METHODOLOGICAL INNOVATIONS Online

Methodological Innovations Online 4 (2009) 8-17

Linking Social Capital to Small-worlds: A look at local and network-level processes and structure

Christina Prell

Abstract

In the past decade, two topics have generated much interest in the idea of social networks and network analysis. These are social capital, popularised by Robert Putnam, and small-worlds, popularised by Duncan Watts and Albert-László Barabási. Social capital highlights local processes and network structures, theorizing the ways in which relations and their patterns link individuals and groups to resources and beneficial outcomes. Small-worlds emphasizes global network structures, describing how large, heterogeneous networks can nonetheless appear small to individual actors, largely as a result of the high clustering and weak, bridging ties that make up these networks' structure. Although social capital and small-worlds share social networks as a common basis, they emphasize different sides of a spectrum: social capital focuses on the local and small-worlds on the global. In addition, both focus on seemingly different social phenomena: social capital emphasizes access to resources, whereas small-worlds emphasize the tension of actors living in a social world that is simultaneously large and small. In spite of these differences, the literature points towards overlaps in the ways in which network structure is described: both social capital and small-worlds discuss structures of openness and closure, and these structural overlaps provide a means by which to start exploring, on a theoretical level, additional ways in which to bring about a synthesis of the two bodies of literature. In this paper, I situate social capital as an explanatory framework for the emergence of small-worlds. I do this through three phases: first, I discuss how each topic describes and theorizes openness and closure. Next, I develop a series of propositions that show how social capital can be linked to small-worlds in a coherent framework. Finally, I offer an empirical illustration of these propositions through the use of p*, one of the models from the larger family of exponential random graph models (ERGMs), which allow analysts to test the probability of certain local structural tendencies in a given network.

Key words: Social capital, small-worlds, network theory, network evolution

Introduction

Social capital and small-worlds have become exceedingly popular topics within and beyond academia. Robert Putnam's (2001;1993) books, *Making Democracy Work*, and *Bowling Alone*, brought attention to the to the role social networks play in improving the well-being of individuals, communities, and society at large. Similarly, popular science books such as Duncan Watt's (2003) *Six degrees: the science of a connected age*,

Correspondence: C. Prell, Department of Sociological Studies, University of Sheffield, Northumberland Road, Sheffield, S10 2TU, UK. Tel.: (+44)0114222 6402. E-mail: c.prell@sheffield.ac.uk

ISSN 1748-0612online
DOI:

and Albert Barabási's (2002) book, *Linked: the new science of networks*, both revealed how a variety of real-world networks – ranging from food webs to telecommunication systems – all share a similar network structure referred to as 'small-worlds.' Although social networks and network analysis were popular topics before the advent of these books, one can easily argue that interest in the role networks play in our world increased dramatically upon these books' arrival. Yet in spite of this great popularity, which in turn has spawned much interest and debate around social networks and network analysis, there has been little discussion of how the lessons learnt from social capital research can be brought together with those from small-worlds. In this paper, I explore the overlaps between these two bodies of literature to see the extent to which combining insights from social capital with those from small-worlds might lead to a fuller understanding of the role of networks in the social world, and how a network structure can evolve.

Although on first glance, social capital theory and small-worlds seem to discuss different phenomena (the one focuses attention on how social relations benefit individuals and groups; the second, on how random strangers can be linked according to structural patterns), there exist overlaps on both a conceptual and structural level. Both discussions emphasise similar structural features in their descriptions of networks, and on closer examination, both mention similar outcome variables associated with these structural features. Thus, in what follows, I will offer an overview of the social capital and small-worlds literature, followed by a discussion on how these two bodies of literature inform one another. What emerges from this discussion is insight into the way in which small-world networks evolve: social capital sheds light on how actors pursue particular goals and resources, and the role of actors' networks in these pursuits. In turn, these local actions and interactions on the part of actors accumulate, forming overtime the global network structure of a small-world. The article ends with an illustration of how these overlaps bear out within the context of a well-known, publicly available dataset. The p* model is applied to this dataset to uncover the connections between local and global structure within the context of social capital and small-world discussions.

Social capital: the difference between open and closed structures

Social capital's main argument is that individuals and groups invest in their ties to gain access to resources or benefits (Bourdieu 1986; Coleman 1988; Coleman 1990; Lin 2001a; Putnam 2001; Putnam 1993). Social networks form a type of 'capital', and this form of capital acts as an intermediate goal for larger ones such as attaining better jobs, achieving better performance, improving one's well-being, and so forth. Although some authors do attempt to link social capital to society at large (see for example Putnam, 1993; 2001; Narayan, 1999; Woolcook and Narayan, 2000), most studies pertaining to social capital look at individual actors or small groups and their networks. Thus, social capital is seen, more or less, as a local network phenomenon (see Prell 2006 for review). In this paper, I would like to focus more precisely on the aspect of the social capital discussion that pertains to local network structure and the perceived outcomes of those structures. This discussion will be divided into two sections: closed structures and open structures.

