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Venture capital networks in the UK: National or regional?

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Abstract

A key ingredient of the UK innovation policy has been to encourage local access to venture capital finance in order to support the development of small innovative entrepreneurial firms. However research, particularly in the US, has shown the venture capital industry to be organised at both a national and regional level, especially in terms of syndicate networks. Venture capitalists develop relationships with other investors to help to facilitate the transfer of information and knowledge about investment opportunities, as well as develop long term trust between investors which help reduce various investment costs. The formation of investment syndicates provides an important basis for the development of relationships between investors. In this paper we use a detailed dataset of UK investment tracking over 1900 entrepreneurial firms between 2000 and 2006 to analyse syndicate networks. In agreement with US literature, our analysis indicates a national level network structure, controlled by the major UK investors. In contrast to literature on regional clustering, our analysis indicates absent or weak network ties between locally constrained investors. However, our research emphases the opportunity for public policy to help stimulate the venture capital industry by focusing on the role of Government finance in co-ordinating networks at a national as opposed to regional level.

1 Introduction

Financial capital, a critical part of any innovation system, is especially important for supporting the development of entrepreneurial activities. For the small firm, a range of funding sources can be used to grow a business, including public grants, funding from friends and family, bank loans and other forms of credit. However, innovative business developing new products and services frequently require significant investment to grow beyond start-up phase. For innovative businesses which can demonstrate the ability to grow rapidly, venture capitalists are expected to provide significant investment in return for a share of equity in the business.

Research on industrial clustering (Marshall, 1920; Porter; 1990, 2000) and Regional Innovation Systems (RIS) has shaped current policy thinking towards regionally focused initiatives (Boekholt van der Weele, 1998; for a critical review of RIS see Doloreux and Parto, 2005). Niosi and Banik (2005) define RIS as, "geographical concentrations of interacting organisations (innovative firms, research universities, government laboratories and venture capital firms) aimed at the development of specific technology" (p.343). Thus RIS are expected to combine the necessary ingredients for the development of innovative entrepreneurship at the regional level.

A key ingredient of the regional policy approach has been to encourage access to venture capital finance to support the development of small innovative entrepreneurial firms. For example, over the last decade the UK Government have established a number of venture capital funds managed at a regional or sub-regional level, such as Regional Venture Capital Funds (RVCF) and University Challenge Funds. However in contrast to the RIS perspective, research on venture capital has outlined an industry with complex patterns of activity, organised at a national and regional level (Florida and Kenney, 1988; Sorenson and Stuart, 2001). In this paper we use network analysis, an ideal tool to study the organisation of venture capital in the UK, to understand its national and regional structures.

Networks are formed from relationships and ties between different actors. The theory of social capital predicts that relationships have value and can be used to help achieve purposeful actions. By examining the structure of networks and the variation in the location of different types relationships (e.g. structural and relational social capital), we can understand the importance of different types of investors or investor groups, and their impact on the functioning of the network of ties. Venture capitalists develop relationships with other investors to help to facilitate the transfer of information and knowledge about investment opportunities, as well as develop long term trust between investors which help reduce various investment costs. The formation of investment syndicates provides an important basis for the development of relationships between investors.

In the UK, syndication networks have received a low level of attention in the academic literature, particularly those relating to early stage investments. The primary aim of this research is to investigate whether we observe established patterns of syndicate networks in the UK. The second aim is to analyse the structure of these networks compared to the literature on other national VC networks. We propose that investor networks facilitate the transfer of important information and knowledge that support the development of the venture capital industry in the UK. In particular we

seek to understand whether venture capital networks are organised at a regional or national level. By studying networks of this type, we provide an important insight into the organisation of the venture capital industry in the UK to inform future policy decision making.

The paper is organised as follows. First we review social capital theory and its application for the analysis of network structures; next we examine the literature on the geography of venture capital and the organisation of the industry, which are used to produce a set of expectation for the structure of UK networks. Then we review the analytical approach of the paper, before discussing the network analysis results. Finally we conclude.

