the linear equation slope exponents and intercepts in Table 30 (page 187), the slope values are -1.23 for the 1999 Fortune US 1000 and -0.64 for the 2007 Fortune Global 200 women directors. The intercepts are 3.97 for the 1999 Fortune US 1000 and 1.79 for the 2007 Fortune Global 200 women directors. The R^2 values range from 0.84 to .97 indicating an excellent fit to the linear trend line.

In Figure 37 (page 189) the 1999 Fortune US 1000 women-only trend line falls within the predictive equation lower range, while the 2007 Fortune Global women-only trend line falls well out of the range, mirroring the mixed gender data.

This further highlights the necessity to treat the betweenness results of the 2007 Fortune Global 200 with caution due to the small number of women with a betweenness greater than zero. Where there are sufficient numbers of directors Glass Network theory is supported.

6.3.7.3 Top Fifteen directors and their gender

Who are the top fifteen directors by betweenness in the 2004 and 2007 Fortune Global 200 and the 2004, 2005 and 2007 NZX networks and what is their gender?

Table 32 (page 190) indicates that in the 2004 and 2007 Fortune Global 200 network four men and only one woman appeared in the Top Fifteen in both years. In 2004 two women ranked 12th and 14th respectively. The woman at rank 12, Lynn Martin, moved to rank 7 in 2007. Table 33 (page 191) shows that no director appeared three times in the NZX Top Fifteen, but five male directors and one woman appeared twice. In 2004 three women appeared ranked at 6th, 7th and 13th. One in 2005 was ranked at 5 and another in 2007 was ranked at 7. The volatile nature of this ranking reflects the high turnover in directors in both networks, but it is notable that, despite the small percentages of women in the networks, they do rank in the Top Fifteen on betweenness, roughly in proportion to the general female percentages in the network.

This finding supports Glass Network theory that director networks are self-similar with gender proportions stable and constant over time.

6.3.8 Testing Glass Network theory against longitudinal and random networks

6.3.8.1 Network description and component analysis of longitudinal and random networks

Of the two networks tracked over three years, the turnover of directors was noteworthy. Table 34 (page 192) shows that on average 45% of the Fortune Global 200 and 49% of the NZX directors had been replaced. In the Fortune Global 200 network, the continuing male turnover was 10% higher than the female director turnover with only 54% of male directors continuing compared to 64% of women directors retaining their seats. It was the reverse in the NZX network with an average of 52% of male directors continuing but only 41% of the women directors continuing. These trends are also reflected in the gender ratios. In the Fortune Global 200 network the percentage of continuing female directors increased marginally from 10% to 12.2%. In the NZX network the percentage of women directors declined marginally from an average of 6.7% to 5.3%.

In the component analysis presented in Table 35 (page 193) for the continuing directors it can be seen that the number of components that the network broke into did not differ materially for the Fortune Global 200 network, with an average of 69 components compared to 61 in the full network. The NZX continuing director networks broke into fewer components, that is, an average of 48 compared to 58 in the full network. In contrast, as Table 36 (page 193) illustrates, the random networks showed much greater fragmentation of the networks, with the Fortune Global 200 and NZX halves having on average 106 and 110 components respectively. The Fortune Global 200 thirds were the most fractured, with an average of 131 components reflecting the reduced links between randomly allocated directors to each segment.

The percentage of directors in the largest component did not differ materially between the full and continuing director networks, both in the Fortune Global 200 and the NZX networks, at an average 61% and 62% respectively.

In the continuing director networks Glass Network theory predicts that more women will be found in the largest connected component than the unconnected components in mixed gender networks. From the chi-squared results given in Tables 37 and 38 (page 194) the null hypothesis that male and female directors are found in the largest connected component in the same ratio as the total gender ratio for the director network, was similarly rejected for the 2004 and 2007 Fortune Global 200 directors with x^2 values of 9.4 with p <.01 and 17.2 with p <.001. It was also rejected for the 2004 NZX network with a x^2 values of 6.0 with p <.05, but accepted for the 2007 NZX network of continuing directors. In the full NZX networks none of the gender differences in the large components were significant. The lack of significant data in the 2007 NZX continuing director network may also be a function of the small size of the network and the contraction of the NZX network in this year.

The examination of the unconnected components of the 2004 and 2007 Fortune Global 200 and NZX continuing directors' networks and the random 2007 Fortune Global 200 thirds and halves networks and the 2007 NZX halves networks followed the same methodology as the full and female only networks and produced very similar results. Figure 38 (page 195) gives the component plot with the continuing directors' trend lines against the random directors' trend lines. These all fall into a tight cluster within the predictive high and low ranges. The NZX networks for 2005 and 2007, which exhibit more divergence in the full network, do not show this pattern with the continuing directors, nor do the random networks.

This evidence provides support for the Glass Network theory proposition that in relation to each other, the ranked size of the unconnected components (excluding the largest component) in continuing director networks follows a logarithmic or power law pattern.

The results with the unconnected components of the random networks appear contradictory in that they conform tightly to the observed pattern by falling within the predicted ranges, rather than displaying more variability. Albeit only a small number of random networks were considered, this is indicative of an underlying self-similarity that is not destroyed if the directors are randomly assigned to smaller segments, supporting Glass Network theory propositions.

6.3.8.2 Seat spreads of longitudinal and random networks

The spread of seats for the continuing directors as well as the directors randomly allocated to network segments is presented in Appendix Two. In all cases, including by gender, the seat spreads follow the pattern predicted by Glass Network theory following the underlying power law. Most directors have one seat, with connector directors having decreasing numbers of multiple seats.

6.3.8.2.1 Generated seat spreads in longitudinal and random networks

The results from the analysis of the expected seat spreads by gender for the 2004 and 2007 Fortune Global 200 and NZX continuing directors are presented in Appendix Five. The NZX continuing directors showed the best conformance to the theoretical non-symmetrical model, as shown in Figure 42 (page 202). This is supported by the lack of significant findings for NZX networks in the chi squared analysis reported in Table 40 (page 200).

The 2004 and 2007 Fortune Global 200 continuing director plot in Figure 41 shows greater variability and the same 'braided' pattern, with more directors with two or three seats and fewer directors than predicted with four plus seats. This is supported by the chi squared analysis reported in Table 40, where significant differences ($p < .001$) are reported for both 2004 and 2007 for the continuing Fortune Global 200 directors. Gender analysis found similar results, with only male directors showing significantly different actual to expected values. Female continuing directors seat spreads for both 2004 and 2007 followed the theoretical model closely.

The random seat spreads for the continuing directors is a further illustration of the problems associated with generating comparable random networks, particularly if self-similarity is thought to be characteristic of director networks. Firstly, random allocation of directors to smaller network segments results in varying sizes of the largest connected components depending on where the random allocation process places the connector directors, as shown in Table 36 (page 193). In the random halves of the NZX networks the largest connected components were of a similar size, 45 and 57 directors respectively, indicating that the random distribution of connector directors was relatively even. In the Fortune Global 200 network the largest connected component of the 1st half consisted of 295 directors and the second half 597 directors. This directly affects the seat spread and the derived measures such as degree and betweenness.

As Figure 44 (page 203) shows the actual seat spreads of the random first and second halves of the 2004 and 2007 NZX networks closely follow the expected seat spreads generated by the non-symmetrical bifurcation process. This is supported by the non-significant results reported from the chi squared analysis in Table 38 (page 197).

Similar to the full 2004 and 2007 Fortune Global 200 networks the random network seat spreads in Figure 43 (page 203) show greater variability and the braiding pattern. Even though one half is much larger than the other, the patterns are constant. This is supported by the significant results reported from the chi squared analysis in Table 38.

What is problematic is that this dataset at the outset showed greater variability and the random allocation of directors to each half could be expected to result in greater variability. The significant results merely indicate that there is a difference between the expected and actual values, but do not give an estimate of how big the difference is. The fact that the NZX random halves did not show any significant differences despite the random allocation of the directors to each half supports the Glass Network theory hypothesis that networks, even when randomised in this fashion, do show self-similarity in the smaller segments.

These results from the continuing director networks support the earlier conclusion that the close convergence of actual and expected seats in the networks supports the Glass Network hypothesis that the theoretical non-symmetrical bifurcation process is a good fit for the observed seat spreads and resulting power law pattern to the distribution. Similarly female director results follow the theoretical distribution more closely than male directors. The results from the randomised halves of these networks tend to favour the Glass Network hypothesis that even randomised network segments will show self-similarity.

6.3.8.2.2 Seat spreads analysed using the comparative methodology in longitudinal and random networks

The summary seat spread results for the largest connected component of each director network are presented in Table 39 (page 197) giving the number of male and female seats and for each gender the percentage of connector directors to total directors, the derived linear equations and associated R^2 from the log-log plot of the male and female directors' spread of seats. From Table 39 in the continuing director networks it can be seen that the percentage connector director seats to total seats by gender are remarkably similar and only vary between genders by less than 10%, in a similar manner to the full networks. The pattern observed in Table 17 (page 165), that overall there is a higher percentage of female connector directors to total directors continues, except for the 2004 Fortune Global 200 directors.

The linear equations derived from the seat spread log-log plots are presented in Table 39 and Figure 39, with the same predicted range. These show that the 2004 and 2007 Fortune Global 200 male continuing director and the female 2004 Fortune Global 200 networks fall well within the ranges. The 2007 female Fortune Global 200 trend line, along with the NZX male trend lines, show greater divergence, only partially falling in the predicted ranges. The NZX females do not conform in either year. This may reflect the smaller numbers in the NZX network with the contracting 2007 NZX female network being the most divergent.

The trend line plots for the random director networks presented in Figure 40 (page 199) shows that the random Fortune Global 200 1st and 2nd halves fall clearly within the predicted seat spread ranges. The smaller Fortune Global 200 random thirds show more variability falling partially within the range while the NZX random halves show the most variability. Again, this may be reflecting the smaller size of the NZX network, but these results are not as divergent as the NZX continuing women directors in Figure 39, despite directors being randomly allocated to each half.

These results support the Glass Network proposition that the seat spreads of single seat and connector directors follow a power law pattern across networks that is constant over time and similar by gender. Random networks reflect the underlying self-similarity by not diverging widely from the predicted ranges and the trend lines are comparable to the actual data.

6.3.8.2.3 Female connector directors as preferred directors

From the summary results from the chi-squared analysis presented in Table 19 (as shown on page 172 and based on the seat spreads in Appendix Two), the null hypothesis that the ratio of male to female continuing connector directors' seats in the largest connected components of the mixed gender networks is equal to the total ratio of male to female continuing director seats is accepted for the Fortune Global 200 and NZX continuing director networks. There is no evidence in these networks that long term women directors are favoured for additional board seats in these networks. As no additional data was available for the Fortune US 1000 networks the extent of this trend in that network could not be assessed.

These results do not support the Glass Network hypothesis that known women directors already above the glass net are preferred, particularly in environments where there are governance or affirmative action initiatives. Continuing directors who have a known track record or seniority would be expected to benefit from preferential attachment tempered by assortativity over single seat directors, but only to the extent the power law driving the seat distribution permits. The significant results for the 2007 Fortune Global 200 network in Table 19 may be an artefact of the data or this network responding to affirmative action with single seat directors gaining additional board appointments with continuing women directors being overlooked. With the current research design this issue cannot be resolved.

6.3.8.3 Assortative mixing in longitudinal and random networks

As Table 43 (page 206) indicates, the largest component of the continuing director networks is positively assortative with the 2007 Fortune Global 200 the highest at average 0.269, with an average for the NZX of 0.222. In all networks the Quadratic

Assignment Procedure (QAP) strongly found that the observed assortativity was significantly less than the expected assortativity with a p <= to 1.

This result supports Glass Network theory that there is a strong preference in director networks for continuing directors of similar degree around the boardroom table.

6.3.8.4 Degree analysis in longitudinal and random networks

The results for the mean degree of the 2004 and 2007 Fortune Global 200 and NZX directors continuing directors and the random director networks are presented in Tables 41 and 42 (pages 204 and 205). With normalised degree in parentheses, these, as expected, are less than the full networks and range from an average 10.9 (1.3) for the Fortune Global 200 continuing directors and 5.7 (2.0) for the NZX continuing directors. The random datasets show similar, but slightly more variable, results.

Following the comparative analysis methodology, Table 34 (page 192) presents the summary results for the 2004 and 2007 Fortune Global 200 and the NZX continuing directors with the log-log plot of the trend lines for male and female continuing directors in Figure 45 (page 209) and the 2007 Fortune Global 200 NZX random network in Figure 46 (page 210). All the continuing director networks and the random director networks fall comfortably within the red lines of the predictive ranges even though it could be expected for the degree of random halves and third networks would show greater variability.

These results support the Glass Network proposition that the degree of directors follows the known power law pattern across networks that is constant over time and similar by gender.

The Wilcoxon matched pairs signed rank test by degree results in Table 45 (page 208) shows that the medians for the matched pairs are identical at 10 for the 2004 and 2007 Fortune Global 200 directors and 5 for the NZX directors. These only varied by one degree when the directors present for only one year were added. A mixed pattern of results emerged from testing of the null hypothesis that that there is no median shift or difference in the median degree values. This was rejected for the Fortune Global 200 matched pairs (z=2.03 with p <.05), but accepted when the directors present for only one year were added in. This was accepted for the NZX matched pairs with a very nearly significant probability of p.056 and rejected for when the directors present at only one point in time were added in (z=5.96 p <.001). The NZX results for degree were very significantly different when the directors who had only been present in the network were added back in, indicating that volatility in degree was from the fluctuating director numbers rather than from a stable continuing core. This was the reverse for the Fortune Global 200 directors.

6.3.8.5 Betweenness analysis longitudinal and random networks

The mean raw and normalised scores of the Freeman betweenness measure for the largest connected component of the 2004 and 2007 Fortune Global 200 and the NZX continuing directors are presented in Table 46 (page 211). The mean raw scores of the Freeman betweenness measure for the largest connected component of the 2007 Fortune Global 200 and NZX random directors' thirds and halves are presented in Table 47 (page 212).

Analysis of these scores, whether in raw or normalised form, shows stability within networks over time. For example, the continuing NZX directors have an average of 674 while the betweenness of the 2007 Fortune Global 200 continuing directors is 2103. The random networks do show more variability, particularly in the random third networks where one third has a low of 45 while the highest has a betweenness value of 240.0.

Complex network theory suggests that mean values are of little value given the disparity in distribution within a network and the low percentages of directors that have a betweenness score, 16% in the Fortune Global 200 and 30% in the NZX networks. This suggests, not unexpectedly, that a national director network is more interlocked than a global director network. However, the gender similarity is intriguing and has not been reported previously.

The percentages of directors with betweenness scores greater than zero, in relation to directors of the same gender with a betweenness score of zero, were calculated for the 2004 and 2007 Fortune Global 200 and the NZX continuing directors and are presented in Table 48 (page 211). These results indicate variability of less than 6% between the sexes, in a manner similar to the full network, with women directors having slightly higher percentages except for the 2004 Fortune Global 200 network. The follow-up chi-squared analysis results presented in Table 49 (page 213), tested the hypothesis that:

There is no difference between the proportion of female directors with betweenness scores of greater than zero compared to the male directors with a betweenness scores of greater than zero, in the largest connected component of the 2004 and 2007 Fortune Global 200 and NZX director networks found no significant differences between the sexes as expected.

This is a persistent longitudinal trend in these networks and indicates that where women directors have betweenness scores and by default are connector directors, they do not differ from their male colleagues. Further investigation is needed to determine whether the result from the Fortune US 1000 directors of a significant difference is an exception or whether American male or female directors do differ in their connectedness.

The comparative analysis methodology offers further insight into this observation, with the summary results in Table 51 (page 216) and the plot of the linear equations for male and female continuing directors in Figure 47 (page 214), and the 2007 Fortune Global 200 and NZX random directors' thirds and halves in Figure 48 (page 215). On betweenness the continuing directors all fell within the red lines of the predictive ranges with the exception of the 2004 NZX females betweenness, which had a different slope although similar intercept with $y = -1.722x + 4.146$ with an R^2 value of 0.935. Examination of the raw scores indicated that this was due to a group of senior women connector directors of whom three appeared in the Betweenness Top Fifteen for 2004, in Table 33 (page 191). By 2005 only one remained and betweenness scores fell back into the range.

Figure 48 depicts the random betweenness scores, all director networks fell within the predictive ranges with the exception of the 2007 NZX random first half. Inspection of the data revealed no distinctive grouping of directors and can be ascribed to the random allocation of that group to the NZX first half, the only clearly definable deviation from the pattern observed with the full network and the other random networks.

The Wilcoxon matched pairs signed rank test by betweenness results in Table 50 (page 215) showed that the medians for the matched pairs were 7826.9 for 2004 and 7968.1 for the 2007 Fortune Global 200 directors, a small difference of 1.8%. The median scores for the NZX director matched pairs were 1488.4 for 2004 and 1265.6 for 2007, a difference of 14.9%. A more consistent pattern of results emerged from testing of the null hypothesis that that there is no median shift or difference in the median betweenness values. This was accepted for both the Fortune Global 200 matched pairs and when the directors present at only one point in time were added in. This was accepted for the NZX matched pairs but rejected when the directors present at only one point in time were added in ($z=2.57$ $p < .01$). These results indicate that both the Fortune Global 200 and the NZX directors are very similar in betweenness over time except when the NZX directors present only once or with a betweenness score greater than zero once were added in, indicating that volatility in betweenness was from the fluctuating director numbers in the NZX rather than from a stable continuing core.