The role of closed structures

Within the social capital literatures, closed structures are referred to as 'closure social capital' (Burt, 1992; 2001; 2005) and as 'bonding social capital' (Putnam 2001). Such closed structures are ones made up of strong ties, where the majority of network members are tied to one another (Burt 2005; Burt 2001; Coleman 1990; Putnam 2001), and where the three primary outcomes linked to this structure are positive: (a) trust among actors, (b) accomplishing complex tasks, and (c) sharing, getting by and help in crises.

a) *trust among actors*: When actors share strong ties with each other, they tend to trust each other (Blau 1964; Blau 1994; Burt 2005; Coleman 1988; Coleman 1990; Granovetter 1982; Krackhardt 1992; Putnam 2001;

Uzzi 1996). People who trust one another confide secrets with each other, and trust one another with those secrets. Trust is a source of well-being in and of itself, but in addition, trust lays the foundation upon which other kinds of exchanges can take place (Blau, 1964; 1994), namely, emotional support, mutual confiding, help in times of crises, loaning of money and other kinds of resources (Wellman and Frank 2001).

b) *accomplishing complex tasks through mutual understanding*. Research has shown that strong ties and closure can assist actors in accomplishing complex tasks, primarily through reducing the need for elaborate communication (Burt, 2001; 2005; Granovetter, 1982; Uzzi, 1992). Actors embedded in closed structures tend to have a deeper knowledge and understanding of one another, which goes hand in hand with shared understandings of particular work processes, as well as an intuitive awareness of each other's strengths and weaknesses, roles and responsibilities, needs and preferences. Thus, these actors can 'fill in the gap' in instances where not all the information is given, and perform complicated tasks without the need to pause and communicate over the different steps.

c) *sharing, getting by and help in crises.* The members of closed structures tend to help one another when and where they can, but their help is most keenly felt in times of crises or an emergency (Granovetter 1982; Putnam 2001; Wellman and Frank 2001). In addition, closed structures reinforce norms of sharing and responsibility, and thus network members feel a stronger sense of obligation to help when help is needed. Finally, when the norms found in closed structures are focused on pro-social goals such as attending school, closed structures are more helpful in guiding individual actors towards reaching these goals (Coleman 1988).

This summary highlights some of the key benefits of closure. Yet research has also shown that the benefits of closure come alongside disadvantages— notably (a) redundancy in information, (b) norm constraints, and (c) socially undesirable behaviour—which can be detrimental to actors or the group as a whole.

a) redundancy in information. Actors in closed structures tend to share the same (or similar) pool of knowledge, because they spend much of their time in one another's company. They lack an influx of new ideas and information, thus making innovation in the group difficult (Burt, 2001; 2005; Granovetter, 1982).

b) norm constraints. Just as shared norms can act as a positive influence in guiding individual actors toward socially desirable behaviours, this tendency for norm-reinforcement can constrain individuals' freedom.

c) *socially undesirable behaviour*. Closed structures lead towards norm reinforcement, and this can be a negative consequence when these norms are socially undesirable: hate groups such as neo-Nazis and the Ku Klux Klan provide examples of how 'negative' norms that can flourish in closed networks (Portes 1998; Putnam 2001).

The role of open structures

In contrast, and partially as a result of the perceived negatives of closure, an alternative view of social capital has emerged that focuses on open structures composed of weak, bridging or brokerage ties that cut across the more cohesive sub-groups of a network (Putnam 2001; Burt 2005). This alternative view can be summarized as the "openness" argument. These structures are described as consisting of weak ties that cut across disconnected segments of a network. The open structures described in the social capital literature draw heavily on Granovetter's (1973) strength of weak ties article, in which he argues that weak ties, in bridging across cohesive clusters, provide cohesion in a large, heterogeneous society. In doing so, Granovetter (1973) perceived weak ties as providing a link between the micro and macro levels of society.

Just as closed structures lead to both beneficial and negative outcomes, the same applies to open structures. Four are most relevant and are summarized below:

a) *access to new and diverse information and resources*. Actors who share weak ties tend to be dissimilar from one another; they exist in different social circles, interact with different groups, and engage in different activities. Because of this dissimilarity, these actors, through their weak ties, can potentially gain a great deal from one another: a rich diversity of new information, new opportunities, new resources, and new ideas for solving problems (Burt, 1992; 2001; 2005; Granovetter, 1973; 1982; Lin, 2001).

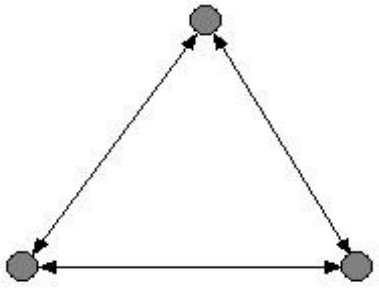
b) *the need for more elaborate communication*. This access to diversity comes with a price. For the very reasons why actors sharing weak ties tend to be so dissimilar, these same actors potentially need more elaborate communication for mutual understanding: 'Filling in the gap' is not so easy, and the potential for miscommunication or misunderstanding is much greater (Granovetter 1982).

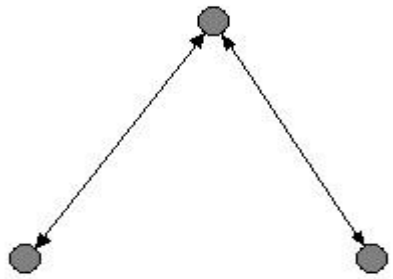
c) *less trust*. The weak ties found in open structures are poor conduits for trust. Actors sharing weak ties tend to have little knowledge by which to judge one another's credibility and trustworthiness. In addition, the lack of closure found in these structures can provide too few checks and reinforcements for socially desirable behaviour. Actors might be more willing to behave dishonestly if they know the likelihood for punishment is low (Burt, 2001; 2005; Coleman, 1988; 1990).