2 Networks as a resource: Social capital theory

In this paper we analyse the networks formed between investors in early stage firms which have received venture capital finance. We analyse the network structures guided by social capital theory (Granovetter, 1973; Lin, 2002). Starting from the perspective of any given individual, social capital is, "the capital captured through social relations" which are a "social asset by virtue of actor's connection and access to resources in the network or group of which they are members" (Lin, 2002 p.19). We build on previous research on social capital in the entrepreneurial setting, associates social capital with superior performance (Cohen and Fields, 1999), achieving successful outcomes (Lin, 2002) and like other forms of capital it can be accumulated over time (Garnsey and Heffernan, 2005).

We use Nahapiet and Ghoshal's (1998) view of social capital, in terms of structural and relational social capital. Structural social capital relates to the structure of whole networks, such as configurations, density of ties, and how different actors are connected. Relational social capital on the other hand, is derived from the different types of personal relationships which develop between individuals, such as trust or friendships. Different types of relational social capital in a network may influence the behaviour of people, such that even if two networks are structurally similar, they may lead to different outcomes.

Our starting point for evaluating relational capital is Granovetter (1973) proposition that network analysis should consider ties as varying between strong or weak. Granovetter (1973 p.1360) stated that, "the strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confidentiality), and the reciprocal services which characterise the tie". Thus strong ties, for example between relatives, friends or where homophily is high, are characterised as intense, frequent, reciprocated relationships. Weak ties on the other hand are often formed between acquaintances where the frequency of contact between two agents is lower and less intense.

Strong ties are associated with trust based relationships and resource sharing (Granovetter, 1973; Lin, 2002). As strong ties require maintenance and commitment, they are prone to forming closed groups, whose members tend to be alike, for example in terms of status, or structural[i] position (Lin, 2002). In strongly tied groups, information flows freely, providing efficiency advantages over groups connected with only weak ties (Coleman, 1990). As a result, members of closed groups tend to have access to similar types of information and resources; new information is most likely to be sourced through weak ties which connect different groups together (Granovetter, 1973). Unlike strong ties, weak ties provide a breath of relationships which are un-obligated and involve dissimilar

relationships. Lin (2002) proposes that weaker ties between actors facilitate access to heterogeneous resources, characterising ties across structural positions. However, weaker ties are predicted to be less effective in achieving actions because they lack trust and so represent weaker incentive to share resources (Coleman, 1990; Lin, 2002).

The location of strong and weak ties has implications for the flow of information or knowledge through a network. Granovetter (1973) proposed that weak ties act as bridges between groupings of strong ties, such that it is mainly weak ties that connect between different groups and allow the flow of information from one social group to another. In social capital theory a weak tie bridge from one social cluster provides access to resources embedded in another social cluster that would otherwise be unavailable (Lin, 2002).

3 Venture capital investment and geography

The distribution of investment for small to medium sized enterprises (SME) in the UK, like in other countries, is frequently concentrated into one or two key geographical areas (Florida and Kenney, 1988; Martin, 1989; Mason and Harrison, 2002; Parris, 2009). These locations are anticipated to provide the most beneficial nurturing environment for start-up firms, often co-located with clusters of innovative firms or technology complexes (Florida and Kenney, 1988). These concentrations of innovative activity are frequently described in the literature as being supported by access to local resources such as the core knowledge required to support the start up, experienced human capital, proximate investors and benefit from access to knowledge and information flowing around local informal networks (Florida and Kenney, 1988; Powell et al, 2002; Castilla et al, 2000)

In the UK the distribution of investment is uneven, and concentrated towards the south (Martin, 1989). In addition most investors have offices in London (Rosiello and Parris, 2009). On the other hand, the need to access the best opportunities should drive investors to explore all opportunities, rather than just those occurring near to London. Following this logic, overtime a geographical concentration of investment should reflect a demand for investment from locally based entrepreneurial teams with high quality ideas for commercial development.