6.4 Relating the results to Glass Network theory

6.4.1 Where are the women directors in director networks?

This research has been able to answer the commencing question on the location and numbers of women directors in director networks. The seat spread analyses in Appendix Two, Tables 2.3 and 2.4 show that most directors only have one seat whether the full network or the largest connected component is being considered. 50-70% of network seats are single seats. Table 2.4 also shows that the percentages of male and female connector directors with two or more seats, in relation to single seat directors, are very similar. This was further established in the director betweenness results in Tables 27, 28 and 29 (pages 185 and 186), which found no significant differences in directors with a betweenness score greater than zero, that is connector directors and those with a zero betweenness score, except for the 1999 Fortune US 1000.

The director turnover rates in the 2004-2007 period were also determined. Turnover of both male and female directors is high at 40 - 60% (Table 26, page 184) indicating that director networks demonstrate a robustness and stability unaffected by a high rate of changing inputs and outputs. The mixed results in Tables 31 (page 187) and 39 (page 197) show that gendered turnover was network related rather than an overall trend, indicating that local factors may play a strong role in the specifics of director turnover. What can be concluded is that men and women resign their directorships in roughly the same proportions in a network and there appears to be no marked pattern to retain one gender over another. The variability does appear to be in the numbers of single seat directors with novice or less well connected directors not having their terms renewed in an economic downturn.

The small numbers of women in director networks suggests a marginal position of little influence, but this research has found the opposite in the two larger networks with non-significant findings for the smaller NZX networks. Women directors are found in significantly more numbers in the largest connected component of a network than in the unconnected components. If better social skills and networking are strengths of women directors then this finding is not surprising. However, other explanations offer themselves. It may be that women are better than men at promoting themselves for board positions, and prefer the less risky positions in more successful companies with bigger boards or are selected by more liberal chairmen in larger companies responding to affirmative action pressures. Company and board size cannot be excluded when considering why more women are found in the largest connected components.

Glass Network theory also suggests that preferential attachment will affect the numbers of women directors in the largest component. A woman director through the glass net and already on a substantial board will be preferred over aspiring women directors. Female connector directors will be preferred over single seat directors, particularly if the pressure for affirmative action is strong. As Table 19 (page 171) indicates, this trend of preferring female connector directors is apparent in the 1999 Fortune US 1000 and the 2007 Fortune Global 200 networks. A higher proportion of female connector directors will be reflected in a growing largest component with a greater percentage of female directors, particularly where women directors are appointed as supernumeraries and token directors.

The largest component varies in size across networks, being the largest in the 1999 Fortune US 1000 dataset (87.7% of the network). This is a well understood phenomenon in natural networks and physical materials and can fluctuate considerably in size, as the NZX data in Table 12 (page 159) shows. Its presence in director networks has not been fully appreciated and its impact on gendered director networks is considered for the first time here. In the small women-only director networks the ,not unexpected, finding of many more unconnected components than in the larger networks reveals very starkly the reality of the professional lives of women directors. Most women directors never serve on boards with other women directors and only have access to each other through the men in their board networks or other organizations.

The need to perform analyses on the largest component is appreciated in the networking literature, but has not been historically appreciated in the director literature as the reworking of the seat spread data from Hillman et al. (2002) in Appendix Four indicates. In this thesis the point has been clearly made by stating where the largest component or all director data is analysed.

The phenomenon of lobby boards where directors sit on multiple boards together, often subsidiaries of larger companies, has recently been recognised (Battiston & Catanzaro, 2004), but is difficult to deal with in director network analysis. In WOB terms the problem is compounded as lobby directors can consist of single gender or mixed gender pairs, triplets etc. This thesis deals with the problem of lobbies by including all listed companies and by dichotomising the link between directors. It is not known how many women directors are lobby directors and the implications of this for their location in director networks and the influence on their careers.

6.4.2 Role and importance of network components

The further analysis of the network components undertaken in this thesis followed a trend observed in the data that the size of the unconnected components was ordered. Regularities in the size of the unconnected components will have a bearing on the development of nested director networks and the extent to which director networks can be scale-free. The unconnected networks exist as networks in their own right and as the comparative methodology revealed in Figure 25 (page 162) exist in a specific pattern in relation to each other, following a power law. This was one of the unexpected findings of the research. This relationship forms an integral part of the discussion presented later, which relates glass networks to other known power laws and accounts for the presence of power laws in director networks.

6.4.3 Role and importance of seat spreads

As the research progressed, the importance of seat spreads in determining director network structures became apparent. Long known in interlock research as channels of communication and influence, their significance for gendered networks had not been appreciated, although usefully reported in a number of censuses. The finding that the seat spreads of women directors followed the same distributions as male directors albeit on a smaller scale (as shown in Figures 26 and 27 on pages 166 and 167), is a critical plank in Glass Network theory. This was supported by the analysis of seat spreads in the historical literature in Table 7 and Figure 21 (pages 125 and 126) even though the connected and unconnected components of networks were mixed together.

The use of generating functions to derive theoretical random models (Conyon & Muldoon, 2008; Newman et al., 2001) had focused on derived measures such as degree and had ignored the implied seat spreads underlying degree calculations. The finding that a theoretical seat spread by gender could be generated that was a good fit to the actual data was one of the important results of this research. Determining that the underlying parameter of the non-symmetrical distribution used in the generating function was equal to two (Tables 4 and 5 on pages 117 and 118) makes this intuitively easy to grasp and to illustrate visually. The characteristic curves presented in Figure 18 (page 121) of the world of perfect diversity or the more realistic world of an 80/20 gender split gives a visual model that can be readily appreciated when gendered networks are matched to it. It is a more sophisticated measure for the tracking of affirmative action interventions than monitoring percentages.

Glass Network theory makes the point that single seat directors and connector directors must be regarded differently and may well show differing behaviour patterns as the queen bee syndrome literature indicates. Glass Network theory stresses that male and female connector directors are likely to show similar behaviour patterns, particularly in relation to competitive and leadership behaviours in the boardroom. A gender neutral 'connector director syndrome' is more appropriate in this context than the derogatory queen bee terminology.

6.4.4 Role and importance of connector directors

Identifying connector directors as those directors with two or more seats in substantive companies gives an objective, gender free and non-emotive way to define and explain the importance of certain directors in director networks. They are critical to the formation of the network and indeed in some analyses the single seat directors can be ignored as irrelevant. The term also avoids elitist notions as conceptualised in the popular themes of old boy networks and queen bees. Glass Network theory has incorporated and expanded these two concepts and accounts for the effects previously attributed to them. Glass Network theory suggests that all networks have a small amount of inbuilt diversity as an adaptive feature and accounts for the presence of some women in director networks even when business norms are severely segregationist, such as those found in Japan (Renshaw, 1999).

Integral to the idea that glass nets exist at multiple levels in director networks is the prediction that a power law drives the number of connector directors at each level. As fewer and fewer connector directors gain additional seats this relationship becomes apparent between connector directors. This process naturally culminates in one or two 'super-trophy' directors (Branson, 2007a) accounting for directors of high degree in a network and right-tailed frequency distributions. The betweenness Top Fifteen director data in Tables 32 and 33 (pages 190 and 191) illustrates the transitory nature of super-trophy status and reflects the high turnover rates in director networks. One conclusion from Glass Network theory is that there will always be connector directors of different degree in the network and the identity and personal characteristics of these directors is irrelevant to the functioning of the network. Random forces are just as likely to elevate a director to a higher level in the seat spread hierarchy as outstanding personal attributes. These random forces are just as likely to elevate women connector directors to super-trophy status as the presence of women directors in the betweenness Top Fifteen indicates.

Those men and women who do become directors of companies of substance are likely to have an enabler, either a personal characteristic or a means of influence that makes them acceptable at specific points in time and under specific circumstances, while equally qualified and experienced colleagues are not. Enablers can be as random as being in the right place at the right time and may require no specific action on the part of the selected person. Enablers may be access to resources and other networks, exceptional or unusual skills, celebrity status, membership of a specific family, political influence or other markers of fitness recognised by a recruiting board (Branson, 2007a).

In other words, the glass network does not differentiate on gender, and probably neither on race or ethnicity once a director is through the first glass net and subject to the selective forces of the connector director power law, if there are no pressures for affirmative action. The reworking of the historical data relating to African American women directors in Appendix Four of the Hillman et al. (2002) seat spread data, shows that African American female directors, although on a smaller scale, are no different to other directors in terms of seat spreads, while the forces of preferential attachment responding to affirmative action pressures favour African American female directors already through the glass net to African American male directors.

6.4.5 Role and importance of small-worlds and assortativity

As the research progressed, the importance of small-worlds in gendered director networks diminished. It was quickly established that all the networks including the women-only directors' networks were small-worlds (Tables 20 and 21 on pages 174 and 175) as were the continuing director networks (Table 41 on page 204). The expected high levels of clustering and short path lengths were also observed in all networks. When the calculations of the small-world quotient in the random networks (Table 47 on page 212 and Appendix Seven) also found positive values greater than 1, the value of this measure was questioned. The absolute values of the quotient vary depending on the size of the network, but this is not considered relevant.

Two possible explanations are offered for this notable similarity in the small-world data. These results are a strong indication of self-similarity between director networks and extracted sub segments. Random allocation to a network on the basis of artificial attributes does not destroy the self-similarity of the network nor the small-world traits that are measured here.

Alternatively, Conyon & Muldoon (2006; 2008) have questioned the validity of measuring small-worlds with this quotient as the underlying random distribution is a Poisson distribution, which will find a small-world more often than a different random distribution. They concluded that small-world traits are no more pronounced than would be expected by chance in a statistically similar, but randomly assembled network and that boards of directors, especially in the United States, are no more 'clubby' than expected. Newman et al. (2001) experimented with other random distributions and tested them against the Davis et al. (2003) data used here and found a good fit with elements of the small-world such as clustering and path length, but not with numbers of board interlocks. These discrepancies were resolved by introducing assortativity, a finding subsequently confirmed by Conyon & Muldoon (2006).

The assortativity results in this thesis confirmed these findings for all networks and in the smaller women-only networks confirmed positive assortativity for the 1999 Fortune US 1000 network.

Two conclusions can be drawn from this section of the research. Firstly, it is now established that women-only director networks are likely to be small-worlds and that women directors in mixed gender networks do not show different patterns of clustering or path lengths from their colleagues of similar degree in the largest connected component. If they did do so, the patterns of clustering and path lengths across different networks would be markedly different depending on the numbers of women in the networks, with more women being found in the unconnected components having been excluded from the largest components by differing clustering patterns. In particular, differences in the numbers of female connector directors and their links in the network would be apparent in these measures.

Secondly, this research has confirmed the importance of assortativity or the preference for directors of similar degree around a boardroom table. Women-only director networks appear also to be assortative if the data sets are large enough for reliable measures. This preference will shape network structures and confirms Glass Network theory that women directors through the glass net, and in particular women connector directors, have a similar network structure to their male colleagues.

What the research has not addressed, but Glass Network theory has considered, are intersection issues where males of low degree are preferred over females of equal or higher degree. The contention that limited amounts of diversity naturally prevail in a network provides the solution. Once the acceptable proportions of diversity have been observed to be reached, that is the token woman or Black director has been appointed to a board, then the forces of homophily are asserted and gender preferences dominate in the selection of the next director.

6.4.6 Role and importance of degree and betweenness

Director degree and betweenness were selected for analysis as these characteristics of social networks have featured heavily in the scale-free and small-world literature. The presence of power laws has been confirmed in director networks for degree by several authors (Battiston & Catanzaro, 2004; Davis et al., 2003; Newman, 2002; Newman, 2003a; Newman & Park, 2003; Newman, et al., 2001) but none for betweenness. However, Goh et al. (2002) has found strong evidence for power laws driving betweenness centrality in other complex and natural networks. As a measure of social influence it is important to establish the same distribution of betweenness in director networks and to determine gender differences or similarities.

The results of this research confirm the presence of power laws in director degree and betweenness distributions and that male and female directors in mixed gender and women-only networks show the same spreads and fit within the predictive ranges for degree in Figures 34 and 35 (pages 181 and 182) and betweenness in Figures 36 and 37 (pages 188 and 189) for the full networks, Figures 46 and 47 (pages 210 and 214) for the degree and betweenness of the continuing director networks.

The results for the random networks show evidence supporting self-similarity in director networks as the random degree and betweenness results fall comfortably into the predictive ranges in Figures 45 and 46 respectively. Only one instance of outlier or deviant trend lines was observed for the NZX networks. Again, random networks randomly assigned on the basis of an artificial attribute to a network cannot be distinguished from real networks.

Both degree and betweenness are derived measures from seat spreads, confirming the importance of seat spreads in shaping the network structure. As seat spreads have been shown to follow a power law in Table 17 (page 165) and Figures 26 and 27 (pages 166 and 167, and a power law can be generated by a simple non-symmetrical function that is a good fit to actual data, then it is to be expected that degree and betweenness will follow suit.

6.4.7 Limitations of the current research

The current research focuses on a specific form of affiliation network, the one mode director-director network, and ignores the company-company networks. It also largely ignores the economic and political environments in which directors operate. As a result, this gives an incomplete picture of director networks and is deliberately simplistic. It can also be argued that the comparative methodology used is too simplistic and more sophisticated tools are necessary. Interpreting changes in slope and intercepts can be confusing, a problem that setting high and low ranges was intended to minimise.

This research did not focus on establishing exact power laws for each measure but rather attempted to indicate a range within which actual director networks operate. No claims to exactitude were made, as recent work points to difficulties with determining power law equations by least-squares regression methods (Conyon & Muldoon, 2006; Clauset et al., 2009). A combination of maximum-likelihood fitting methods with goodness-of-fit tests based on the Kolmogorov-Smirnov statistic is a more promising approach if exact equations are required. Since completing the data analysis, the Netminer 3 developers have brought out a module that uses this method to determine power law equations.

The sample of datasets was limited, and in particular analysis of a more current Fortune US 1000 dataset would reinforce the findings. The results show that large datasets are necessary and the lack of statistically significant results in the NZX and women-only networks may be a function of the small sample size rather than absence of an underlying relationship. Diversity in director networks does require a longitudinal approach. A longer time frame than the three years covered in this research is necessary and the inclusion of seat spread counts in ongoing censuses important.

Gendered director networks need to be studied in their totality, it is not sufficient to only report on women directors as is the trend in many censuses. This research attempted to overcome past limitations by including male and female directors into the analysis.

Determining gender is subject to a degree of error, but a more likely source of error is in identifying accurately directors with multiple seats. This research was constrained by the data limitations and errors imposed by third party collectors of the data, whose focus was often only on the gender of a director and not on the accurate spelling of their full name. For example, the two Peter Wilsons in the NZX datasets required very careful cross checking. This exercise highlighted the need for a standard method for separating out directors with common names.

The research assumed at the outset that governance and affirmative action interventions had been largely unsuccessful, but the results do indicate that in the US director network as early as 1999 there was some movement towards increasing diversity, particularly in the increasing numbers of connector directors with two seats and the reducing numbers of directors with five or more seats. The 2007 Fortune Global 200 network also indicates the start of a similar trend. This was revealed by the expected seat spread analysis. The model generating the expected seats needs further testing against more datasets and may need some modification to more accurately represent actual director networks.

Separating out the influence of social interventions and the baseline network structure is complex. It may be too late and too difficult to do this in US director networks. It may be easier to establish a universal structure in the director networks of other countries. The emerging director networks in countries moving away from socialism to capitalism in largely unregulated environments may be better sources of data. Datasets from Norway and South Africa, both before and after the introduction of legislated affirmative action, may provide more illuminating datasets. There is an opportunity to measure director networks in France before and after the proposed quota introduction rather than to conduct this analysis retrospectively as it would now have to be done for Norway and South Africa.

The comparison of the networks to random networks needs further work as it was limited by access to iterative software and the seven random data sets were created by manual methods. Current research on the generation of random networks shows how thinking on randomness in networks is developing quickly with often conflicting results. The approach used here of creating artificial attributes and then extracting sub-graphs should be pursued further as interesting indications of emerging patterns of organization in random networks are hinted at in the results, where the random allocation of connector directors to sub-graphs was either even or bunched across the network segments.

6.4.8 Extending Glass Network theory to include geographic proximity

The results from the present study support Glass Network theory, but the original discourse did not consider one element that is needed to extend and complete Glass Network theory. This is a consideration of the role that the physical location of directors plays in the structure of a glass network.

When considering how social networks grow and change, location in geographic space must be a pre-disposing factor for the conjunction of nodes. In director networks, actual encounters with fellow directors in a variety of settings including common boards, should foster the development of ties and encourage invitations to join boards (Davis et al., 2003). Friedland and Palmer (1994) found geographic proximity to be a frequent source of invitations to join boards with firms in the same area sharing directors among themselves. Among Fortune 1000 firms, 27% of ties were between companies headquartered in the same state with multiple overlaps common. 8% of connected companies shared two or more directors.

As directors are generally to be found at company headquarters, company location and size are factors that directors consider when accepting a board appointment. Early economists and sociologists, notably Gibrat in the 1930s, reported that firm sizes followed a log normal distribution, a historically persistent pattern. Axtell (2001) extended this further with the large dataset of US taxpayers to show that in the US, firm sizes follow a power law or Zipf's law, the signature of a scale-free network.