As described above, closed and open structures can benefit as well as disadvantage actors. Because trade-offs are evident with both kinds of structures, many scholars have now heralded a mixture of the two as the ideal structure for achieving positive outcomes. For example, Narrayan (1999) argues that healthy societies need a combination of cohesive subgroups in the form of families and tribal clans that are then linked together through both weak ties. Woolcook and Narayan (2000) argue that bonding and bridging social capital, i.e. closure and brokerage, are needed for communities to be truly healthy. Burt (2001) makes a similar argument for organizations, saying that brokerage across structural holes gives value to an organization, and closure can help actors in the organization realize the value buried in the structural holes.

Taken together, the research on social capital suggests how certain network structures lead towards certain outcomes. One way to neatly encapsulate the benefits and disadvantages linked to these two structures is through portraying these structures as triangle graphs (Figure 1). As noted by Prell and Skvoretz (forthcoming 2008), closed structures can be portrayed as a closed triangle (Figure 1 (a)), and openness as an open triangle (also referred to in the literature as a 2-star) as shown in Figure 1 (b)).

Figure 1: Closed and open structural benefits summarized

 (a)	***The benefits of closed structures include***: More trust and mutual understanding Good for communicating about complex information and tasks Reinforces pro-social group norms Helps in gaining access to support in times of crises and emergencies ***The disadvantages of closed structures include:*** Redundant information Can constrain actors Can promote and reinforce anti-social norms

(b) 	***The benefits of openness include***: New information and ideas flow through weak ties and open structures Individual actors receive strategic benefits from occupying a broker position ***The disadvantages of openness include***: Not ideal for complex tasks/information Actors sharing weak ties are less likely to trust one another Communication more complex, requires more efforts

Extensions: the goal pursuit of actors

Although social capital thus emphasizes the outcomes of certain structures, it provides clues for how these network structures arise or how they are maintained. For example, Lin (2001a; 2001b) emphasizes how social actors *invest* in their social ties to pursue either expressive or instrumental goals. Expressive goals include things such as gaining affection and social support, whilst instrumental goals include gaining more or new kinds of resources. In pursuing expressive goals, actors invest in ties to others who are similar to themselves. This is more commonly known in the literature as the homophily effect, a well-documented occurrence in social networks that refers to the situation where actors are attracted to one another because of their similarity, and they thus choose to interact with each other based on this similarity (Friedkin 1998; Skvoretz 1990). Pursuing instrumental goals involves actors investing in ties to dissimilar others, a process more commonly known as the heterophily effect (Blau, Blum and Schwartz 1982). Thus, investment in ties is linked to particular goals of actors and the perceived similarity or dissimilarity of actors' partners.

These investments in ties have consequences for the local structures that emerge. Actors who are similar to one another and who interact for expressive purposes tend to share strong ties with one another, and these strong ties lead towards dense local structures such as closed triangles (Bourdieu 1986; Coleman 1990; Putnam 2001). In contrast, the investments in ties for instrumental gains tend to take place through weaker ties. These weaker ties are more likely than strong ties to act as bridges across denser areas of a network (Burt, 1992; 2001; 2005; Putnam, 2001). Whereas strong ties lead to closed triangles, weak ties lead to open triangles, and these open triangles form the basis for bridging social capital.

Taken together, social capital posits that actors' goals are linked to their network strategies, which in turn help to explain how certain ties get used for specific purposes, how ties are formed and maintained, and how these ties correlate with local structures of open and closed triangles. Discussions of network structures on a larger, more global scale become the focus when we start paying attention to small-worlds.

Small-worlds: a need for more theory

With small-worlds, the discussion centres less on the beneficial outcomes of local network structures, and more around how various kinds of networks share similar global features, i.e. how various networks can be seen as 'small-worlds.' Small-worlds are characterized as large, thinly populated networks, where network members are embedded in clusters, yet at the same time linked together by a small number of steps. In short, small-worlds hold the three features of low-density, high-clustering, and short average path-length.

The small-worlds phenomenon is best summarized by the situation many of us have experienced where we meet a complete stranger, only to find out that we share a common acquaintance with this person (i.e., 'what a small-world!'). Thus, there is a paradox of individuals being simultaneously embedded in clusters yet also linked to others far away in the network. In addition, small-worlds research has shown how a variety of networks share the same structural signature of small-worlds. These include the Internet, the World Wide Web, food webs, and telecommunication infrastructures (Barabási 2002; Barabási 2000; Barabási and Albert 2001; Newman, Barabási and Watts 2006; Watts 1999; Watts 2003).

Research on small-worlds traces back to Milgram's experiments in the United States in the late 1960s, where a sample of respondents were asked to send letters to a target individual in a different part of the country. Individuals were asked to forward a letter onto someone whom they knew personally, and whom they felt would be closer to, or actually know, the target individual (Milgram 1967; Travers and Milgram 1969). Each link in the chain of letters was recorded by the researchers, leading to findings showing the average person was only six links removed from the target individual. After Milgram's research, small-worlds received little attention until the late 1990s, with the publication of Watts and Strogatz's article in *Nature* (Watts and Strogatz 1998). In this and subsequent articles , the authors (primarily Watts) demonstrate through computer simulations how a highly structured network, referred to as 'connected caveman' network, can transform into a small-world structure through randomly re-assigning a small number of links (Watts 1999; 2003; Watts and Strogatz 1998). Their connected caveman graph consisted of dense clusters connected to one another, where each cluster was composed of 5 nodes. This highly structured network was positioned as one artificial 'extreme' structure, the other extreme structure being a completely randomized network. Watts (1999) argues that small-worlds exist "somewhere in-between" these two artificial extremes, i.e. "the real world lies somewhere between these two extremes but precisely where is anybody's guess"(Watts 1999). This lack of sociological explanation is something I shall return to shortly.