In line with this proximity argument several studies have shown that investors are co-located with their investments in the US, (Powell et al, 2002, Griffith et al, 2007) and in the UK (Rosiello and Parris, 2009). Explanations for this include the need to maintain close oversight and monitoring of investments (Gompers and Lerner, 2001), to provide hands on advice and guidance to the firm (Powell, 2002). Also important is the use of local networks to gain access to information on opportunities and recruit investment partners (Florida and Smith, 1990) or other relevant 'know what' and 'know how' (Zook, 2002, 2004).

Extensive literature on industrial clusters cites the use of local networks as an important benefit of locating within a cluster (Marshall, 1925; Porter, 2000; Iammarino and McCann, 2006). A key benefit for firms located in clusters is the use of localised networks which provide access to knowledge and information spillovers or externalities (see Marshall, 1925; Jaffe et al, 1993; Audretsch and Feldman, 1996). By bring people together in the same location the likelihood of interactions between them increases (Cowan and Jonard, 2008). Likewise the venture capitalist can benefit from accessing local network resources by reducing information costs and asymmetries and decreasing reaction time to new opportunities. For example, working with local businesses means venture capitalists can build

networks to access important information on the background of local firms, entrepreneurs and new technological research developments which build investors confidence to commit to new entrepreneurial projects. This is one explanation for the localised nature of VC activity. A locally embedded investor can gain both early mover and transaction cost advantages over less connected competitors.

However, do interactions between investors need to be locally embedded? Investors often prefer to work on the basis of trusted referrals, rather following up on the receipt of unsolicited business plans (Bygrave, 1987, 1988; Zook, 2004). A preference for working with familiar contacts has implications for the spatial organisation of the industry. The organisation of the venture capital industry will also have implications for VC's ability to obtain reliable information on opportunities located around the UK. As social space and geographical space coincide, people are more likely to develop relationships when they share the same geographical space[ii]. As venture capitalists also benefit from the flow of information regarding new opportunities and utilise networks to develop associations to improve the performance of their investments, it follows that an investor's ability to access new deals will decrease with distance from the investment opportunity (Sorenson and Stuart, 2001). In the next section we consider the structure of the investor networks in terms of structural and relational social capital, and the implications of geography.

4 Venture capital networks

4.1 Network structures

Investor referrals provide a starting point for the formation of syndicates. The practice of syndication is frequently used as a tool to manage risk and obtain new information (Bygrave, 1988; Lockett and Wright, 2001; Manigart et al, 2006). In a syndicate several investors participate in funding the same firm. Often, one investor is the lead and other investors participate as follow-on investors. Syndication can reduce the financial risk of investment, by diversifying an investor's portfolio and reducing idiosyncratic risks (Sharpe, 1964; Norton and Tenenbaum,1993). However, in sectors or industries where uncertainty is high, for example in the development of new technology or markets, syndication can provide access to additional information and knowledge that can reduce uncertainty faced by the investor (Bygrave, 1987, 1988). Over time a "dense inter-firm network may be created" based on syndicated relationships between different investors (Manigart et al, 2006. p.135). In this way relationships between investors facilitate sharing of information regarding opportunities. Thus syndicates can be viewed as the building blocks of larger venture capital networks, an important source of information and knowledge for investors.

Networks, particularly those based on syndication between investors, play an important role in overcoming the difficulties presented by the distance between investor and opportunity (Sorenson and Stuart, 2001; Kogut et al, 2005). Sorenson and Stuart (2001) find investors who have a central position in the syndication network, can reach more distant opportunities by using their relationships with other investors to identify and evaluate new opportunities.

"VC firms with a history of provincial investment patterns and those without central positions in the industry's co-investment network tend to invest locally; those who have established many and dispersed relationships with other VC firms invest across geographic and industrial spaces more frequently." (Sorenson and Stuart, 2001. p.1584)

Kogut et al (2005) find that a giant network component quickly develops in their models of venture capital syndication. This component provides full geographical coverage of the US. Despite an emphasis in the literature on investor proximity and clusters, their findings show syndication networks operate on a national basis. The rapid formation of a large network component is thought to be a distinctive form of organisation in the venture capital industry with implications for the overall success of the venture capital industry. At the centre of Kogut et al (2005) giant component are experienced investors whose names are synonymous with venture capital. These investors operate nationally and repeatedly syndicate with other nationally orientated investors, in preference to searching out new entrants to expand their network of ties. Sorenson and Stuart (2001) find that older more established investors with central network positions are able to invest over larger distances than younger less experienced peripheral investors. In this way established investors at the centre of the network acts as 'spanners across geographies', by building trust based relationships with other established investors in different locations.