Not only does company size follow a power law, but city size does as well. For example, the second largest city in the US is half the size of the largest, the third largest US city a third the size of the largest, etc, a power law expressed as $y = cx^{-1}$, where c is the size of the city. As noted by Gabaix and Ioannides (2004):

> The existence of very large cities, the very wide dispersion in city sizes, the remarkable stability of the hierarchy between cities over decades or even centuries, and the role of urbanization in economic development are all particularly interesting qualitative features of urban structure worldwide. Another surprising regularity, Zipf's law for cities, has itself attracted considerable interest by researchers (Gabaix & Ioannides, 2004, p. 2341).

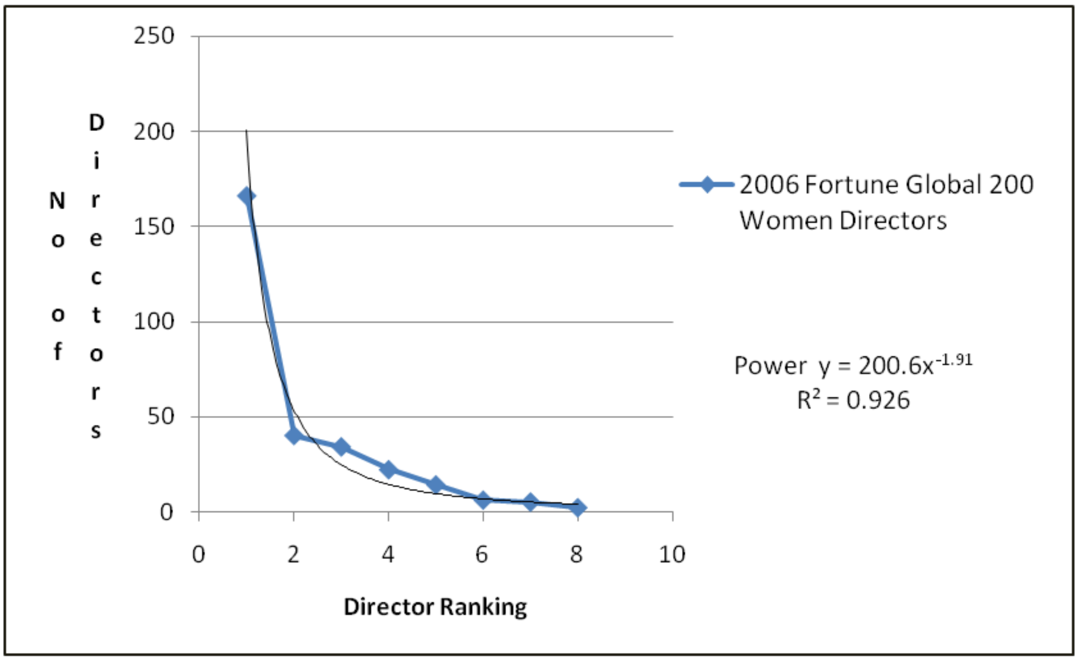
Sassen (2001) extends this further into the global city, the handful of the major cities that now act as sites for concentrating resources and services for the control of dispersed global empires. The twentieth century has seen the emergence of global companies with international boards. Information on the numbers of women on global boards by country is available from the 2007 CWDI census and presented in Table 52.

Table 52.
2007 Fortune Global 200 Directors by Country (CWDI Report 2007)

Country	Male Directors	Female Directors	Gender Ratio	% Female Directors/Total Female Directors
United States	775	166	4.7	17.6
Germany	328	40	8.2	10.9
United Kingdom	211	34	6.2	13.9
France	266	22	12.1	7.6
Netherlands	111	14	12.1	7.6
Switzerland	57	6	9.5	9.5
Japan	384	5	76.8	1.3
Italy	66	2	33.0	2.9
Totals	2198	289	7.6	11.6

From this table of directors (not seats) ranked by female directors, a plot of women directors can be constructed. Figure 49 shows that a power law can be fitted to this distribution of women directors by country with R^2 over 0.9. A log-log plot of this data gives a straight line with a linear trend line $y = -1.910x + 2.302$ with an $R^2 = 0.926$.

Figure 49.
2007 Fortune Global 200 Women Directors by Country



Examination of the country location of firms with global women directors reveals a predictable pattern of large developed nations, with the exception of Japan which contains some of the largest cities and companies. The higher number of US women directors may reflect the effects of diversity activism.

Gabaix and Ioannides (2004) point out that many of the statistical issues associated with ranking cities by size are similar to firm size. This can be extended to director networks. Gabaix and Ioannides (2004, p. 2357) comment that "Perhaps this similarity of firms and cities will help guide some new theorizing. In any case, this strong support of Zipf's law for firms should increase one's posterior about the probability of Zipf's law for cities". The presence of power laws in director networks does not seem unusual given that these two dominating patterns directly impact the makeup of boards of directors. Postulating that these power laws may also apply to women directors and their networks is not a large leap of logic.

Glass Network theory, then, suggests that larger firms are located in the larger urban areas, both of which distributions follow the power laws of scale-free networks. These distributions are stable relationships that have persisted over long periods of time. Larger firms tend to have larger boards with more connector directors whose degree also approximates a power law and who prefer directors of similar degree. The directors from the larger firms tend to be found in the largest connected components of the director network. The components of the director network, once the large or giant component has formed, also tend to follow a power law. Seat spreads also follow a power law within the large component and in the network as a whole.

Larger firms tend to have more women on their boards, the bulk of whom are token directors and are not connector directors. As larger firms are more likely to be located in large cities, women directors are more likely to found in the large cities or be associated with chairpersons who appoint them to boards based in those same cities. Once through the glass net, a small proportion of these women (based on the power law driving the seat spread) become increasingly desirable as directors on other boards. As they become connector directors and appointed to boards with other directors of similar degree, the self-reinforcing mechanisms of the Matthew's effect, or the 'rich get richer' rules of preferential attachment, elevate a small (but predictable proportion) even further to super-trophy director status. Some of these women will penetrate another glass net and go on to be appointed to international boards. Again, a select few will go on to become connector directors in global companies.

As a result, the connector women directors are more likely to be found in the largest connected components of the director network. It then follows that female connector directors in the largest component of the director network are more likely to be found in the larger firms and cities and their proportions would similarly follow a power law based on firm size and size of location city. As larger firms are more profitable, company performance will be positively related to the number of women on a board. In other words the final numbers of women directors are the consequence of a sequence of nested power laws where there is no active intervention to increase their numbers and a feedback mechanism maintains a dynamic equilibrium.

A form of dynamic equilibrium, with a stable gender ratio approximating the Pareto 80/20 rule, then prevails in expanding or contracting economies, with the director body experiencing a related fluctuation in the rate of director turnover. This equilibrium is robust and stable despite continually changing inputs and outputs, and resistant to efforts to change it.

In conclusion, the implication of this discussion is that director networks exhibit the characteristics that they do because they cannot be considered in isolation to the location in which they are found and the prevailing laws that drive the distribution of cities and companies. Women directors, also being located in those locations and subject to the same force, will have similar networks. Gender, like the artificial random attributes created for this research, will have little impact on the network structure unless affirmative action interventions are brought to bear on it.

Chapter Six Summary

The discussion of the results commences with an analysis of some of the statistical issues encountered. This is followed by a detailed discussion of the results relating to the research question set including the testing of Glass Network theory against the continuing directors and random networks. The results are related to Glass Network theory with a consideration of the role and importance of the network components, seat spreads, connector directors, small-worlds, assortativity, degree and betweenness.

Based on these results, Glass Network Theory is extended with a discussion of the relationship of power laws in city size, and company size to board composition and director networks.

Chapter Seven. Conclusion

7.1 Introduction

As the first social network analysis of women directors' networks this research has necessarily been broad in scope. By answering a simple question about the location of women in director networks a theoretical structure was built from supporting evidence which takes into account far more than gendered networks. It places boards of directors' research firmly within the domain of scale-free network analysis while pushing the boundaries of these new theories into the real world of directors. It also addresses questions of gender preference and why the exclusion of women from boardrooms occurs. It has sought to build an inclusive theory that extends to male directors who are subject to the same competitive power law driven processes. One of the strengths of Glass Network theory is that it is gender neutral.

It is an all encompassing theory that provides a new view of the social structures that support current governance and business practices at board level. This research applies social network analysis concepts in a new way to gendered director networks. Old concepts of homophily are given fresh impetus by emphasizing the principle of self-similarity in director networks. Glass Network theory has also provided a means to understand self-similarity and scale through the mechanism of glass nets and the role of connector directors in establishing nested director networks. Concepts of scale-free and small-world networks have allowed the focus of Glass Network theory to range from the global to the local.

Until now, WOB researchers have assumed that they can compare director networks without considering the implications of scale and location. Scale has not been an issue, as readers and researchers always know which network is under consideration and the country of operation while intuitively knowing its ranking in terms of size. US director networks, given the scale of the economy and population numbers, cannot be anything but larger than New Zealand networks. Introducing the Fortune Global 200 networks into this research has clearly highlighted notions of scale and location.

Although consisting of similar numbers of companies to the NZX it has double the directors and no specific location.

The economic horsepower and influence of NZX companies pales into insignificance when compared to these global companies, yet this research shows more similarities than differences between these director networks. Assumptions that director networks may be similar because common principles of capitalism underlie Western economies (Conyon & Muldoon, 2008) need to be questioned. The new evidence for common mechanisms, such as assortative mixing, across natural and social networks shows that the shape of network structures is likely to be independent of economic philosophies. This can be extended to gendered director networks where mechanisms like preferential attachment and early advantage deriving from initial conditions are independent of prevailing belief systems about similarities and differences between males and females.

This research also took a non-conventional view on randomly gendered networks by preserving the network structure while creating artificial director attributes, rather than the usual approach of creating random networks from simple elements. Although the testing was not extensive, the results support arguments for self-similarity in director networks and compound the problem of what is randomness in director networks. Random forces at a local level, such as the innumerable recruitment and selection decisions preferring one individual over another, result in an emergent structure following observable patterns at another level. These second order patterns are invisible in the normal course of events. Revealing these is the great achievement of complex network theory and social network analysis, stimulated by the recent advances in network theory achieved by Watts, Newman and Barabási and many others.

Applying this new knowledge to the problem of women on boards of directors was the intent of this thesis. The outcome of this research is a new theory in the initial stages of conceptualization. This theory is called Glass Network theory, has its antecedents in the glass ceiling literature which is rooted in WOB research. Glass Network theory has the potential to be extended to other forms of social preference, or conversely discrimination. It takes a new view on diversity as a normal characteristic of any complex network whose ultimate function is to permit the growth and adaptation of the network to changing circumstances. Glass Network theory also accounts for the robust nature of complex gendered networks of directors in a dynamic equilibrium that resists the efforts of social change agents.

There are two unintended outcomes to this research. Firstly, it suggests that the relationship between the presence of women directors and company performance is correlational not causal. Using improved company performance as a reason for increasing board diversity is not credible if there is no causal relationship. It predicts that the value in diversity school of research will ultimately wither through lack of significant findings. Secondly, it provides a clear rationale for affirmative action agents to pursue quotas and enforced social change where this is desired. The motivation to increase board diversity above the expected levels found in a network not yet subject to affirmative action, becomes a political issue of equity and fairness.

The model of expected seat spreads is a new tool to track the impact of affirmative action interventions. It can determine the initial level of diversity in the network and measure it against the theoretical model. It can then track the changes resulting from the unique solution developed by each country to fit in with their existing legislative structure. Once equity is achieved it will not persist without enforcement. Gender equity on boards of directors needs to be actively maintained and guarded as networks will lapse back to earlier levels of diversity or possibly revert to the opposite, where directing becomes a career with more women than men, as has happened in the teaching profession.

7.2 Implications for diversity interventions

Efforts to ameliorate the lack of female representation on boards of corporate directors is moving from a feminist and fringe effort to one of significant interest by national policy makers. The necessity for broad diversity and equity is being incorporated into the good governance guidelines of international policy committees and platforms of political parties. While often not legally enforceable diversity policies are the de facto policies in the state sectors of many Western countries. In countries operating under free market conditions compulsory board gender equity policies are being considered by stock exchanges as an interim step to enforced quotas. Government agencies and private initiatives are funding and investing in organizations that conduct research and promote diversity. In New Zealand organizations such as the Equal Employment Opportunities Trust (www.eeotrust.org.nz) offer awards and publicity to employers who support work diversity, and are centres of excellence meeting policy, training and resource demands.   The research results from this thesis suggest that many of these policies and practices need to be reviewed and re-adjusted to accommodate network effects that either help or hinder diversity candidates. In particular recruitment and selection practices for directors need to be reviewed as Glass Network theory highlights specific techniques such as shoulder tapping that perpetuate the status quo.

In addition the tools developed in this thesis provide a gender neutral and scientific approach to tracking and monitoring diversity initiatives. As the model of board equity is best displayed graphically and the underlying mathematical constructs relatively simple, the model is accessible to a wide audience. As a priority further tools are needed to assist governments and policy makers monitor diversity initiatives. These will flow from a deeper understanding of director networks and the increasing sophistication of social network analysis software. As many WOB researchers and activists understand only too clearly, that what gets measured gets changed, WOB research is now in a position to move on from census taking to promoting and monitoring large scale diversity interventions.

Glass Network theory clearly shows that women directors cannot be treated as an amorphous mass by WOB researchers. Distinct stages exist in the career of a director, not all of which are achievable by everyone. Most directors are aspiring directors, and few would decline a board appointment in a substantial company if offered one. All therefore share the necessity to prepare and present oneself in the most favourable light should the opportunity arise. Preparing CVs, developing networks and credible experience are common tasks most aspiring women directors will have performed. Many are directors of SME companies, while a significant number will have executive experience, but not board or governance experience, and will be attempting to remedy this with non-profit experience (Hawarden & Marsland, 2009).

Those through the glass net will have one listed directorship in a substantial company and may have an enabler such as family connections or celebrity status that facilitated this happening. These directors are unlikely to gain further board seats. Very few, although no doubt competent and personable, will progress to further directorships and become connector directors. At that stage, the benefits of preferential attachment kick in and connector directors can pick and choose board appointment and other opportunities. These are the women who will be called on for advice and mentoring of less successful women. Depending on the level of demand, their responses and affability, they may or may not be swiftly labelled as queen bees.

Encouraging the development of personal strategies that individual women can follow forms the basis of much of the advice given in WOB associations. Researching gender differences at a psychological level and suggesting strategies for success may not be productive in network terms, as these balance out as the emergent network reaches a dynamic equilibrium. Glass Network theory is sceptical about the value of such strategies. The success of personal efforts is hard to predict and in the long run women should expect to be unsuccessful, no matter what they try. It is a competitive numbers game with more losers than winners and with filtering mechanisms that let limited and predictable numbers through the glass nets.

Glass Network theory has accounted for the resistance to change in director networks, which has important implications for diversity interventions. It suggests that the schools of thought that hope for incremental change by persuading women directors to change themselves to be more like male directors will not succeed. Glass Network theory has also shown that the value-in-diversity school of thought may find correlations between the presence of women on boards and company performance, but it will not be able to prove a causal connection. Other common factors such as board size, company size and location city are more likely to explain the apparent correlation.

This leaves the mandatory quota school. To successfully change gender ratios on boards of directors, Glass Network theory supports the mandatory quota school of WOB researchers. The inertia of glass networks deters social change and to be effective formal affirmative action is required with quotas maintained and enforced. The historical evidence has shown that private sector companies will not change unless forced to do so, and even then delay changing as long as possible. When faced with affirmative action pressure such corporates respond adaptively to their best advantage by preferring women directors already through the glass net. Token and compliant women directors, often a family member, also get co-opted to meet the letter of the law.

Informal affirmative action as present in the state sectors of several countries, notably New Zealand and Australia (Vinnicombe et al., 2008) have been remarkably successful in achieving high levels of women in executive and governance positions. This is dependent on political will and has not transferred to the private sector despite supply problems of women directors with suitable education and experience being solved. The ethics and effectiveness of quotas for boards of directors is a philosophical discussion beyond the remit of this research, but future discussions can be grounded in Glass Network theory. The numbers required to effect gender equity on boards are predictable and are not voluminous. The evidence to date from countries implementing affirmative action indicates that business is barely disrupted by the presence of more women on boards. It is too early to say if the changes are beneficial. Lessons learned from the suffragette movement and the long struggle to achieve universal suffrage in Western countries should be remembered by WOB activists.

This research has confirmed notions expressed in earlier research (Hawarden, 2008; Hawarden & Stablein, 2008; Hawarden & Marsland, 2009) that although many aspire, few succeed. One of the challenges of affirmative action at board level is to create more opportunities for more women in an area where there are inherently very few opportunities and the men currently filling those boardroom seats are likely to be reluctant to give them up.

7.3 Future research

Glass Network theory is in its formative stages, and somewhat sweeping in its potential applicability (although this is seen as a strength). Its reach into global and local networks puts it tentatively into a class of universal theory that shows ‘consilience’ or the synthesis of knowledge from different specialized fields of human endeavour (Wilson, 1998). Glass Network theory opens up numerous avenues for future research. Its neutrality lends itself to investigating other diversity issues. Intersection issues of race and gender need to be developed further.

Some research avenues flow on directly from this research. For example, applying the comparative methodology to more networks and in particular a current US network is a critical next step. Testing the seat spread function further is also required to confirm its validity. Generating a wider range of random networks and testing these concepts against them would also be important.