Alongside Watts' work in popularizing small-worlds sits that of Barabási and his colleagues (2002; Barabási 2000; Barabási and Albert 2001). This team of physicists offer a slightly different view of small-worlds and how these small-worlds arise: rather than actors huddled together in highly dense clusters, Barabási demonstrates how individual actors can become 'hubs' in a network, accruing an ever higher number of ties through 'preferential attachment.' Preferential attachment refers to a process whereby individuals are attracted to others who are relatively popular in the network. As an actor gathers more and more ties, he or she becomes increasingly more visible to others, thus attracting even more ties. The end result is a small-world: all individual nodes in the network can reach one another through a relatively short number of steps. The hubs in this version of a small-world are what create the clustering as well as the short cuts.

Summary and limitations

The work of Watts and Barabási generated a lot of new research in different disciplines (see Newman, Barabási and Watts 2006 for a collection of essays on this topic). This new research primarily focused on uncovering a variety of different networks in the natural (not social) world that could be classified as 'small-worlds.' None of this work, however, attempted to develop richer sociological accounts for the small-worlds phenomenon. Thus, for a period, the only understanding of what factors contributed to the shaping of a small-world included the random re-assignment of ties uncovered by Watts and Strogatz (1998) and the process of preferential attachment discussed by Barabási (2002).

Some sociologists noted this absence of sociological explanation (Crossley 2008; Robins, Pattison and Woolcock 2005; Scott 2009), noting, for example, the general absence of discussion regarding social and/or structural influence; the artificiality of Watts' connected caveman, and the oversimplification of Barabási

relying entirely on the notion that the rich get richer in their ties. In addition, after some time, other sociologists attempted more sociologically credible explanations. For example, many turned to Pool and Kochen's (1978) arguments that the majority of actors in society have acquaintance networks ranging from 500-1000 in number, a number high enough to account for the bridging ties that short-cut distances through a network, essentially creating a small-world (Adamic and Adar 2005; McCue, 2002). Others built on this acquaintance-network argument, noting how acquaintance networks form from where people live and work (Adamic and Adar 2005), or where people are drawn, such as a conferences or clubs, where the shared topic of interest attracts individuals together from near and far geographical distances (Crossley 2008; Feld 1981; Feld 1982). These arguments are straightforward and sociologically credible, yet as McCue (2002) notes, to understand fully small-worlds, one would need to move beyond discussions of acquaintance networks and attempt to uncover what network properties give rise to small-worlds (McCue 2002).

This need to uncover network properties responsible for small-worlds was addressed by Robins, Pattison, and Woolcock (2005). Here, the authors demonstrate through computer simulations how a small-world structure can emerge from a combination of low-density along with relatively high numbers of open and closed triangles. They interpreted these findings as showing that a network is likely to become a small-world if i) individuals seek more than one network partner; ii) these individuals do not seek out too many partners, iii) the network shows a tendency toward transitivity[1], and iv) this tendency would be neither too strong (or else the network becomes too clique-like), nor too weak (or else the network would not develop clusters).

Thus, more recent research on small-worlds has improved the sociological explanations for small-worlds, yet all of this work is still fairly 'bare-bones'. There are still a number of areas that could use more attention or elaboration. For example, none of the previous work has taken a serious look at the *kinds of the social relations* that link actors together. There is some distinction between 'weak' and 'strong' ties, and there is some elaboration on this distinction by likening weak ties to acquaintance relations, yet beyond this, we hear little in this discussion for which kinds of relations, under which conditions, might lead to particular network structures. In addition, there is little discussion about *why* actors might form certain ties and not others. Again, the notions of acquaintance networks and preferential attachment do not sufficiently cover the variety of potential causes.

Social capital as explanatory vehicle?

As the literature on social capital demonstrates, social capital research and theory provides rich detail on how different kinds of relations and local structures link actors to different outcomes. In addition, social capital sees actors as being motivated to invest in their ties to gain access to resources, which in turn have consequences for the kinds of local structures that arise. There is thus a richness and complexity within social capital regarding individual actors, their motives, and their local networks, and the question now is whether or not such a theory could justifiably be linked to small-worlds as a means for explaining how small-worlds form?

There are a number of overlaps that point towards this potential of bringing social capital and small-worlds together. First, the high presence of open and closed triangles found in Robins et al's (2005) simulations resemble the open and closed structures found within social capital discussions. Whereas social capital discusses how open and closed structures connect actors to particular resources and benefits, the small-worlds

[1] The authors actually state 'structural balance' instead of transitivity. Structural balance is very similar to transitivity, the difference being that a triangle is balanced if two friends feel the same way about a third actor (like or dislike). Transitivity is not based on positive or negative relations. I have opted for transitivity here for simplicity, as transitivity was introduced earlier in the discussion.

literature relates these two structural features (along with low-density and a large number of actors) to the more global network characteristics of clustering and small path-lengths.