4.2 Core structures: centrality and trust

Research on US syndicate networks has shown there to be a core group of repeatedly syndicating investors (Sorenson and Stuart, 2001). Bygrave (1987) found in a sample of over 400 US VC firms, a core of 61 investors was found in ¾ of the portfolio firms. These results suggest an extensive US network formed around central investors. Bygrave (1988) also finds that relationships between investors were particularly dense in hi-tech investments. In hi-tech investments the need to gather information to reduce uncertainty is highest; as a result the networks were tighter with denser linkages.

Investors central to the network are invited to join syndicates from other VC's looking to attract the reputation of established investors. If the VCs are in different geographies the resulting syndication can create long distance relationships. The syndicate network provides an institutional structure that allows the "expansion of the spatial range of exchange in markets that rely on private information or a high degree of trust for transactions to occur" (p.1584). These networks also benefit the firm; for example, firms hoping to obtain funding in a region without a local VC community may find it difficult to gain access to the wider venture capital networks (Sorenson and Stuart, 2001).

The centrality of investors in the network has been shown to increase the performance of their funds, portfolio exits and firm survival rates, after controlling for other factors known to influence VC performance (Hochberg et al, 2007a, 2007b). Well networked VC's could also use their network resource to compensate for lower levels of experience. The connectivity benefits were highest for those VC's connected to other 'well connected VC's. Strongly linked investors were expected to have greater control over cooperating, which explains why Hochberg et al (2007b) found deal valuations to be positively linked to measures of the network size.

It seems likely that investors with more extensive ties will have a greater geographical range (Sorenson and Stuart, 2001), as well as access to a larger choice of deals throughout the network, particularly given their control over the development of new relationships with peripheral investors (Hochberg et al, 2007b). It would appear that centrally networked investors have better access to high quality opportunities regardless of their own location. However, trust between investors is

show to be important for establishing a core network; investors prefer working with previous affiliates as this reduces the risk of investing (Sorenson and Stuart, 2001). On one hand the formation of trust requires time and a frequency of contact, that makes it trust based relationships more likely to occur locally. However, they also find that the likelihood of a long distance investment is increased if they participate in a syndicate containing a prior affiliate, where that affiliate is local to the deal (Sorenson and Stuart, 2001).

4.3 Expectations

The previous discussion and review of literature lead to the development of a set of expectations regarding the structure of UK venture capital networks. We expect the UK network will be organised as a giant network structures, covering all UK regions. We expect the network to be structured by the established players who operate on (i) on a national basis; (ii) at the centre of the network, and (iii) that relationships between the central players will be formed of strong repeated (dense) linkages; (iv) building on the expectation that established investors will act as the co-ordinators of the network, together with uneven geographical investment flows, we expect established players to be key for linking different geographical concentrations of activity. It follows that experienced actors have the ability to run multiple offices, as well as invest outside of their own locality using their wider network of contacts to support their investments. Therefore established investors will control connections of local investors to the main component.

We expect that local regional investors will be (i) smaller in size; (ii) and being locally constrained, will be strongly connected to other smaller local investors resulting in localised densely populated sub-networks where local investors syndicate together on local opportunities; (iii) finally because of difficulties in attracting large investors we expect variation in the strength ties connecting local groups to the main network component. It follows that peripheral areas of the network will be characterised by groups of strongly inter-connected investors associated with specific UK regions.