The extension of the theory into power laws driving company and city size needs more work and supporting evidence. Testing hypotheses concerning the presence of power laws in director network components, seat spreads, and betweenness would be an easy extension for a mathematician or physicist familiar with probability distributions. Mathematical proofs with the rigour of earlier research would lend much support to Glass Network theory.

Testing the hypothesis that all networks have a limited diversity built in to them asks for innovative ways of detecting this in a variety of natural and social networks. Research looking for the enablers of connector directors may reveal interesting patterns. This would be an extension of work already done on the personal characteristics of successful women directors, but would approach it from a different perspective.

Researching some of the underlying mechanisms such as preferential attachment and homophily would strengthen the foundations of Glass Network theory. Extending the work on lobbies further would be a productive avenue as well. Although not included in this thesis, some preliminary work was done on the current data sets. The indication is that the percentage of lobbies is low, but as other network research has indicated, this does not mean that the effects are negligible.

With regard to specific Women on Boards research, two avenues can be followed. Firstly, extending research into individual director attributes to include the stages of a directors career outlined here and, more specifically, if there are differences between single seat and connector directors. More research could place the queen bee literature on a sounder footing. Secondly, the nature and the consequences of the board changes introduced through the quota system in Norway and Spain needs detailed monitoring and research. The seat spread generating function could be used to establish the pre-quota scenario and monitor the post-quota changes against expected values.

The importance of the South African Black Economic Empowerment legislation has not been fully appreciated by WOB researchers for its impact on intersection issues of race and gender at board level. Analysing all these diversity programs from the view point of Glass Network theory would be a worthwhile project.

This research is value free in the sense that it makes no judgement on the merits of affirmative action on boards of directors, except for warning that unexpected outcomes to change efforts are likely to be the norm rather than the exception. Director networks are non-linear systems and predictions are by definition difficult, if not impossible. Intended change commenced with the best of possible motives may result in less than desirable outcomes. This is not to say that social change should not be implemented, but rather should be done with due thought, care and a reversal mechanism available. The initiatives by South Africa, Norway, Spain and probably France to enforce quotas for women directors provide a fascinating opportunity to see Glass Network theory in practice.

Publications from this Research

1. Hawarden, R. (2008). *New Zealand woman directors: Many aspire but few succeed*. Paper presented at the 1st Australian National Conference on Diversity on Boards, Sydney Australia.. Retrieved from http://www.womenonboards.org.au/events/diversity2008/papers/hawarden.htm

2. Hawarden, R., & Marsland, S. (2009). *How are the governors governed: Growth and diversity in an elite New Zealand director small-world.* Paper presented at the Academy of Management Conference, Chicago, USA.

3. Hawarden, R., & Stablein, R. (2008). New Zealand woman directors: Many aspire but few succeed. In S. Vinnicombe, V. Singh, R. J. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* UK: Edward Elgar Publishers.

References

Adams, S., & Flynn, P. (2005). Actionable knowledge: consulting to promote women on boards. *Journal Of Organizational Change Management, 18*(5), 435-450

Adams, S., & Flynn, P. (2006). Local knowledge advances women's access to corporate boards. *Corporate Governance: An International Review, 13*(6), 836-846.

Adler, R. (2001). *Women in the executive suite correlate to high profits.* Malibu USA: Glass Ceiling Research Centre.

Akande, A. (1994). The glass ceiling: Women and mentoring in management and business *Journal of Workplace Learning, 6*(1), 21 - 28.

Alexander, M. (2003). Boardroom networks among Australian company directors, 1976 and 1996: The impact of investor capitalism. *Journal of Sociology, 39*, 231-251.

Alexander, M., Murray, G., & Houghton, J. (1994). Business power in Australia: The concentration of company directorships holding among the top 250 companies. *Australian Journal of Political Science, 29*, 40-61.

Altman, Y., Simpson, R., Baruch, Y., & Burke, R. (2005). Reframing the 'glass ceiling' debate. In R. Burke & M. Mattis (Eds.), *Supporting Women's Career Advancement: Challenges and Opportunities* (pp. 58-81). UK: Edward Elgar Publishing.

Andriani, P., & Passionate, G. (2004). Complexity theory and the management of networks. In P. Andriani & G. Passionate (Eds.), *Complexity theory and the management of networks: Proceedings of the workshop on Organisational networks as distributed systems of knowledge*. UK: Imperial College Press.

Appelbaum, S., Audet, L., & Miller, J. (2003). Gender and leadership? Leadership and gender? A journey through the landscape of theories. *Leadership & Organization Development Journal, 24*(1), 43-51.

April, K., & Dreyer, S. (2007). Gender Unplugged in the South African Executive Boardroom. *Effective Executive 10*(12), 62-77.

Arfken, D., Bellar, S., & Helms, M. (2004). The ultimate glass ceiling revisited: The presence of women on corporate boards. *Journal of Business Ethics, 50*, 177-186.

Axtell, R. (2001). Zipf distribution of U.S. firm sizes. *Science, 293*(5536), 1818-1820.

Ball, P. (2004). *Critical mass: How one thing leads to another*. UK: William Heineman.

Barabási, A.-L. (2003). *Linked - The new science of networks.* USA: Penguin Books Ltd.

Barabási, A.-L., & Albert, R. (1999). Emergence of scaling in random networks. *Science, 286*, 509-512

Barabási, A.-L., & Bonabeau, E. (2003). Scale-free Networks. *Scientific American, May*, 50-59.

Barabási, A.-L., Jeong, H., Néda, Z., Ravasz, E., Schubert, A., & Vicsek, T. (2002). Evolution of the social network of scientific collaborations. *Physica A 311*, 590-614.

Barnett, V., & Lewis, T. (1994). *Outliers in Statistical Data* (3rd ed.). New York: John Wiley & Sons Ltd.

Battiston, S., Bonabeau, E., & Weisbuch, G. (2003). Decision making dynamics in corporate boards. *Physica A 322* 567 – 582.

Battiston, S., & Catanzaro, M. (2004). Statistical properties of corporate board and director networks. *European Physical Journal, 38*, 345–352.

Baum, J., Shiplov, A., & Rowley, T. (2003). Where do small-worlds come from? *Industrial and Corporate Change, 23*(4), 697-725.

Baxter, J., & Wright, E. (2000). The glass ceiling hypothesis: A Comparative study of the United States, Sweden, and Australia. *Gender and Society, 14*(2), 275-294.

Bell, M., & Nkomo, S. (2001). *Our separate ways: Black and White women and the struggle for professional identity.* Boston, MA: Harvard University Press.

Bellar, S., Helms, M., & Arfken, D. (2004). The Glacial Change. *Business Perspectives, 16*(2), 30-37.

Bilimoria, D. (2000). Building the business case for women corporate directors. In R. Burke & M. Mattis (Eds.), Women on corporate board of directors: International research and practice. Dordrecht: Kluwer Academic Publishers.

Bilimoria, D. (2006). The relationship between women corporate directors and women corporate officers. *Journal of Managerial Issues, 8*(1), 47-61.

Bilimoria, D., & Piderit, S. (1994). Board committee membership: Effects of sex-based bias. *Academy of Management Journal, 37*(6), 1453-1477.

Borgatti, S. (2005). Centrality and network flow. *Social Networks, 27*(55-71).

Borgatti, S. P., Everett, M.G. and Freeman, L.C. (2002). Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies

Bohorquez, J., Gourley, S., Dixon, A., Spagat, M., & Johnson, N. (2009). Common ecology quantifies human insurgency. *Nature, 462*(911-914).

Branson, D. (2007a). No seat at the table: How corporate governance and law keep women out of the boardroom. US: New York University Press.

Branson, D. (2007b). Where Are the Women Directors? *Conference Board Review, 44*(5), 51-54.

Branson, D. (2009). *The last male bastion: Gender and the CEO suite in America's public companies*. New York: Routledge, Taylor and Francis Group.

Broome, L. (2008). The Corporate Boardroom: Still a Male Club. *The Journal of Corporation Law, 33*(3), 665-680.

Buchanan, M. (2002). *Nexus: Small-worlds and the groundbreaking science of networks*. US: WW Norton &Company Inc.

Burgess, Z., & Fallon, B. (2003). A longitudinal study of women directors in Australia. *Women in Management Review, 18*(7), 359 - 368.

Burgess, Z., & Tharenou, P. (2002). Women board directors: characteristics of the few. *Journal of Business Ethics, 37*, 39-49.

Burgess, Z., & Tharenou, P. (2000). What distinguishes women non-executive directors from executive directors? In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities* (pp. 111-128). Dordrecht: Kluwer Academic Publishers.

Burke, R. (1997a). Women on corporate boards of directors: a needed resource. *Journal of Business Ethics, 16*, 909-915.

Burke, R. (1997b). Women directors: Selection, acceptance and benefits of board membership. *Corporate Governance, 5*, 118-125.

Burke, R. (2000). Company size, board size and numbers of women corporate directors. In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities*. Dordrecht: Kluwer Academic Publishers.

Burke, R., & Mattis, M. (2000). *Women on corporate boards of directors: International challenges and opportunities.* Dordrecht: Kluwer Academic Publishers.

Burke, R., & Mattis, M. (Eds.). (2005). *Supporting women's career advancement: Challenges and opportunities*. UK: Edward Elgar Publishing.

Burris, V. (2005). Interlocking directorates and political cohesion among corporate elites. American Journal of Sociology, 111(1), 249-283.

Burt, R. (1979). A structural theory of interlocking corporate directorates. *Social Networks, 1*(4), 415-435.

Burt, R. (1998). The Gender of Social Capital *Rationality and Society, 10*(1), 5-46.

Burt, R. (2000). The network structure of social capital. In B. Straw & R. Sutton (Eds.), *Research in Organizational Behavior, Volume 22* (pp. 345-423). USA Elsevier Science Inc.

Burt, R. (2005). *Brokerage and closure: An introduction to social capital* Oxford: Oxford University Press

Businesswomen's Association. (2008). *BWA South African women in corporate leadership census 2008*. Retrieved 7 September 2009, from http://www.bwasa.co.za/Portals/4/docs/CENSUS2008.pdf

Businesswomen's Association. (2009). *BWA South African women in corporate leadership census 2009*. from http://www.bwasa.co.za/Census/2009CensusResults/tabid/14513/Default.aspx

Calás, M., Smircich, L., & Bourne, K. (2007). Knowing Lisa? Feminist analyses of 'gender' and 'entrepreneurship'. In D. Bilimoria & S. Piderit (Eds.), *Handbook on women in business and management* (pp. 78-105). UK: Edward Elgar Publishing Inc.

Calás, M., Smircich, L., & Bourne, K. (2009). Extending the Boundaries: Reframing 'Entrepreneurship as Social Change' through feminist perspectives. *Academy of Management Review, 34*(3), 552-569.

Caldarelli, G. (2007). *Scale-free networks: Complex webs in nature and technology* UK: Oxford University Press.

Callaway, D., Hopcroft, J., Kleinberg, J., Newman, M., & Strogatz, S. (2001). Are randomly grown graphs really random? *Physical Review E 64*, 041902.

Campbell, K., & MÍnguez-Vera, A. (2008). Gender diversity in the boardroom and firm financial performance. *Journal of Business Ethics, 8*, 435–451.

Carley, K. (1999). On the evolution of social and organizational networks. In S. Bacharach, S. Andrews & D. Knoke (Eds.), *Research in the sociology of* *organizations: Networks in and around organizations* (Vol. 16, pp. 3-30). US: JAI Press Inc.

Carlile, P., & Christensen, C. (2005). The cycles of theory building in management research. from http://www.hbs.edu/research/pdf/05-057.pdf

Carter, D., Simkins, B., & Simpson, W. (2003). Corporate governance, board diversity, and firm value. *Financial Review, 38*(1), 33-53.

Catalyst & Businesswomen's Association. (2004). *BWA South African women in corporate leadership census 2004*. Retrieved 7 September 2009, from http://www.catalyst.org/file/90/2004%20south%20african%20census%20report.pdf

Catalyst. (2006a). 2005 Catalyst Census of Women Board Directors of the *Fortune* 500.

Catalyst. (2006b). 2005 Catalyst Census of Women Corporate Officers and Top Earners of the *Fortune* 500.

Catanzaro, M., Caldarelli, G., & Pietronero, L. (2003). Assortative model for social networks. from arXiv:cond-mat/0308073v1

Chung, F., & Linyuan, L. (2002). The average distance in random graphs with given expected degrees. *Proceedings of National Academy of Sciences, 99*(25), 15879-15882.

Clauset, A., Shalizi, C., & Newman, M. (2009). Power-law distributions in empirical data. from http://arxiv.org/PS_cache/arxiv/pdf/0706/0706.1062v2.pdf

Collins, J., & Chow, C. (1998). Its a small-world. *Nature, 393*(6684), 409-410.

Collinson, D., & Hearn, J. (2003). Breaking the silence: on men, masculinities and managements. In R. Ely, E. Foldy, M. Scully & Center for Gender in Organizations Simmons School of Management (Eds.), *Reader in Gender, Work, and Organization* (pp. 75-86). UK: Blackwell Publishing Ltd.

Conyon, M., & Mallin, C. (1997). Women in the boardroom: evidence from large UK companies. *Corporate Governance, 5*(3), 112-117.

Conyon, M., & Muldoon, M. (2006). The small-world of corporate boards. *Journal of Business Finance & Accounting, 33*(9/10), 1321–1343.

Conyon, M., & Muldoon, M. (2008). Ownership and control: A small-world analysis. In J. Baum & T. Rowley (Eds.), *Advances in Strategic Management: Network Strategy* (Vol. 25, pp. 31-65). UK: Emerald Group Publishing Limited.

Cooper, V. (1997). Homophily or the Queen Bee syndrome: Female evaluation of female leadership. *Small Group Research 1997; 28; 483, 28*(4), 483-499.

Corporate Women Directors International (2004). CWDI 2004 Report: Women Board Directors of the Fortune Global 200 United States

Corporate Women Directors International (2007). CWDI 2007 Report: Women Board Directors of the Fortune Global 200 United States

Cotter, D., Hermsen, J., Ovadia, S., & Vanneman, R. (2001). The glass ceiling effect. *Social Forces, 80*(2), 655-682.

Currie, J. (2006). *The invisible safety net: Protecting the nation's poor children and families*. US: Princeton University Press.

Cyram. (2009). NetMiner 3.3.1. Seoul: Cyram Co., Ltd.

Daily, C., Trevis Certo, S., & Dalton, D. (1999). A decade of corporate women: some progress in the boardroom, none in the executive suite. *Strategic Management Journal, 20*(1), 93-99.

Daily, C., Trevis Certo, S., & Dalton, D. (2000). The future of corporate women: Progress toward the executive suite and the boardroom? In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities* (pp. 11-23). Dordrecht:: Kluwer Academic Publishers.

Dalton, D., & Dalton, C. (2008). On the progress of corporate women: Less a glass ceiling than a bottleneck? In S. Vinnicombe, V. Singh, R. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* (pp. 184-197). UK: Edward Elgar Publishing Ltd.

Dalton, D., Dalton, C., & Trevis Certo, S. (2004). Women as directors: The 'inside' story. *Directors and Boards, Fall*, 36-38.

Davidson, M., & Burke, R. (2004). *Women in management worldwide*. UK: Ashgate Publishing Ltd.

Davidson, M., & Cooper, C. (1992). *Shattering the glass ceiling: The woman manager*. London: Paul Chapman.

Davies-Netzley, S. (1998). Women above the glass ceiling: Perceptions on corporate mobility and strategies for success. Gender and Society, 12(3), 339-355.

Davis, G. (1991). Agents without principles?: The spread of the poison pill thorough the intercorporate network. *Administrative Science Quarterly, 36*(4), 605-633.

Davis, G. (1993). Who gets ahead in the market for corporate directors: The political economy of multiple board memberships. *Academy of Management Best Papers Proceedings*, 202-206.

Davis, G. (1996). The significance of board interlocks for corporate governance. *Corporate Governance, 4*, 154-159.

Davis, G., & Greve, H. (1997). Corporate elite networks and governance changes in the 1980's. . *The American Journal of Sociology, 103*(1), 1-37.

Davis, G., & Mizruchi, M. (1999). The money center cannot hold: Commercial banks in the U.S. system of corporate governance. *Administrative Science Quarterly*, 44, 215-239.

Davis, G., & Thompson, T. (1994). A Social Movement Perspective on Corporate Control. *Administrative Science Quarterly, 39*(1), 141-173.

Davis, G. F., Yoo, M., & Baker, W. E. (2003). The small-world of the American corporate elite, 1982-2001 *Strategic Organization, 1*(3), 301-326.

de Anca, C. (2008). Women on corporate boards of directors in Spanish listed companies. In S. Vinnicombe, V. Singh, R. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* (pp. 96-107). UK: Edward Elgar Publishing Ltd.

Desvaux, G., Devillard-Hoellinger, S., & Baumgarten, P. (2007). (McKinsey & Company) Women Matter: Gender diversity, a corporate performance driver retrieved from http://www.mckinsey.com/locations/swiss/news_publications/pdf/women_matter_english.pdf

Devlin, P. (1999). Top corporate jobs elude women especially in bigger companies. *National Business Review*, 10.

Dodge, M., & Stinson, C. (2007). *Microsoft Office Excel 2007 Inside Out*. US: Microsoft Press.

Donner, F., & Hymowitz, C. (2009). France Weighs Gender Quotas for Company Boardrooms. from http://www.forbes.com/2009/12/04/french-legislation-boards-quotas-forbes-woman-leadership-directors.html

Eagly, A., & Carli, L. (2007a). *Through the labyrinth: The truth about how women become leaders*. US: Harvard Business School Press.