Another potential overlap lies in the discussion on how a small-world structure influences network-level behaviour. Watts (2004) and Baldassarri and Diani (2007) both argue that a small-world structure enables a network as a whole to function better, be able to cooperate, and thus perform better. This is not too far removed from social capital discussions that point towards a mixture of open and closed structures resulting in maximum performance within organizations (Burt, 2001; 2005) as well as providing an ideal structure for healthy communities and societies (Putnam, 2001; Woolcook and Narayan, 2000). Taken together, both social capital and small-worlds see open and closed structures as important for particular behaviours and outcomes. With these similarities in mind, I have devised a set of five propositions to help clarify the relationship between social capital and small-worlds. These propositions consider the unique focus of each body of literature, whilst making best use of the overlaps.

Propositions linking social capital and small-worlds

The below propositions link social capital and small-worlds together in the following way: concepts and arguments from social capital are mainly found in the first four propositions, and the remaining two propositions reflect small-worlds arguments. Social capital is thus being used to describe and explain how actors develop and make use of their networks in pursuing particular goals and linking to particular resources and benefits. These processes accumulate over time, and in doing so, it is hypothesized here that this accumulation leads to a small-world structure.

1. Actors develop their own social networks. Actors are born with certain networks (e.g. family and kin), but they also actively seek out, and develop, additional network ties. Certain factors influence how actors form and use their networks. These include (but are not limited to) what sorts of goals an actor pursues; what kinds of resources can be found in the actor's network; whether or not others to whom an actor is tied are similar or not; and whether an actor shares a friend in common with another actor. These factors influence the different network strategies that actors develop, thus influencing whether actors invest in their strong or weak ties to particular others.

2. Actors' individual networks can be characterized as open, closed, or both. In general, weak ties lead towards more open structures and strong ties to more closed structures. Actors are all born with certain networks that can be characterized as open, closed, or both, yet they can also take action to re-shape, expand, or contract these networks in line with their particular goals.

3. The different structures of an actor's network provide access to different kinds of resources and support. Closed and open structures give access to different kinds of resources and support. Closed structures and strong ties help actors gain access to affection, emotional and social support. Open structures and weak ties help actors gain access to new and different kinds of resources.

4. Actors' network strategies can likewise affect resource distributions and network structure. Actors invest in their ties and gain access to certain resources via their ties. These actions have consequences such that resources circulate through the network, network structures shift and change, and these changes likewise affect actors' later network strategies.

5. The accumulation of actors' networks gives rise to a small-world network. As actors make use of their networks, and as they continually rebuild and reshape their networks in pursuing particular goals, the accumulation of these actors, their resources and their networks give rise to a small-world structure.

6. The small-world structure of a network enables cooperative behaviour and other beneficial outcomes. In some ways, the argument has come full circle: open and closed structures on the local level give individual actors access to certain resources and benefits. They also, when combined correctly, give rise to a small-world structure, which in turn, gives the network as a whole benefits similar to the ones individual actors accrue on the local level.

The propositions listed above act as heuristics in laying out the main structural and conceptual overlaps in the two bodies of literature. In addition, the propositions summarize how this literature informs tie formation, the development of local structure, the development of global network structure, and the benefits accrued on the local and global level from these structures. Taken together, there are some useful, productive ways in which these two literatures come together. In the remaining space of this article, I will evaluate a network dataset through the lens of the propositions offered above, in part to illustrate the comparative overlaps as proposed in this article, but in addition, see what new insights can be gained from taking a close look at one empirical example.