Eagly, A., & Carli, L. (2007b). Women and the labyrinth of leadership. *Harvard Business Review Reprint, September*, 1-11.

Erdös, P., & Renyi, A. (1959). On random graphs. *Publicationes Mathematicae, 6*, 290-297.

Erhardt, N., Werbel, J., & Schrader, C. (2003). Board of director diversity and firm financial performance. *Corporate Governance: An International Review, 11*(2), 102-111.

Erkut, S., Kramer, V., & Konrad, A. (2008). Critical mass: Does the number of women on a corporate board make a difference? In S. Vinnicombe, V. Singh, R. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* (pp. 222-232). UK: Edward Elgar Publishers

Escover, J. (1994). The Value Measure. *Management Decision, 32*(1), 12-14.

Farrell, W. (2005). *Why men earn more: The startling truth behind the pay gap - and what women can do about it*. US: American Management Association.

Farrell, K., & Hersch, P. (2005). Additions to corporate boards: the effects of gender. *Journal of Corporate Finance, 11*, 85-106.

Ferris, S., Jagannathan, M., & Pritchard, A. (2003). Too Busy to Mind the Business? Monitoring by Directors with Multiple Board Appointments. *Journal of Finance, 58*(3), 1087-1111.

Firth, M. (1987). Multiple Directorships and Corporate Interlocks in New Zealand Firms. *Journal of Sociology, 23*(2), 274-281.

Freeman, L. (1979). Centrality in social networks: Conceptual clarification. *Social Networks, 1*, 215–239.

Freeman, L. (2004). *The Development of social network analysis: A study in the sociology of science* Canada: Empirical Press

Friedland, R., & Palmer, D. (1994). Space, corporation, and class: Toward a grounded theory. In F. R & B. D (Eds.), *Now/Here: Space, time, and modernity* (pp. 287-334). US: University of California Press.

Gabaix, X., & Ioannides, Y. (2004). The Evolution of City Size Distributions. In H. J & J. Thisse (Eds.), *Handbook of Urban and Regional Economics, Volume IV: Cities and Geography (pp. 2341-2380)*. Amsterdam: North-Holland Publishing Company.

Gamba, M., & Kleiner, B. (2001). The old boys' network today. *International Journal of Sociology and Social Policy, 21*(8/9/10), 101-107.

Gatrell, C., & Cooper, C. (2007). (No) cracks in the glass ceiling: women managers, stress and barriers to success. In D. Bilimoria & S. Piderit (Eds.), *Handbook on Women in Business and Management (pp. 57-77)*. UK: Edward Elgar Publishing Inc.

Gladwell, M. (2000). *The Tipping Point*. UK: Abacus.

Gladwell, M. (2008). *Outliers: The story of success*. UK: Penguin Books Ltd.

Gleick, J. (1987). *Chaos*. U K: Vintage Group.

Goh, K., Oh, E., Hawoong, J., Kahng, B., & Kim, D. (2002). Classification of scale-free networks. *Proceeding of the Natlonal Academy of Sciences, 99*, 12583-12588.

Goldin, C. (1990). *Understanding the Gender Gap: An economic history of American women*. UK: Oxford University Press, Inc.

Goldstein, M., Morris, S., & Yen, G. (2004). Problems with fitting to the power-law distribution. *European Physical Journal B, 41*, 255–258

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360-1380.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology, 91*(3), 481-510.

Granovetter, M. (1995). *Getting a job: a study of contacts and careers* (2nd ed.). Chicago: University of Chicago Press.

Halford, S., & Leonard, P. (2001). *Gender, Power and Organisations*. UK: Palgrave Macmillan.

Hambrick, D., Cho, T., & Chen, M. (1996). The influence of top management team heterogeneity on firms' competitive moves. *Administrative Science Quarterly, 41*, 659–685.

Hammer, Ø., Harper, D., & Ryan, P. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica, 4*(1), 9 and retrieved from http://folk.uio.no/ohammer/past/.

Hanneman, R., & RIddle, M. (2005). Introduction to social network methods. from http://faculty.ucr.edu/~hanneman/nettext/

Harrison, D., & Klein, K. (2007). What's the difference? Diversity constructs as separation, variety or disparity in organizations. *Academy of Management Review, 32*(4), 1199-1228.

Haslam, S., & Ryan, M. (2008). The road to the glass cliff: Differences in the perceived suitability of men and women for leadership positions in succeeding and failing organizations. *The Leadership Quarterly, 19*(5), 530–546.

Haunschild, P., & Beckman, C. (1998). When do interlocks matter?: Alternate sources of information and interlock influence. *Administrative Science Quarterly 43*(4), 815-844

Hawarden, R. (2008). *New Zealand woman directors: Many aspire but few succeed*. Paper presented at the 1st Australian National Conference on Diversity on Boards, Sydney Australia.

Hawarden, R., & Marsland, S. (2009). *How are the governors governed: Growth and diversity in an elite New Zealand director small-world.* Paper presented at the Academy of Management Conference, Chicago, USA.

Hawarden, R., & Stablein, R. (2008). New Zealand woman directors: Many aspire but few succeed. In S. Vinnicombe, V. Singh, R. J. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* UK: Edward Elgar Publishers.

Helfat, C., Harris, D., & Wolfson, P. (2006). The pipeline to the top: women and men in the top executive ranks of U.S. Corporations *Academy of Management Perspectives, 20*(4), 42-64.

Helgesen, S. (1990). *The female advantage: women's ways of leadership*. USA: Doubleday Currency.

Helgesen, S. (1995). *The web of inclusion*. USA: Currency Doubleday.

Herd, J. (2005). *Cracks in a glass ceiling: New Zealand women 1975-2004*. Dunedin: NZ Federation of Graduate Women (Otago Branch).

Herr, J., & Wolfram, C. (2008). Opt-out patterns across Careers: Labor force participation rates among highly educated mothers [Electronic Version], from http://faculty.haas.berkeley.edu/wolfram/Papers/OptOut_Draft_July08.pdf

Herring, C. (2009). Does diversity pay?: The race, gender and the business case for diversity. *American Sociological Review, 74*, 208-244.

Hillman, A., Cannella, A., & Harris, I. (2002). Women and Racial Minorities in the Boardroom: How Do Directors Differ? *Journal of Management, 28*(6), 747-763.

Hillman, A., Cannella, A., & Paetzold, R. (2000). The resource dependence role of corporate directors: Strategic adaption of board composition in response to environmental change. *Journal of Management Studies, 37*, 235-255.

Hillman, A., Shropshire, C., & Cannella, A. (2007). Organizational Predictors of Women on Corporate Boards. *Academy of Management Journal, 50*(4), 941-952.

Hillman, A., Shropshire, C., Certo, T., Dalton, D., & Dalton, C. (2008). What I like about you: Director characteristics and shareholder approval. *Academy of Management Proceedings*, 1-6.

Hoel, M. (2008). The quota story: Five years of change in Norway. In S. Vinnicombe, V. Singh, R. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* (pp. 79–87). UK: Edward Elgar.

Howard, S. (1998). *The changing face of recruitment and selection*. Paper presented at the Institute of Personnel and Development Conference.

Huffcutt, A., & Arthur, W. (1995). Development of a new outlier statistic for meta-analytic data. *Journal of Applied Psychology, 80*(2), 327–334.

Hultin, M. (2003). Some take the glass escalator, some hit the glass ceiling? Career consequences of occupational sex segregation. *Work and Occupations, 30*(1), 30-61.

Huse, M. (2000). Boards of directors in SMEs: a review and research agenda. *Entrepreneurship & Regional Development: An International Journal, 12*(4), 271-290.

Huse, M. (2007). Boards, Governance and Value Creation. New York: Cambridge University Press.

Huse, M. (2008). Women directors and the 'black box' of board behaviour. In S. Vinnicombe, V. Singh, R. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice*. UK: Edward Elgar Publishing Ltd.

Hymowitz, C., & Schellhardt, T. (1986). The glass-ceiling: Why women can't seem to break the invisible barrier that blocks them from top jobs. *The Wall Street Journal, 24 March 1986*.

Ibarra, H. (1992). Homophily and differential returns: Sex differences in network structure and access in an advertising firm. *Administrative Science Quarterly, 37*, 422-447.

Ibarra, H. (1993). Personal networks of women and minorities in management: A conceptual framework. *Academy of Management Review, 18*(1), 56-87.

Ibarra, H. (1997). Paving an alternative route: Gender differences in managerial networks. *Social Psychology Quarterly, 60*(1), 91-102.

Insch, G., McIntyre, N., & Napier, N. (2008). The Expatriate Glass Ceiling: The Second Layer of Glass. *Journal of Business Ethics (2008) 83:19–28, 83*(1), 19-28.

Izraeli, D. (2000). The Paradox of Affirmative Action for Women Directors in Israel. In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities* (pp. 75-96). Dordrecht: Kluwer Academic Publishers.

Izraeli, D. (2003). Gender politics in Israel: The case of affirmative action for women directors. *Women's Studies International Forum, 26*(2), 109-128.

Jackson, J. (2001). Women middle manager's perception of the glass ceiling. *Women in Management Review, 16*(1), 30-41.

Jeong, H., Néda , Z., & Barabási, A.-L. (2003). Measuring preferential attachment in evolving networks. *Europhysics Letters, 61*(4), 567-572.

Johnson, J., Daily, C., & Ellstrand, A. (1996). Boards of directors: A review and research agenda. *Journal of Management, 22*(3), 409-438.

Joy, L. (2008). Women board directors in the United States: an eleven year retrospective. In S. Vinnicombe, V. Singh, R. J. Burke, D. Bilimoria & M. Huse (Eds.), *Women on corporate board of directors: International research and practice* (pp. 15-23). UK: Edward Elgar Publishers.

Joy, L., Carter, N., Wagner, H., & Narayanan, S. (2007). *The Bottom Line: Corporate performance and women's representation on boards*. New York: Catalyst.

Kang, H., Cheng, M., & Gray, S. (2007). Corporate governance and board composition: Diversity and independence of Australian boards. *Corporate Governance: An International Review, 15*(2), 194-207.

Kantor, R. M. (1977). *Men and Women of the Corporation*. New York: Basic Books.

Kazmier, L. (1976). *Theory and problems of business statistics*. US: McGraw-Hill Book Company Ltd

Keele, R. (1986). Mentoring or networking? Strong and weak ties in career development. In L. Moore (Ed.), *Not as far as you think: The realities of working women* (pp. 53-68). US: Lexington Books.

Keiger, D. (2007). Looking for the next big thing. *Notre Dame Magazine*, from http://www.nd.edu/~alb/Public%20Relations/NextBigThing(Barabasi)_NDMag,Vol36,No1,49-53(Sprg07).pdf

Kelly, J., & Gennard, J. (2000). Getting to the top: career paths of personnel directors. *Human Resource Management Journal, 10*(3), 22-37.

Kiel, G., & Nicholson, G. (2006). Multiple directorships and corporate performance in Australian listed companies *Corporate Governance, 14*(6), 530-546.

Kilduff, M., Angelmar, R., & Mehra, A. (2000). Top management-team diversity and firm performance: Examining the role of cognitions *Organization Science, 11*(1), 21–34.

Klenke, K. (1996). *Women and leadership: A contextual perspective*. New York: Springer.

Knight, D., Pearce, C., Smith, K. A., Olian, J., Sims, P., Smith, K. G., et al. (1999). Top management team diversity, group process, and strategic consensus,. *Strategic Management Journal, 20*(5), 445–465.

Kochen, M. (Ed.). (1989). *The small-world*. US: Ablex Publishing.

Kogut, B., & Walker, G. (2001). The small-world of Germany and the durability of national networks. *American Sociological Review, 66*(3), 317-335.

Konrad, A., Kramer, V., & Erkut, S. (2008). Critical mass: The impact of three or more women on corporate boards. *Organizational Dynamics, 37*(2), 145-164.

Kramer, V., Konrad, A., & Erkut, S. (2006). Critical mass on corporate boards: Why three or more women enhance governance [Electronic Version]. *Wellesley Centers for Women's Publications* Retrieved 9 September 2009, from http://www.wcwonline.org/pubs

Kuhn, T. (1962) *The structure of scientific revolutions.* Chicago: The University of Chicago Press.

Kulich, C., Trojanowski, G., Ryan, M., Haslam, S. A., & Renneboog, L. (2008). Who gets the carrot and who gets the stick? Evidence of gender disparities in executive remuneration. *Academy of Management Proceedings,* 1-6.

Lazarfield, P., & Merton, R. (1954). Friendship as a social process: A substantive and methodological analysis. In M. Berger (Ed.), *Freedom and control in modern society* (pp. 18-66). US: Van Nostrand.

Le Blanc, R., & Gillies, J. (2005). *Inside the boardroom: How boards really work and the coming revolution in corporate governance*. Canada: John Wiley & Sons Canada Ltd.

Li, C., & Wearing, B. (2004). Between glass ceilings: female non-executive directors in UK quoted companies. *International Journal of Disclosure and Governance, 1*(4), 355-371

Lin, N. (1989). The smallworld technique as a theory-construction tool. In M. Kochen (Ed.), *The Small-world*. US: Ablex Publishing.

Linehan, M., & Walsh, J. (2000). Beyond the traditional linear view of international managerial careers: a new model of the senior female career in an international context. *Journal of European Industrial Training, 24*(2/3/4), 178-189.

Lusseau, D., & Newman, M. (2004). Identifying the role that animals play in their social networks. *Proceedings of the Royal Society of London. B (Supplement) 271*, S477–S481.

Lynall, M., Golden, B., & Hillman, A. (2003). Board composition from adolescence to maturity: a multitheoretic view. *Academy of Management Review 28*(3), 416-431.

Maddock, S., & Parkin, D. (1993). Gender cultures. *Women in Management Review, 8*(2), 3-9.

Mandelbrot, B. (1999). A Multifractal walk down Wall Street. *Scientific American, 280*(2), 70-73.

Matheson, A. (1997). *Practical beekeeping in New Zealand* (3rd ed.). Wellington: GP Publications.

Mattis, M. (2000). Women corporate directors in the United States. In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities*. Dordrecht: Kluwer Academic Publishers.

Mavin, S. (2006). Venus envy: problematizing solidarity behaviour and queen bees. *Women in Management Review, 21*(4),264-276*.*

McCormick Hyland, M., & Marcellino, P. (2002). Examining gender on corporate boards: A regional study. *Corporate Governance, 2*(4), 24-31.

McGregor, J. (2000). The New Zealand experiment - training to be on board as a director. In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities* (pp. 129-144). Dordrecht: Kluwer Academic Publishers.

McGregor, J. (2008). *New Zealand Census of Women's Participation.* Human Rights Commission and New Zealand Centre for Women's Leadership New Zealand: Massey University.

McGregor, J. (2003). Girl power: Double jeopardy or diversity in action behind boardroom doors in New Zealand. *Women in Management Review, 18*(7), 369-375.

McGregor, J. (2004). Women in management in New Zealand In M. Davidson & R. Burke (Eds.), *Women in management worldwide: Facts, figures and analysis* (pp. 211-224). USA: Ashgate Publishing Ltd.

McGregor, J. (2007). Surprise! Women on the board earn more. *Business Week November 8*, from http://www.businessweek.com/bwdaily/dnflash/content/nov2007/db2007118_811986.htm?campaign_id=nws_insdr_nov9&link_position=link4

McGregor, J., & Fountaine, S. (2006). *New Zealand Census of Women's Participation.* Human Rights Commission and New Zealand Centre for Women's Leadership. New Zealand: Massey University.

McGregor, J., & Olsson, S. (2004). *New Zealand census of women's participation in governance and professional life*. Massey University: Human Rights Commission.

McGregor, J., Thompson, M., & Dewe, P. (1994). Women in management in New Zealand: a benchmark survey. *Women in Management Series, Paper 19*.

McKelvey, B. (2004). "Simple rules" for improving corporate IQ: Basic lessons from complexity science. In P. Adriani & G. Passionate (Eds.), *Complexity theory and the management of networks: Proceedings of the workshop on Organisational networks as distributed systems of knowledge*. UK: Imperial College Press.

McPherson, M., & Smith-Lovin, L. (1982). Women and weak ties: Differences by sex in the size of voluntary organizations. *The American Journal of Sociology, 87*(4), 883-904.

McPherson, M., & Smith-Lovin, L. (1987). Homophily in voluntary organizations: Status distance and the composition of face-to-face groups. *American Sociological Review, 52*(3), 370-379.

McPherson, M., Smith-Lovin, L., & Cook, J. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology, 27*, 415-444.

Meyerson, D. (2001). Radical Change: The quiet way. *Harvard Business Review, 79*(9), 92-100.

Michels, R. (1911). *Political parties: A sociological study of the oligarchical tendencies of modern democracies*. Translated by Eden and Cedar Paul. Ontario: Batoche Books. 2001, from http://socserv.mcmaster.ca/econ/ugcm/3ll3/michels/polipart.pdf

Micklethwait, J., & Wooldridge, A. (2003). The company: A short history of a revolutionary idea. New York: Modern Library.

Milgram, S. (1967). The small-world problem. *Psychology Today, 1*(1), 60-67.

Miller, C., Burke, L., & Glick, W. (1998). Cognitive diversity among upper-echelon executives: Implications for strategic decision processes. *Strategic Management Journal,* 19, 39-58.

Milliken, F., & Martins, L. (1996). Searching for common threads: Understanding the multiple effects of diversity in organizational groups. *Academy of Management Review, 21*, 402–433.

Mizruchi, M. (1996). What do interlocks do? An analysis, critique, and assessment of research on interlocking directorates. *Annual Review of Sociology*, 22, 271-298.

Moen, P. (2005). Beyond the career Mmystique: "Time in," "Time out," and "Second Acts". *Sociological Forum, 20*(2), 189-208.

Moore, G. (1988). Women in elite positions: Insiders or outsiders? *Sociological Forum, 3*(4), 566-585.

Morgan, L. (1998). Glass-ceiling effect or cohort effect? A longitudinal study of the gender earnings gap for engineers, 1982 to 1989. *American Sociological Review, 63*(4), 479-493.

Morrison, A., White, R., & Van Velsor, E. (1987). Breaking the glass ceiling: can women reach the top of America's largest corporations? USA: Addison-Wesley Publishing Company.

Murray, G. (2001). Interlocking directorates: What do they tell about corporate power in Australia? *Journal of Australian Political Economy, 47*, 5–26.

Newman, M. (2001). Clustering and preferential attachment in growing networks. from arXiv:cond-mat/0104209v1 [cond-mat.stat-mech]

Newman, M. (2002). Assortative Mixing in Networks. *Physical Review Letters, 89*(20), 208701

Newman, M. (2003a). Mixing patterns in networks. *Physical Review E, 67*, 026126

Newman, M. (2003b). Properties of highly clustered networks. *Physical Review E, 68*, 026121

Newman, M. (2003c). The structure and function of complex networks. *SIAM Review, 45*(2), 167-256.

Newman, M. (2005a). A measure of betweenness centrality based on random walks. *Social Networks, 27*(1), 39-54.

Newman, M. (2005b). Power laws, Pareto distributions and Zipf's law. *Contemporary Physics, 46*(5), 323-352

Newman, M., Barabási, A.-L., & Watts, D. (Eds.). (2006). *The structure and dynamics of networks*. Princeton: Princeton University Press.

Newman, M., & Park, J. (2003). Why social networks are different from other types of networks. Physical Review E, 68, 036122.

Newman, M., Strogatz, S., & Watts, D. (2001). Random graphs with arbitrary degree distributions and their applications. *Physical Review E, 64*, 026118

Nguyen, H., & Faff, R. (2007). Impact of board size and board diversity on firm value: Australian evidence. *Corporate Ownership & Control, 4*(2), 24-32.

Nicolson, P. (1996). *Gender, Power and Organisation: A Psychological Perspective*. London: Routledge.

Oliver, C. (1990). Determinants of interorganizational relationships: Intergration and future directions. *Academy of Management Review, 15*(2), 241-265.

Pajo, K., McGregor, J., & Cleland, J. (1997). Profiling the pioneers: women directors on New Zealand's corporate boards. *Women in Management Review, 12*(5), 174-181.

Pfeffer, J., & Salancik, G. (1978). *The external control of organizations: A resource dependence perspective* New York: Harper & Row.

Pelled, L., Eisenhardt, K., & Xin, K. (1999). Exploring the Black Box: An Analysis of Work Group Diversity, Conflict and Performance. *Administrative Science Quarterly, 4*(1), 1-28.

Polzer, J., Milton, L., & Swann, W. (2002). Capitalizing on Diversity: Interpersonal Congruence in Small Work Groups. *Administrative Science Quarterly, 47*(2), 296-324

Powell, G. N. (1999). Reflections on the glass ceiling: Recent trends and future prospects. In G. N. Powell (Ed.), *Handbook of Gender and Work* (pp. 325-346). London: Sage.

Powell, G., & Mainiero, L. (1992). Cross-currents in the river of time:conceptualising the complexities of women's careers. *Journal of Management, 18*(2), 215-237.

Pringle, J., & Olsson, S. (2002). Sites of hope and success? A cross perceptual study of executive women in New Zealand public and private sectors. New Zealand Centre for Women and Leadership, Massey University working papers.

Quayle, A., Siddiqui, A., & Jones, S. (2006). Modeling network growth with assortative mixing. *European Physical Journal B 50*, 616-630.

Ragins, B., Townsend, B., & Mattis, M. (1998). Gender gap in the executive suite: CEOs and executive females report on breaking the glass ceiling. *Academy of Management Executive, 12*(1), 28-42.

Renshaw, J. R. (1999). Kimono in the boardroom: the invisible evolution of Japanese women managers. New York: Oxford University Press.

Ridgeway, C. (2001). Gender, status and leadership. *Journal of Social Issues, 57*(4), 637-655.

Riger, S., & Galligan, P. (1980). Women in management: An exploration of competing paradigms. *American Psychologist, 35*(10), 902-910.

Robins, G., & Alexander, M. (2004). Small-worlds among interlocking directors: Network structure and distance in bipartite graphs. *Computational & Mathematical Organization Theory, 10*, 69-94.

Romanelli, E., & Tushman, M. (1994). Organizational transformation as punctuated equilibrium: An empirical test. *Academy of Management Journal, 37*, 1141-1166.

Rose, C. (2007). Does female board representation influence firm Pperformance? The Danish evidence. *Corporate Governance: An International Review, 15*(2), 404–413.

Rosener, J. (1995). *America's Competitive Secret: Utilizing Women as a Management Strategy.* New York: Oxford University Press.

Ross-Smith, A., & Bridge, J. (2008). 'Glacial at best': women's progress on corporate boards in Australia. In S. Vinnicombe, V. Singh, R. J. Burke, D. Bilimoria & M. Huse (Eds.), *Women on Corporate Board of Directors: International Research and Practice* UK: Edward Elgar Publishers.

Roy, M., Fox, M., & Hamilton, R. (1994). Board size and potential corporate and director interlocks in Australasia 1984–1993. *Australian Journal of Management, 19*(2), 201-217.

Ryan, M., & Haslam, S. (2005). The glass cliff: Evidence that women are over-represented in precarious leadership positions. *British Journal of Management, 16*(2), 81-90.

Ryan, M., & Haslam, S. (2007). The glass cliff: Exploring the dynamics surrounding the appointment of women to precarious leadership positions. *Academy of Management Review, 32*(2), 549-572.

Saloner, J. (1985). Old boy networks as screening mechanisms. *Journal of Labour Economics, 3*(3), 255-267.

Sassen, S. (2001). The global city: Strategic site/new frontier? . *Seminar - New Delhi*(503), 29-39.

Schelling, T. (1978). *Micromotives and macrobehavior*. New York: Norton.

Scott, J. (2000). *Social network analysis: a handbook* (2nd ed.). London: Sage Publications Inc.

Sealy, R., Singh, V., & Vinnicombe, S. (2007). *The Female FTSE Report 2007*: Cranfield, UK.

Sealy, R., Vinnicombe, S., & Singh, V. (2008). The Female FTSE Report 2008: A Decade of Delay: Cranfield, UK.

Shafir, G., & Peled, Y. (1998). Citizenship and stratification in an ethnic democracy. *Ethnic and Racial Studies, 21*(3), 408-427.

Shrader, C., Blackburn, V., & Iles, P. (1997). Women in management and firm financial performance: an exploratory study. *Journal of Managerial Issues, 9*(3), 355-372.

Sheridan, A. (2002). What you know and who you know: "Successful" women's experience. *Career Development International 7*(4), 203-210.

Sheridan, A., & Milgate, G. (2005). Accessing Board Positions: a comparison of female and male board members' views. *Corporate Governance, 13*(6), 847-855.

Shilton, J., McGregor, J., & Tremaine, M. (1996). Feminizing the boardroom: a study of the effects of corporatization on the number and status of women directors in New Zealand companies. *Women in Management Review, 11*(3), 20-26.

Siegel, S. (1956). *Nonparametric statistics for the behavioural sciences: International student edition*. Japan: McGraw Hill Book Company Inc.

Singh, V., Terjesen, S., & Vinnicombe, S. (2008). Newly appointed directors in the boardroom: How do women and men differ? *European Management Journal, 26*(1), 48–58.

Singh, V., Vinnicombe, S., & Johnson, P. (2001). Women Directors on Top UK Boards. *Corporate Governance, 9*, 206-216.

Singh, V., & Vinnicombe, S. (2005). *The Female FTSE Report 2004*: Cranfield, UK.

Song, C., Havlin, S., & Makse, H. (2005). Self-similarity of complex networks. *Nature, 433*, 392-395.

South African Women's Charter. (1954). Adopted at the founding conference of the Federation of South African Women [Electronic Version], from http://www.anc.org.za/ancdocs/history/women/wcharter.html#1

Stablein, R., Cleland, P., Mackie, B., & Reid, D. (2005). New Zealand Exchange Limited (NZX) Boards And Directors: It Is A Small-world After All. Paper presented at the

18th Annual Conference of the Australian and New Zealand Academy of Management.

Staines, G., Tavris, C., & Jayaratne, T. (1974). The queen bee syndrome. *Psychology Today, 7*(8), 55-60.

Still, L. (2006). Where are the women in leadership in Australia? *Women in Management Review, 21*(3), 180-194.

Strogatz, M. (2001). Exploring complex networks. *Nature, 410*(6825), 268-276

Strogatz, S. (2003). *Sync: The emerging science of spontaneous order*. USA: Hyperion Books.

Sullins, P. (2000). The stained glass ceiling: career attainment for women clergy. *Sociology of Religion, 61*(3), 243-266.

Taleb, N. (2004). *Fooled by randomness: The hidden role of chance in life and in the markets* New York: Random House Publishing Group.

Taleb, N. N. (2007). *The black swan: the impact of the highly improbable*. New York: Random House.

Talmud, I., & Izraeli, D. (1999). The relationship between gender and performance issues of concern to directors: correlates or institution? *Journal of Organizational Behaviour, 20*, 459-474.

Tan, M., & Keong, L. (2006). Directorship Interlocks in Singapore: A social network analysis. *Corporate Ownership & Control, 4*(1), 65-76.

Taylor, M. (2001). *The moment of complexity: Emerging network culture*. Chicago: The University of Chicago Press.

Taylor, S. (2000). Review of Kimono in the Boardroom: The Invisible Evolution of Japanese Women Managers, by Jean R. Renshaw. *Academy of Management Review* 25(3), 670-679.

Terjesen, S., & Singh, V. (2008). Female Presence on Corporate Boards: A Multi-Country Study of Environmental Context. *Journal of Business Ethics 83*(1), 55-63.

Terjesen, S., Sealy, R., & Singh, V. (2009). Women Directors on Corporate Boards: A Review and Research Agenda. *Corporate Governance: An International Review, 17*(3), 320–337.

Thomson, P., & Graham, J. (2005). *A Woman's Place is in the Boardroom*

New York: Palgrave McMillan

Travers, J., & Milgram, S. (1969). An Experimental Study of the Small-world Problem. *Sociometry, 32*(4), 425-443.

Travis, G., & Collins, H. (1991). New light on old boys: Cognitive and institutional particularism in the peer review system *Science, Technology, & Human Values, 16*(3), 322-341.

Useem, M. (1984). *The inner circle: Large corporations and the rise of business political activity in the U.S. and U.K.* US: Oxford University Press.

Van der Walt N., & Ingley C. (2003). "Board Dynamics and the Influence of Professional Background, Gender and Ethnic Diversity of Directors". *Corporate Governance: An International Review*, 11(3), p 218-234.

Vinnicombe, S., Singh, V., Burke, R., Bilimoria, D., & Huse, M. (Eds.). (2008). *Women on corporate board of directors: International research and practice*. UK: Edward Elgar Publishing Ltd.

Vinnicombe, S., Singh, V., & Sturges, J. (2000). Making it to the top in Britain. In R. Burke & M. Mattis (Eds.), *Women on corporate boards of directors: International challenges and opportunities* (pp. 57-73). Dordrecht: Kluwer Academic Publishers**.**

Waldrup, M. (1992). *Complexity:The emerging science at the edge of order and chaos*. New York: Simon & Schuster.

Walker, G., & Borrowdale, A. (1994). Interlocking directorships in New Zealand publically listed companies. *Company and Securities Law Journal, 12*, 331-335.

Wang, P., González, M., Hidalgo, C., & Barabási, A.-L. (2009). Understanding the spreading patterns of mobile phone viruses. *Science, 324*(5930), 1071-1076.

Watts, D. (1999a). *Small-worlds: The dynamics of networks between order and randomness.* USA: Princeton University Press.

Watts, D. (1999b). Networks, Dynamics and the Small-world Phenomena. *American Journal of Sociology, 105*(2), 493–527.

Watts, D. (2003). *Six Degrees: The science of a connected age* USA: WW Norton & Company

Watts, D. (2004). The "new" science of networks. *Annual Review of Sociology, 30*, 243-270.

Watts, D., & Strogatz, S. (1998). Collective Dynamics of ‘small-world” networks. *Nature, 393*, 4.

Westphal, J., & Khanna, P. (2003). Keeping directors in line: Social distancing as a control mechanism in the corporate clite. *Administrative Science Quarterly,* 48, 361-398.

Westphal, J., & Stern, I. (2006). The other pathways to the boardroom: How interpersonal influence behaviour can substitute for the elite credentials and demographic majority status in gaining access to the board appointments. *Administrative Science Quarterly, 51*, 169-204.

Westphal, J., & Stern, I. (2007). Flattery will get you everywhere (especially if you are a male Caucasian): How ingratiation, boardroom behaviour, and demographic minority status affect additional board appointments at U.S. companies. *Academy of Management Journal, 50*(2), 267–288.

Westphal, J., & Zajac, E. (1995). Who Shall Govern? CEO/Board Power, Demographic Similarity, and New Director Selection. *Administrative Science Quarterly, 40*, 60-83.

White, D., & Borgatti, S. (1994). Betweenness centrality measures for directed graphs. *Social Networks, 16*, 335-346.

Williams, C. (1992). The Glass Escalator: Hidden Advantages for Men in the "Female" Professions. *Social Problems, 39*(3), 253-267.

Williams, G. (1997). *Chaos Theory Tamed*. Washington: Joseph Henry Press.

Williams, R., & Lusseau, D. (2006). A killer whale social network is vulnerable to targeted removals. *Biology Letters, 2*(4), 497-500.

Wilson, E. (1998). *Consilience: The unity of knowledge*. New York: Alfred A Knopf Inc.

Wilson, F. (2004). Women in management in the United Kingdom. In M. Davidson & R. Burke (Eds.), *Women in management worldwide*. UK: Ashgate Publishing Ltd.

Wilson-Kovacs, D., Ryan, M., & Haslam, S. (2006). The glass-cliff: women’s career paths in the UK private IT sector. *Equal Opportunities International, 25*(8), 674-687.

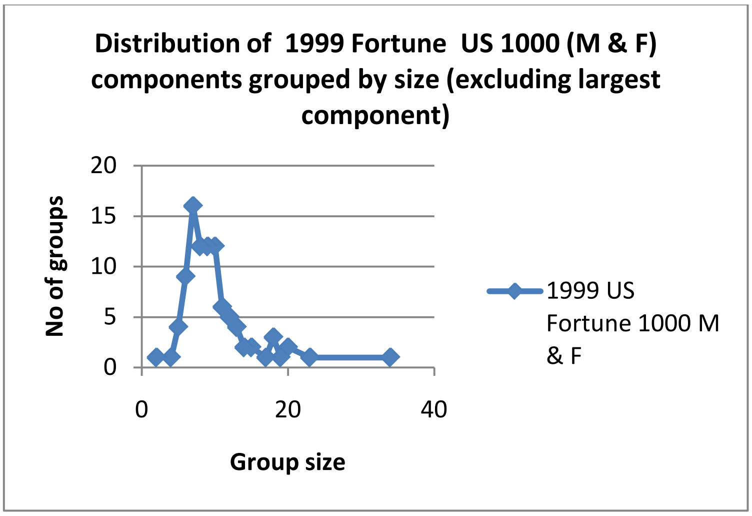
Wittenberg-Cox, A., & Maitland, A. (2008). Why women mean business: Understanding the emergence of our next economic revolution. UK: John Wiley & Sons Ltd.Woodward, D. (2007). *Queen Bee: Biology, rearing and breeding*. New Zealand: Otago University Print.

Zelanchowski, D., & Bilimoria, D. (2003). The experience of women corporate inside directors on the boards of Fortune 1,000 firms. *Women in Management Review, 18*(7), 376-381.

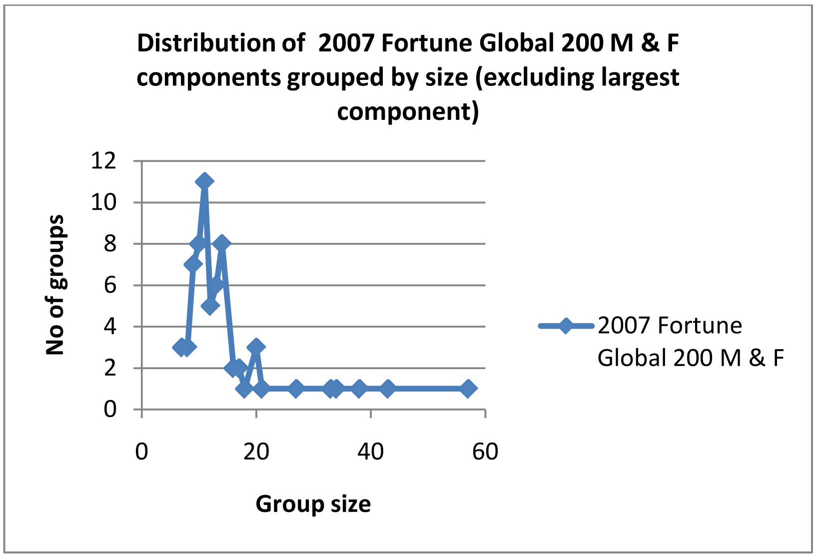
Zonta Women on Board (1986). Report of the Status of Women Committee of the Zonta Club of Auckland.