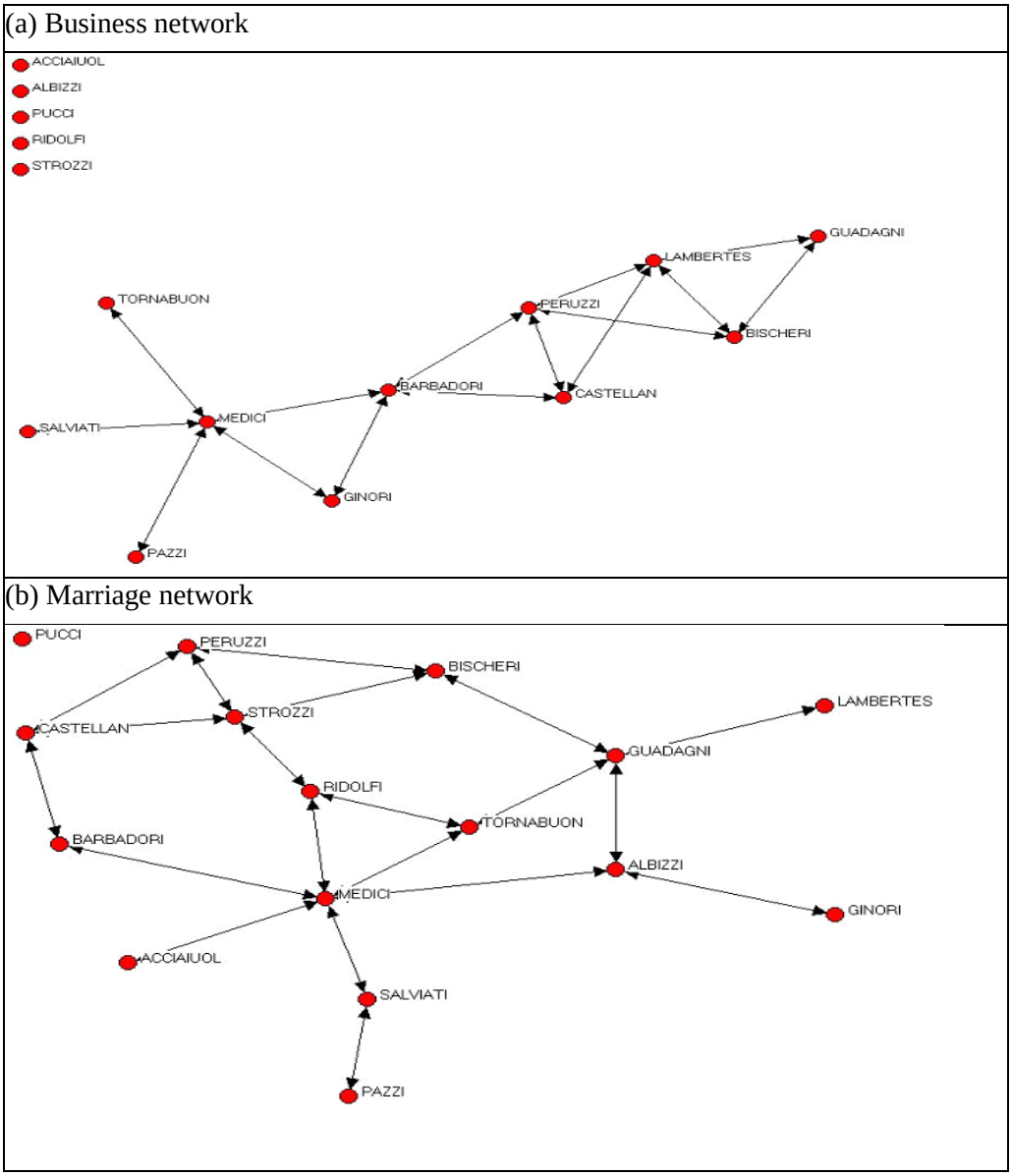
Linking social capital and small-worlds: an empirical example

The dataset

The network data used here are a subset of the data used in Padgett and Ansell's (1993) study on Florentine oligarchs during the 15th Century, and can be found as part of the UCINET, v. 6.2 package. These data hold both marriage and business ties among Florentine families in the 15th Century, where both marriage and business relations are categorized as 'strong ties.' The original dataset contains relational ties between 92 actors, and this subset, publicly available, only contains 16. This particular dataset was chosen, partly for its availability and familiarity within the social network analysis community, and also for its reflection of social capital discussions on the relationship between structure and beneficial outcomes. Thus, in using this dataset, I aim to see whether data reflecting social capital concepts can also be shown to reflect concepts and arguments derived from the small-worlds literature.

Pagett and Ansell (1993) argue that the Medici's rise to power had much to do with the sort of social network they built around themselves. The Medici managed to position themselves at the center of a star-like structure and maintained this position through a process of keeping their relational ties separate as well as using other structural divisions such as geographical distance and social class. Figure 2 below shows the Medici's networks of business and marriage ties circa 1430:

Figure 2: Business and Marriage networks in 15th Century Florence



Please note: graphs generated using UCINET v. 6

As Figure 2 shows, and as Padgett and Ansell (1993) describe in great detail, the Medici combined open and closed structures in their networks in such a way as to reap the most amount of benefits from their unique position. This mixture came in the form of strong ties to others, and the use of social and geographical distance to keep Medici contacts separated from each other. For example, the Medici's married relations lived in different neighbourhoods from the Medici, and were thus kept at a distance through use of the city's geography. In addition, the Medici rarely conducted business with these married relations, and instead formed business ties with those families living close to them. These business ties linked oligarch and non-oligarch families together, and the social divisions between the oligarchs and non-oligarchs were strong enough to keep these Medici partners separate from one another, even though they lived in the same neighbourhood. Thus, multiple structural divisions--based on class, geography, and relational ties--were utilized to keep network contacts separated from one another.

As noted by Padgett and Ansell (1993), the Medici benefited from this unique mixture of closed and open structures. In resting between disconnected families, the Medici helped link these families together. This service resulted in feelings of gratitude and loyalty on the part of these families, as well as feelings of dependence and a need to please the Medici. Thus the Medici were able to accrue favours and feelings of obligations from their network partners, which eventually culminated in the Medici rising to a leadership position within Florence.

This description of the Medici and their network position reflects many of the arguments found in social capital pertaining to open and closed structure, and thus illustrates propositions 1-3 above. In addition, Padgett and Ansell's (1993) description of the Medici provides some insights into how these local open and closed structures were formed, and these insights shed more light on propositions 1 and 2. For example, strong ties were coupled with geographical distance or class divisions, and this combination prevented strong ties from transforming into closed triangles. Thus, mixing strong ties with geography and social class can generate a mixed structure of closure and openness.

Yet the extent to which this Florentine network reflects the characteristics of small-worlds depends on the extent to which propositions 5 and 6 can be illustrated, notably, whether these local structures of the Medici and other families give rise to a small-world (proposition 5), and whether a small-world structure, once found, enables network members to coordinate and cooperate better (proposition 6).

The Medici at the centre of a small-world?

It is difficult to assess the extent to which the present example reflects a small-world, as the current dataset only contains 16 actors, and small-worlds typically consists of hundreds, even thousands of actors. Nonetheless, Padgett and Ansell's (1993) description provides some clues that suggest that such a structure may have surfaced, and furthermore, that this structure produced some of the beneficial outcomes of small-world structures described in the literature.