Appendix One Examples of network components grouped by size showing right tailed distributions and power law distributions

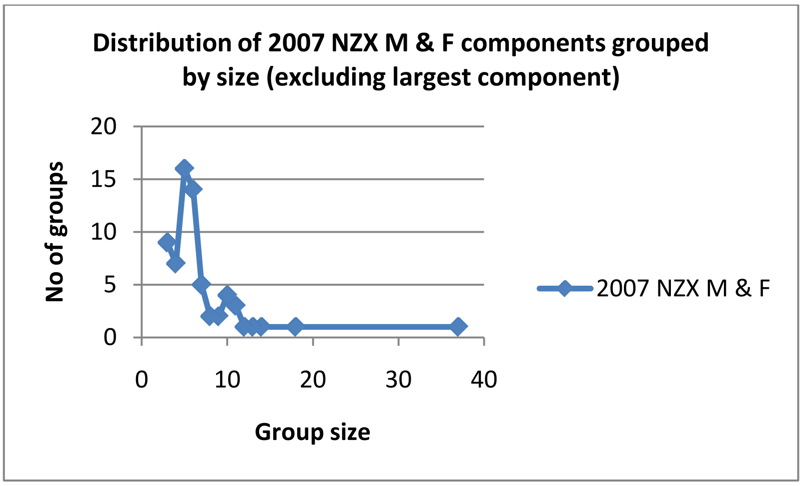
1999 Fortune US 1000 (M & F) components	
Group Size	Number of Groups
6705	1
34	1
23	1
20	2
19	1
18	3
17	1
15	2
14	2
13	4
12	5
11	6
10	12
9	12
8	12
7	16
6	9
5	4
4	1
2	1
96 groups of 7644 directors	



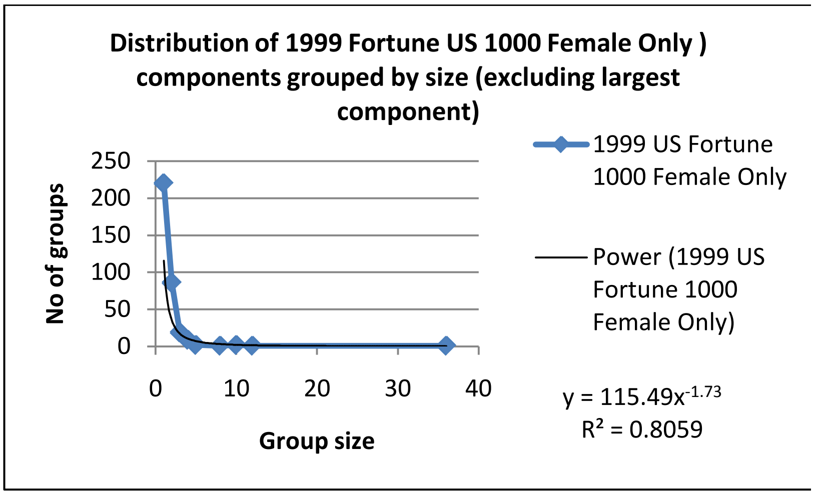
2007 Fortune Global 200 (M & F) Components	
Group Size	Number of Groups
1582	1
57	1
43	1
38	1
34	1
33	1
27	1
21	1
20	3
18	1
17	2
16	2
14	8
13	6
12	5
11	11
10	8
9	7
8	3
7	3
67 groups of 2538 directors	



2007 NZX (M & F) components	
Group Size	Number of Groups
449	1
37	1
18	1
14	1
13	1
12	1
11	3
10	4
9	2
8	2
7	5
6	14
5	16
4	7
3	9



1999 Fortune US 1000 Female only	
Group Size	Number of Groups
88	1
36	1
12	1
10	2
8	1
5	2
4	9
3	19
2	86
1	220
342 groups of 659 directors	



Appendix Two Director and seat spreads

Table 2.1
Director numbers for all directors in the Fortune 1000 director network; the 2004 and 2007 Fortune Global 200 director network; the 2004, 2005 and 2007 NZX director network.

All directors	No of seats held	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	1	5553	483	2053	228	2103	245	775	46	745	56	722	60
	2	944	102	139	26	144	27	89	9	97	8	86	5
	3	330	47	20	2	12	3	29	2	30	2	14	2
	4	104	17	9		3		10	0	13	1	5	
	5	38	8	1		0		4		4		3	
	6	11	1	0		0		1		1		2	
	7	3	1	1		1		0		1			
	8	1											
	9	1											
	Totals	6985	659	2223	256	2263	275	908	57	891.1429	67	832	67

Table 2.2
Director numbers for largest connected component only directors in the Fortune 1000 director network; the 2004 and 2007 Fortune Global 200 director network; the 2004, 2005 and 2007 NZX director network.

Largest connected component directors only	No of seats held	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	1	4685	425	1217	171	1214	187	472	31	485	43	319	30
	2	938	100	130	23	137	26	81	4.5	88	8	67	5
	3	327	47	19	2	11	3	29	1	30	2	12	2
	4	103	17	9		3		10		13	1	5	
	5	38	7	1		0		4		4		3	
	6	11	1	0		0		1		1		2	
	7	3	1	1		1		0		0			
	8	1								1			
	9	1											
	Totals	6107	598	1377	196	1366	216	597	36.5	622	54	408	37
% single seat directors		76.7	71.1	88.4	87.2	88.9	86.6	79.1	84.9	78.0	79.6	78.2	81.1
% connector directors		23.3	28.9	11.6	12.8	11.1	13.4	20.9	15.1	22.0	20.4	21.8	18.9

Table 2.3
Seat spread for all directors in the Fortune 1000 director network; the 2004 and 2007 Fortune Global 200 director network; the 2004, 2005 and 2007 NZX director network for the full network.

All seats	No of seats held	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	5553	483	2053	228	2103	245	775	46	745	56	722	60
	2	1888	204	278	52	288	54	178	18	194	16	172	10
	3	990	141	60	6	36	9	87	6	90	6	42	6
	4	416	68	36		12		40		52	4	20	
	5	190	40	5		0		20		20		15	
	6	66	6	0		0		6		6		12	
	7	21	7	7		7				0			
	8	8								8			
	9	9											
	Totals	9141	949	2439	286	2446	308	1106	70	1115	82	983	76

Table 2.4

Seat spread for largest connected component directors in the Fortune 1000 director network; the 2004 and 2007 Fortune Global 200 director network; the 2004, 2005 and 2007 NZX director network.

Largest component seats only	No of seats held	1999 Fortune US 1000		2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2005 NZX		2007 NZX	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	1	4685	425	1217	171	1214	187	472	31	485	43	319	30
	2	1876	200	260	46	274	52	162	9	176	16	134	10
	3	981	141	57	6	33	9	87	3	90	6	36	6
	4	412	68	36		12		40		52	4	20	
	5	190	35	5		0		20		20		15	
	6	66	6	0		0		6		6		12	
	7	21	7	7		7				0			
	8	8								8			
	9	9											
	Totals	8248	882	1582	223	1540	248	787	43	837	69	536	46
% single seat directors		56.8	48.2	76.9	76.7	78.8	75.4	60.0	72.1	57.9	62.3	59.5	65.2
% connector directors		43.2	51.8	23.1	23.3	21.2	24.6	40.0	27.9	42.1	37.7	40.5	34.8

Table 2.5
Director numbers in the 2004 and 2007 Fortune Global 200;
and the 2004 and 2007 NZX continuing director networks for the largest component only

Continuing directors largest component only	**No of seats held**	**2004 Fortune Global 200**		**2007 Fortune Global 200**		**2004 NZX**		**2007 NZX**	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
	1	579	100	618	110	196	13	160	9
	2	100	18	107	18	58	7	53	1
	3	13	1	9	3	26	2	15	3
	4	8		3		10		5	
	5	1		0		4		3	
	6	0		0		1		2	
	7	1		1					
	Totals	701	119	738	131	295	22	238	13

Table 2.6

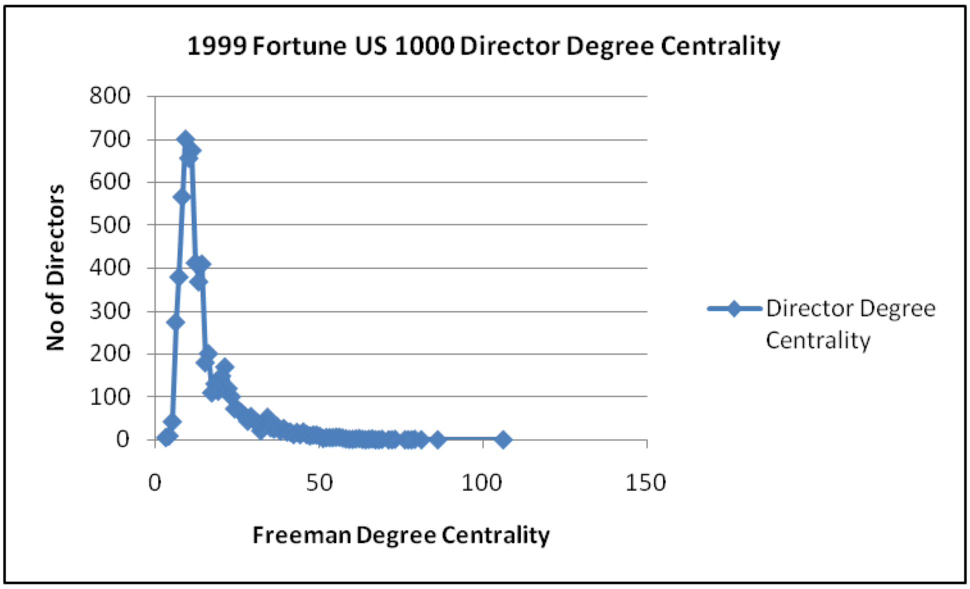
Seat spreads in the 2004 and 2007 Fortune Global 200;
and the 2004 and 2007 NZX continuing director networks for the largest component only

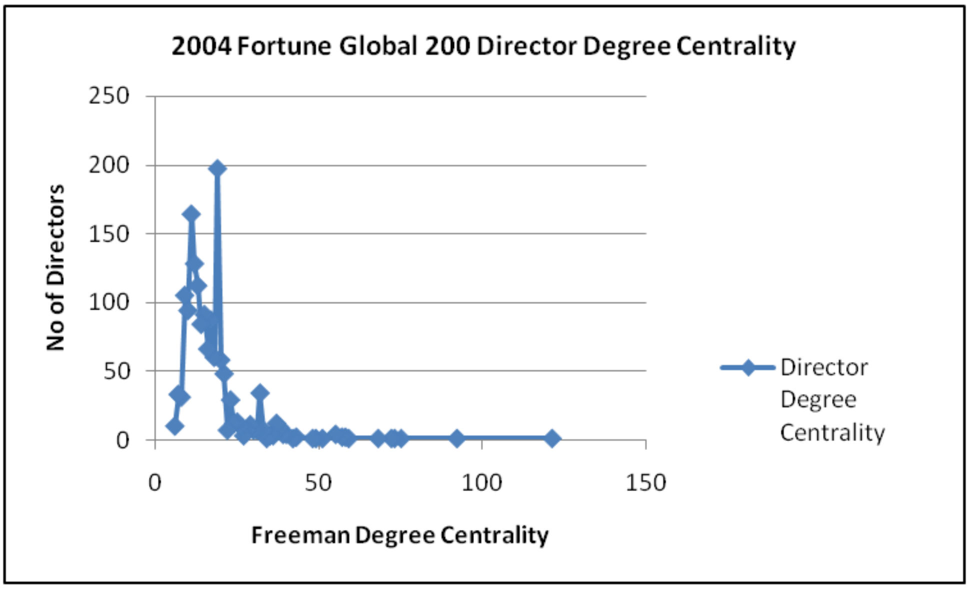
Seats of continuing directors largest component only	No of seats held	2004 Fortune Global 200		2007 Fortune Global 200		2004 NZX		2007 NZX	
		Male	Female	Male	Female	Male	Female	Male	Female
	1	579	100	618	110	196	13	160	9
	2	200	36	214	36	116	14	106	2
	3	39	3	27	9	78	6	45	9
	4	32		12		40			
	5	5		0		20			
	6	0		0		6			
	7	7		7					
	Totals	862	139	878	155	456	33	311	20

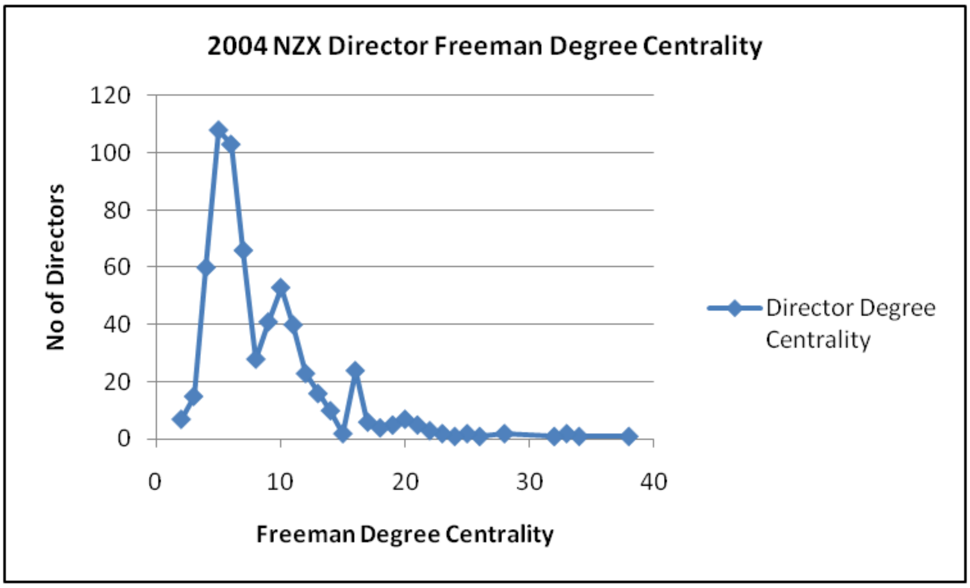
Table 2.7
Seat spreads in the 2007 Fortune Global 200 Random halves and the NZX random halves for the largest component only

Seats of random directors largest connected component only	No s of seats	2007 Fortune Global 200 1st Half	2007 Fortune Global 200 2nd Half	2007 NZX 1st Half	2007 NZX 2nd Half
	1	1174	1174	395	387
	2	168	174	88	94
	3	27	18	24	24
	4	8	4	5	20
	5		7	12	10
	Totals	1377	1377	524	535

Appendix Three Examples of directors' Freeman degree centrality grouped by number of directors per degree, showing right tailed distributions.






2004 NZX Director Freeman Degree Centrality
No of Directors
120
100
80
60
40
20
0
0
10
20
30
40
Freeman Degree Centrality
Director Degree Centrality

Appendix Four Reworking Hypothesis 3 from Hillman, Cannella and Harris (2002) Women and Racial Minorities in the Boardroom: How do directors differ? *Journal of Management, 28*(6), 747-763.

Step 1

Refer to Table 3 from Hillman et al., 2002 and other data given in this paper

1993 Fortune 1000 Directors	African American Female	African American Male	White Female Sample	White Male Sample	Total
One Board	2	35	43	33	113
Two Boards	5	13	15	25	58
Three Boards	2	7	13	16	38
Four or More Boards	7	16	18	25	66
Total	16	71	89	99	275

Step 2

Summary 1993 Fortune 1000 (from Hillman et al., 2002)

Includes sampled White directors	All Males	All Females
One Board	68	45
Two Plus Boards	102	60
Total	170	105

Hillman et al. (2002) chi square=11.57 for df=9 Not significant.

Reworked Square=0.13 df=1 Yates correction applied. Not significant.

Expected ratio of men to women directors is 1.6.