For example, the Medici's structural position of broker also resembles Barabási's description of a hub. That is, the Medici's network position was important for the Florentine network in that it gave otherwise disconnected families a means of reaching one another. The result of the Medici's position, intentional or not, was to make the Florentine network small for many families. In addition, history also credits the Medici for Florence's rise in power during the 15th Century (de Roover 1966; Padgett and Ansell 1993; Rubinstein 1966), suggesting that the Medici's structural advantage benefited not only the Medici or those immediately tied to the Medici. Their influence was felt throughout Florence and much of Europe. Thus, there appears that there was something about the Medici's local network that seems to have affected the larger Florentine network in a positive way. There was a connection between the local and global networks.

The above arguments regarding the link between the Medici's local structure and the Florentine global structure can be strengthened empirically be examining whether the current dataset holds local network properties reflective of those found in certain small-world networks. As mentioned earlier, Robins et al (2005) uncovered combinations of local structures that can give rise to small-worlds. These include low-density and a tendency for both open and closed triangles. More particularly, these local structures include high numbers of 2-stars and closed triangles, low numbers of 3-stars, and a low number of ties in the network (i.e. low density). Uncovering whether this same sort of patterning in local structures occurs within the Florentine families dataset would strengthen the claim that this dataset holds structural features on the local level that could accumulate into small-world features.

Looking for local structure through use of p*

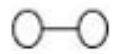
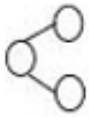
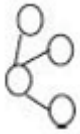
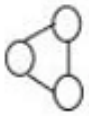
In what follows, I will examine these same local structures in the Florentine families dataset, making use of the p-star (p*) model to test the probability that these local tendencies in the network do not result from chance. The p* model is part of the larger group of models referred to as exponential random graph models (ERGMs) which allow analysts to test the probability of certain local structural tendencies in a given network. In particular, the use of p* helps one uncover whether local structures, such as 2-stars, 3-stars and closed triads, are more often observed in a real network than one might expect from chance alone. In addition, p* controls for how 'lower-level' structures, such as reciprocity between two actors, might affect the tendency for 'higher level' ones, such as closed triads. In doing so, p* helps one uncover the relative contribution of each tendency to the overall network structure. Thus, p* provides a viable approach to exploring and testing some of the structural features of small-world networks (Robins et al 2007).

For these data, a Markov random graph model (one of the models considered part of the p* family) was used to test the tendency for each local structure. This model is a random model that assumes that network variables (such as closed triads and 2-stars) are independent of one another unless they share at least one actor. Such a model differs from ones where network variables are all assumed to be independent (e.g. Bernoulli random graph model) or ones where network variables are assumed to be independent unless they involve the same two actors (dyadic models such as p2). Using the model involves comparing a random network to an observed one, looking specifically at how the local structural tendencies of the random network compares to those of the observed network. In doing so, the model makes use of parameters for the different local structures, where positive parameters indicate more tendency for a structure in the observed network than is expected by chance, and negative parameters indicate fewer instances of this tendency than expected by chance.

The local structures tested for in the Florentine dataset include the presence of ties (referred to as 'density'), 2-star, 3-star and closed triads. These local structures are the same ones discussed by Robins et al (2005) in their article on what local structures give rise to small-worlds. Thus, through testing for these tendencies, one can see the extent to which certain structural features, as discussed in the small-worlds literature, are present in this current example.

The SIENA software package was used for fitting this model. The parameter values, along with their standard errors are presented below in Table 1. By dividing these values by their standard errors, one arrives at a score similar to a t-score, which may then be used for determining levels of significance.

Table 1: Values, standard errors, and t-scores for marriage and business relations

Local structures		**Marriage values, SE and t-score**	**Business values, SE and t-score**
	Density	-1.65 (0.98) t = -1.68	-4.24 (1.10) t = - 3.85 *
	2-stars	-0.01 (0.34) t = 0.03	1.05 (0.64) t = 1.64
	3-stars	-0.01 (0.13) t= 0.08	-0.64 (0.40) t = 1.6
	Closed triads	0.24 (0.49) t = 0.49	1.32 (0.64) t = 2.06*

Note: findings indicated by * are significant at the 0.05 level.

In Table 1, the parameters for all local structures in the marriage relation are not significant. Nonetheless, one can comment on the direction of the tendencies of these local structures, given the positive and negative values of the parameters; as the tendency for closed triads are positive, and the tendency for density, 2-stars and 3-stars is negative, this suggests a network characterized by a small number of ties that are more likely to be found in closed, as opposed to open structures. Therefore, the network does not have a tendency for the mixed structure of openness and closure. The findings also suggest this network of marriage ties does not resemble a small-world: one would expect to see more 2-stars. For the business relation, however, the findings are more promising: the density and closed triad parameter scores are much higher than their standard errors, resulting in scores that are significant at the 0.05 level. The other parameters, i.e. 2-stars and 3-stars, although not significant, move in the direction one would expect: ties occur relatively rarely, indicating low-density, and the positive parameter for 2-stars suggests that the business ties tend to be embedded in open structures, with this tendency capped by the negative 3-star parameter, indicating that local open structures do occur, yet for any one actor, it does not likely occur via many other partners. Thus, for the business network, there is more evidence for local structures that resemble those found in small-world networks. In addition, the fact that there are positive tendencies for both 2-stars and closed triads suggests a tendency for both openness and closure in this network.