Step 4

Re-calculate Male Female Ratio from full network data provided by Hillman et al. (2002)

Total Directors =7422

Female Directors =559 (7.53%)

African American directors =108 (1.45%)

Female African American directors =16

Male African American directors =71

Step 5

Calculate expected values based on provided data

Ratio of men to women directors is 12.2	Male	Female
African American	100	8
White	6763	551
Total (7422)	6863	559

Step 6

Revised Null Hypothesis: African American female directors are not more likely serve on multiple boards than African American male directors

To determine expected values compare to actual data

Used by Hillman et al (2002)
Ratio of African American Men to African American Women directors is 4.4 to 1

	Male	Female
African American	71	16
White	99	89
Total (275)	170	105

Using only African American director data,
calculate twice with an expected ratio of 4.4 and 12.2

	African American Male	**African American Female**	**Total**
One Board	35	2	37
Two Plus Boards	36	14	50
Total	71	16	87

Chi Square (expected ratio of 4.4) x^2=5.8
Significant p< .05 for df=1 Yates correction applied
Chi Square (expected ratio of 12.2) x^2=26.9
Signifcant p< .001 for df=1 Yates correction applied

Conclusion
Revised null hypothesis is rejected.
In 1993 Fortune 1000 companies, female African American directors are more likely to sit on multiple boards than male African American directors

Appendix Five Actual to expected seat spreads by gender from a non-symmetrical bifurcation process

Tables A5.1-6 Expected to actual seat spreads for Fortune US 1000, Fortune Global 200 and NZX datasets

Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

1999 US Fortune 1000 Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	4685	425	5110	4685	425	5110	4020.0	5110
2	1876	200	2076	1816	194	2010	2010.0	7120.00
3	981	141	1122	879	126	1005	1005.0	8125.00
4	412	68	480	428	72	500	502.5	8627.50
5	190	35	225	210	40	250	251.3	8878.75
6	66	6	72	120	6	126	125.6	9004.38
7	21	7	28	49	14	63	62.8	9067.19
8	8		8	32		32	31.4	9098.59
9	9		9	18		18	15.7	9114.30
	8248	882	9130	8237	877	9114		9114.30
Seat spread parameter = 2								

2004 Fortune Global 200 Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	1217	171	1388	1217	171	1388	417.0	1388
2	260	46	306	178	30	208	208.5	1596.50
3	57	6	63	93	12	105	104.3	1700.75
4	36		36	52		52	52.1	1752.88
5	5		5	25		25	26.1	1778.94
6				12		12	13.0	1791.97
7	7		7	7		7	6.5	1798.48
Total	1582	223	1805	1584	213	1797		1798.48
Seat spread parameter = 2								

2007 Fortune Global 200 Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	1214	187	1401	1214	187	1401	387.0	1401
2	274	52	326	163	31	194	193.5	1594.50
3	33	9	42	76	21	97	96.8	1691.25
4	12		12	48		48	48.4	1739.63
5				24		24	24.2	1763.81
6				12		12	12.1	1775.91
7	7		7	6		6	6	1781.95
Total	1540	248	1788	1543	239	1782		1781.95
Seat spread parameter = 2								

2004 NZX Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	472	31	503	472	31	503	327.0	503
2	162	9	171	154	10	164	163.5	666.50
3	87	3	90	78	3	81	81.8	748.25
4	40		40	40		40	40.9	789.13
5	20		20	20		20	20.4	809.56
6	6		6	12		12	10.2	819.78
7							5.1	824.89
Total	787	43	830	777	44	820		824.89
Seat spread parameter = 2								

2005 NZX Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	485	43	528	485	43	528	370.0	528
2	176	16	192	170	14	185	185.0	713.00
3	90	6	96	87	6	93	92.5	805.50
4	52	4	56	40	4	44	46.3	851.75
5	20		20	25		25	23.1	874.88
6	6		6	12		12	11.6	886.44
7				7		7	5.8	892.22
Total	829	69	898	825	67	893		892.22
Seat spread parameter = 2								

2007 NZX Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	319	30	349	319	30	349	233.0	349
2	134	10	144	108	8	116	116.5	465.50
3	36	6	42	51	6	57	58.3	523.75
4	20		20	28		28	29.1	552.88
5	15		15	15		15	14.6	567.44
6	12		12	6		6	7.3	574.72
Total	536	46	582	527	44	571		574.72
Seat spread parameter = 2								

Tables A5.7-10 Expected to actual seat spreads for continuing Fortune Global 200 and NZX datasets.

Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

2004 FG200 Continuing Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	579	100	679	579	100	679	322.0	679
2	200	36	236	136	25	161	161.0	840.00
3	39	3	42	75	6	81	80.5	920.50
4	32		32	40		40	40.3	960.75
5	5		5	20		20	20.1	980.88
6	0		0	6		6	10.1	990.94
7	7		7	7		7	5.0	995.97
Total	862	139	1001	864	130	994		995.97
Seat spread parameter = 2								

2007 FG 200 Continuing Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distributio n**	**Cumulativ e total**
1	618	110	728	618	110	728	305.0	728
2	214	36	250	130	22	152	152.5	880.50
3	27	9	36	56	18	74	76.3	956.75
4	12		12	36		36	38.1	994.88
5	0		0	20		20	19.1	1013.94
6	0		0	6		6	9.5	1023.47
7	7		7	7		7	4.8	1028.23
Total	878	155	1033	873	150	1023		1028.23
Seat spread parameter =2								

2004 NZX Continuing Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	196	13	209	196	13	209	280.0	209
2	116	14	130	124	16	140	140.0	349.00
3	78	6	84	63	6	69	70.0	419.00
4	40		40	32		32	35.0	454.00
5	20		20	20		20	17.5	471.50
6	6		6	6		6	8.8	480.25
480.25	456	33	489	441	35	476		480.25
Seat spread parameter = 2								

2007 NZX Continuing Largest connected component								
Seat category	**Actual male seats**	**Actual female seats**	**Total actual seats**	**Expected male seats**	**Expected female seats**	**Total expected seats**	**Seats available for distribution**	**Cumulative total**
1	160	9	169	160	9	169	209.0	169
2	106	2	108	102	2	104	104.5	273.50
3	45	9	54	42	9	51	52.3	325.75
4	20		20	24		24	26.1	351.88
5	15		15	15		15	13.1	364.94
6	12		12	6		6	6.5	371.47
Total	358	20	378	349	20	369		371.47
Seat spread parameter = 2								

Tables A5.11-15 Expected to actual seat spreads for Fortune Global 200 and NZX datasets random halves.

Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2.

2007 Fortune Global 200 Random 1st Half. Largest connected component						
Seat category	**Actual directors**	**Actual seats**	**Expected directors**	**Expected seats**	**Seats available for distribution**	**Cumulative Total**
1	248	248	248	248	98.0	98.00
2	43	86	24	48	49.0	248.00
3	4	12	9	27	24.5	297.00
4			3	12	12.3	321.50
5			1	5	6.1	333.75
6					3.1	339.88
Total	295	346	285	340		339.88
Seat spread parameter = 2						

2007 Fortune Global 200 Random 2nd Half. Largest connected component						
Seat category	**Actual directors**	**Actual seats**	**Expected directors**	**Expected seats**	**Seats available for distribution**	**Cumulative Total**
1	506	506	506	506	189.0	189.00
2	81	162	47	94	94.5	506.00
3	6	18	15	45	47.3	600.50
4	1	4	8	32	23.6	647.75
5	1	5	1	5	11.8	671.38
6					5.9	683.19
Total	595	695	577	682		683.19
Seat spread parameter = 2						

2007 NZX Random 1st Half Largest component						
Seat category	**Actual directors**	**Actual seats**	**Expected directors**	**Expected seats**	**Seats available for distribution**	**Cumulative Total**
1	38	38	38	38	36.0	36.00
2	12	24	9	18	18.0	38.00
3	2	6	3	9	9.0	56.00
4	1	6	1	4	4.5	65.00
5					2.3	69.50
Total	53	74	51	69		69.50
Seat spread parameter = 2						

2007 NZX Random 2nd Half all seats Largest components						
Seat category	**Actual directors**	**Actual seats**	**Expected directors**	**Expected seats**	**Seats available for distribution**	**Cumulative Total**
1	42	42	42	42	39.0	39.00
2	9	18	10	20	19.5	42.00
3	4	12	3	9	9.8	61.50
4	1	4	1	4	4.9	71.25
5	1	5	1	5	2.4	76.13
6					1.2	78.56
Total	57	81	57	80		79.78
Seat spread parameter = 2						

Appendix Six Log-log plots of actual and expected seat spreads

Figure A6.1
2004 Fortune Global 200 director network Gender breakdown
for expected seats allocated in proportionto gender ratios of actual seats;
seat spread parameter = 2. Largest component only.

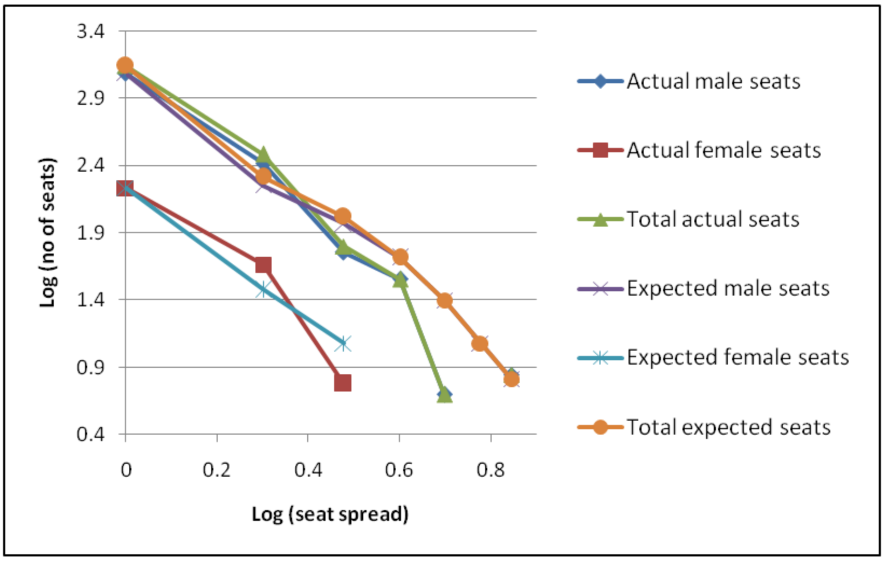


Figure A6.2
2004 NZX director network Gender breakdown
for expected seats allocated in proportion to gender ratios of actual seats;
seat spread parameter = 2. Largest component only.

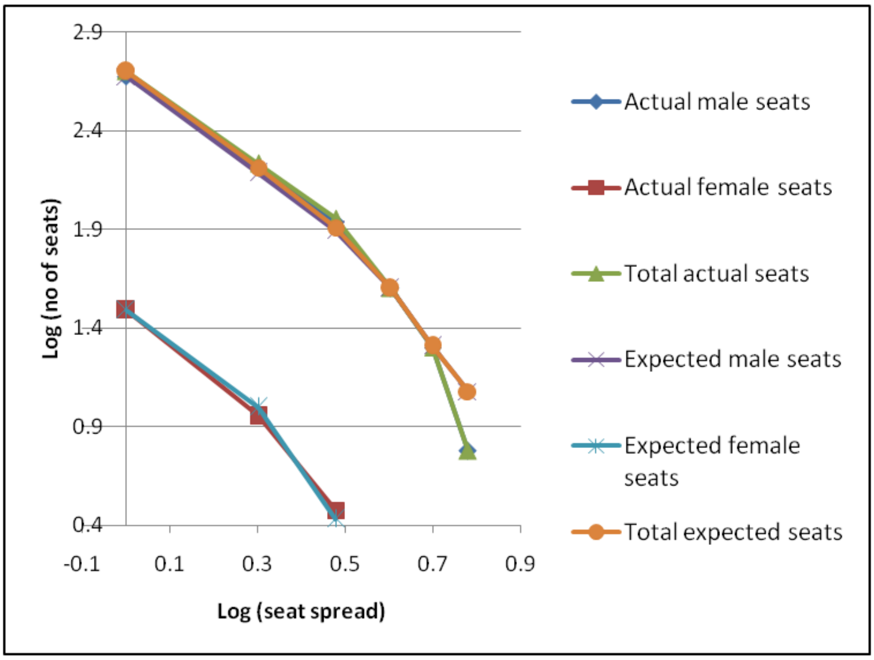
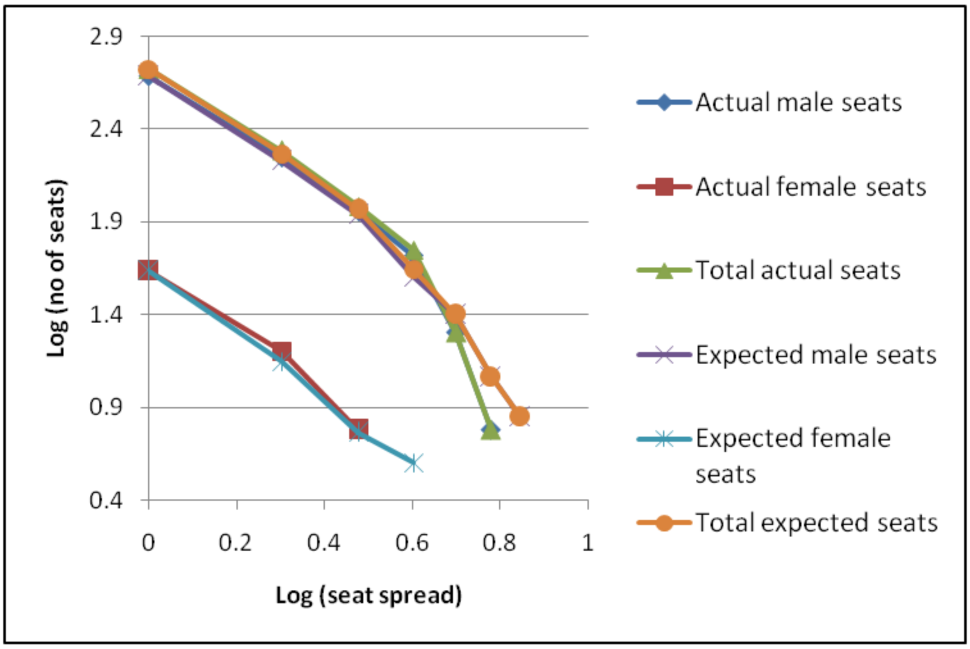


Figure A6.3
2005 NZX director network Gender breakdown for expected seats allocated in proportion to gender ratios of actual seats; seat spread parameter = 2. Largest component only.



Appendix Seven Additional measures of cohesion, centrality and Small-world Quotient for the 2004 and 2007 Fortune Global 200 and NZX random directors.

Follows on next two pages

Largest components only	B2007 NZX Random 1st Half	B2007 NZX Random 2nd Half	C2007 NZX Random 1st Half	C2007 NZX Random 2nd Half	D2007 NZX Random 1st Half	D2007 NZX Random 2nd Half	E2007 NZX Random 1st Half	E2007 NZX Random 2nd Half
No of directors	1269		1269		1269		1269	
No of Components	103	108	102	103	107	110	108	104
No of Directors in Largest Components (%)	424	351	504	492	529	382	514	462
	33.4	27.7	39.7	38.8	41.7	30.1	40.5	36.4
Density	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Density Standard Deviation	0.14	0.16	0.13	0.13	0.13	0.15	0.13	0.13
Reach	73.9	79.1	82.0	75.9	96.2	77.7	95.4	72.6
(Normalised Reach)	0.17	0.23	0.16	0.15	0.18	0.2	0.2	0.16
Reach Standard Deviation	12.5	16.1	17.0	12.1	15.2	14.0	20.9	12.4
Clustering Coefficient	0.92	0.92	0.92	0.92	0.92	0.93	0.92	0.92
Mean Geodesic Distance	8.1	6.0	10.0	9.8	7.7	6.7	7.7	10.0
Mean Degree	8.2	8.8	9.1	8.3	9.0	8.8	9.1	8.2
(Normalised Degree)	1.9	2.5	1.8	1.7	1.7	2.3	1.8	1.8
Degree Standard Deviation	3.9	4.3	4.5	3.4	4.2	3.9	4.8	3.5
Minimum Degree	2	1	1	2	1	3	1	1
Maximum Degree	30	50	55	32	52	30	56	24
Clustering Coefficient Random	0.006	0.007	0.018	0.017	0.017	0.023	0.018	0.018
Geodesic Random	3.4	3.3	2.8	2.9	2.9	2.7	2.8	2.9
Small-world quotient	16.9	16.5	14.3	16.3	20.0	16.5	19.1	15.1

Largest components only	B2007 NZX Random 1st Half	B2007 NZX Random 2nd Half	C2007 NZX Random 1st Half	C2007 NZX Random 2nd Half	D2007 NZX Random 1st Half	D2007 NZX Random 2nd Half	E2007 NZX Random 1st Half	E2007 NZX Random 2nd Half
No of directors	449	450	449	450	449	450	449	450
No of Components	102	106	107	98	107	108	101	105
No of Directors in Largest Components (%)	64	69	61	103	58	53	53	41
	14.3	15.3	13.6	22.9	12.9	11.8	11.8	9.1
Density	0.11	0.07	0.08	0.05	0.07	0.11	0.09	0.11
Density Standard Deviation	0.31	0.25	0.26	0.22	0.25	0.31	0.29	0.32
Reach	24.2	22.7	20.1	30.1	20.01	18.4	19.4	17.2
(Normalised Reach)	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Reach Standard Deviation	5.3	4.5	3.8	6.3	3.8	2.9	3.2	3.2
Clustering Coefficient	0.89	0.83	0.83	0.86	0.85	0.88	0.87	0.87
Mean Geodesic Distance	3.7	4.2	4.4	4.7	3.9	4.5	3.9	3.1
Mean Degree	6.6	4.6	4.5	5.2	4.0	5.6	4.7	4.5
(Normalised Degree)	10.5	6.7	7.5	5.1	7.0	10.7	9.1	11.3
Degree Standard Deviation	4.9	2.7	2.8	3.6	2.7	2.9	2.8	3.2
Minimum Degree	1	1	1	1	1	2	1	1
Maximum Degree	19	18	19	20	18	16	16	15
Clustering Coefficient Random	0.10	0.07	0.07	0.05	0.07	0.11	0.09	0.11
Geodesic Random	2.2	2.8	2.7	2.8	2.9	2.3	2.6	2.5
Small-world quotient	5.1	8.2	7.0	10.2	9.3	4.3	6.5	6.3