Taken together, these findings suggest evidence for the presence of the local structures leading to small-world networks. The business relation of the Medici show these tendencies more clearly than the marriage relation, however both exhibit the tendency for the combination of open and closed structures. The lack of a significance score most likely results from the small number of nodes in this dataset.

Summary and conclusion

This paper positioned social capital as a sociological framework for explaining how small-worlds arise. The paper began with a literature review of social capital and small-worlds, where a gap in the literature regarding

small-worlds was highlighted. This gap pertained to the lack of sociological insight into the explanations given for what influences the formation of small-worlds. Overlaps on a structural level were then noted between social capital and small-worlds, where these overlaps formed the basis for arguing for a more in-depth look at the explanatory potential of social capital for small-worlds. A set of propositions were then introduced, which linked the two bodies of literature in such a way as to highlight how a small-world network might evolve: starting with the individual, then moving to the formation of local structures, and finally moving to the global level of small-worlds, I have shown how social capital and small-worlds research provide insights into different stages of this evolution, with social capital focusing on the local and small-worlds on the global.

To explore these propositions empirically, I analyzed a subset of the Florentine families dataset studied by Padgett and Ansell (1993). The analysis illustrated how local dynamics can influence global ones, and how the presence of a hub, in the form of the Medici, could arguably transform the Florentine network into a small-world. The propositions outlined here were thus supported, and were shown to have heuristic value for analyzing networks both from a social capital and small-worlds angle.

Future research on this topic will focus on expanding on the propositions outlined here, and this will be done through the use of agent-based modeling. Indeed, work is currently in progress towards this end (Prell, Snijders and Turmbull 2008). As the social network research continues its trajectory on linking micro structures to macro ones, this conversation on linking social capital to that of the global features of small-worlds is both timely and productive.

This research is supported by the ESRC's First Time Award grant scheme.

References

Adamic, L. and Eytan A. (2005) 'How to search a social network', *Social Networks* 27:187-203.
Barabási, L. (2002) *Linked : the new science of networks*. Cambridge, Mass.: Perseus Pub.
Barabási, L. (2000) 'The large-scale organization of metabolic networks', *Nature* 407:651-654.
Barabási, L., and Albert, R. (2001) 'Emergence of scaling and random networks', *Science* 286:509- 512.
Blau, P., Blum, T., and Schwartz, H. (1982) 'Heterogeneity and intermarriage', *American Sociological Review* 47, 45–62.
Bourdieu, P. (1986) 'The forms of capital', in J.G. Richardson (ed.) *Handbook of Theory and Research for the Sociology of Education.* New York: Greenwood Press.
Burt, R. (2005) *Brokerage and Closure: An Introduction to Social Capital*. Oxford: Oxford University Press.
Burt, R. (2001) 'Structure Holes versus Network Closure as Social Capital', in, K. Cook N. Lin, and R. Burt (eds.) *Social Capital: Theory and Research*. New York: Aldine de Gruyter.
Coleman, J. (1988) 'Social Capital in the Creation of Human Capital', *American Journal of Sociology* 94:95-120.
Coleman, J.S. (1990) *Foundations of social theory.* Cambridge: Belknap Press of Harvard University of Press.
Crossley, N. (2008) 'Small-World Networks, Complex Systems and Sociology', *Sociology* 42:261-277.
Feld, S. (1981) 'The Focused Organisation of Social Ties', *American Journal of Sociology* 86 1015–35.
Feld, S. (1982) 'Social Structural Determinants of Similarity among Associates', *American Sociological Review* 47:797–801.
Granovetter, M. (1973) 'The strength of weak ties', *American Journal of Sociology* 78:1360-1380.

Lin, N. (2001a) 'Building a Network Theory of Social Capital', in, N. Lin, K. Cook, and R. Burt. (eds.) *Social Capital: Theory and Research*. New York: Aldine De Gruyer.

Lin, N. (2001b) *Social capital: a theory of social structure and action*. Cambridge, UK; New York: Cambridge University Press.

McCue, B. (2002) 'Another view of the "small-world', *Social Networks* 24:121-133.

Newman, M. E. J.; Barabási, L. and Watts, D. J. (2006) *The structure and dynamics of networks*. Princeton: Princeton University Press.

Pool, I. and Kochen, M. (1978) 'Contacts and influence', *Social Networks* 1:5–51.

Prell, C. L. (2006) 'Social Capital as Network Capital: Looking at the Role of Social Networks Among Not-For-Profits', *Sociological Research Online*, 11: http://www.socresonline.org.uk/11/4/prell.html.

Putnam, R. D. (2001) *Bowling Alone: the collapse and revival of American community*. London: Simon & Schuster.

Putnam, R.D. (1993) *Making democracy work: Civic traditions in modern Italy*. Princeton, NJ: Princeton University Press.

Robins, G., Pattison, P. and Woolcock. J. (2005) 'Small and other worlds: Global network structures from local processes', *American Journal of Sociology* 110:894-936.

Watts, D. J. and Strogatz, S. H. (1998) 'Collective dynamics of small-world networks', *Nature* 393:440-442.

Watts, D. J. (1999) 'Networks, dynamics and the small-world phenomenon', *American Journal of Sociology* 105:493-527.

Watts, D. J. (2003) *Six degrees : the science of a connected age*. New York: Norton.