5 Method

In this paper we use investor syndicates reported for deals in the UK to create a cumulative representation of network of ties between investors. We investigate the structure of investor networks to observe the presence of national and regional networks. We have used the literature to generate a number of expectations regarding the role and structure of syndication networks. In this section we outline how we will compare the structure of networks observed in the UK to these expectations.

5.1 Relational data

This paper uses the Library House database of early stage investment deals in the UK. Library House was a research organisation based in the UK[iii] until 2009 which monitored entrepreneurial activity across Europe. Library House, "discover, research and profile fast-growth, innovation-led private companies, their people and investors" and collect information directly from firms and their investors. The Library House database provides rich information on UK early stage venture capital investment. The data used in this paper includes details of 1,950 UK companies which received an investment between January 2000 and September 2006. Random checks of the details of firms in the database were made against other newspaper and Internet sources to confirm the accuracy of the data.

Library House provide detailed SME firm information, including the names of investors in each round, and characteristics of the firm including new innovations. In some cases the data available on the investors in a round will provide the fund name. Using the Internet, and the membership details of trade associations, such as the BVCA we drafted a list of all investors active in the UK. The list was used to determine the names of active investors, or fund managers, as opposed to the names of specific funds. In cases where a fund is administered through one agent, but the investment managed through a second party, the details of the named managing investor were used.. Our data does not include 'fund of fund' type relationships, as we interested in understanding the relationships between the active investor as opposed to the financing source. Firms without named investors were excluded from the analysis.

5.2 Network analysis

We use two types of one mode network representations. Firstly to provide an insight into the regional activity of investors in the UK, we use our data represent the ties formed by each investor across UK regions. The UK can be divided into twelve regional areas, or Government Office regions, which include nine English regions, Northern Ireland, Scotland and Wales. We attribute each firm in the dataset to a UK region based on the main office location. In the regional representation we trace each investor activity across UK regions, based on the location of firms in their portfolio. A connection between regions is created when an investor's portfolio contains firms in more than one region. We also count the number of different investors active in each region to see the local level of activity.

Our second network representation is based on syndication. We use two definitions of syndication to construct the relationships in the network following Brander et al (2002). The first is a wide definition of syndication, based on the shared affiliation of investors to the same firm. In the mode 1 network representation of an affiliation network, a line between two investors indicates that they share an affiliation to at least one firm. This representation contains an implicit assumption that an informal relationship exists between investors, even if no formal co-investment occurs (i.e. investors active in the same round). It is reasonable to assume some communication occurs between investors that fund the same firm, even if at different times, giving rise to weak ties. Clearly in cases where there are multiple common affiliations it is likely that there is a strong relationship between investors.

The alternative definition of a syndicate is based on formal co-investment. In a co-investment network a tie between investors only exists if they participate in funding the same firm at the same time. Compared to affiliation network, the co-investment network is a representation of more formal relationships between investors. Thus co-investment networks are expected to be more fragmented than affiliation networks and provide a more formal view of relationships between investors. We can then compare how co-investment network differ from affiliation networks. A large difference would indicate that investors use different networks for obtaining information compared to the relationships they build through investing with other investors.

In all network examples described in this paper no distinction is made when drawing the networks as to which period individual investments relate. As we only show the network formed from the cumulative activity of investors in our dataset, we concentrate our analysis to examine the

expectations generated from the literature for the structure of the network, rather than how the network may evolves or the performance outcome of the network structure.

Sociograms of the networks representations are drawn using Pajek and UCINET (Netdraw) routines and optimised for visual analysis using algorithms available with the software. Our main aim is to analyse the relationships between investors, formed by investing the same companies or investing across regions. We also use the width of the line representing each tie to show the strength of ties between investors, the wider the line the greater the number of ties. We assume relationships that occur between network actors more frequently are stronger than those occurring only once than once. As in Cowan et al (2007) we use repeated ties between firms to represent stronger relational social capital.

Finally to determine the geographical properties of the networks we use the each investors portfolio to determine whether they operate as local (in one UK region), multi-regional (2-4 regions) or national (5 or more UK regions). Finally we identify overseas investors as those without a UK office, using information from the BVCA and Internet searches.

6 Results

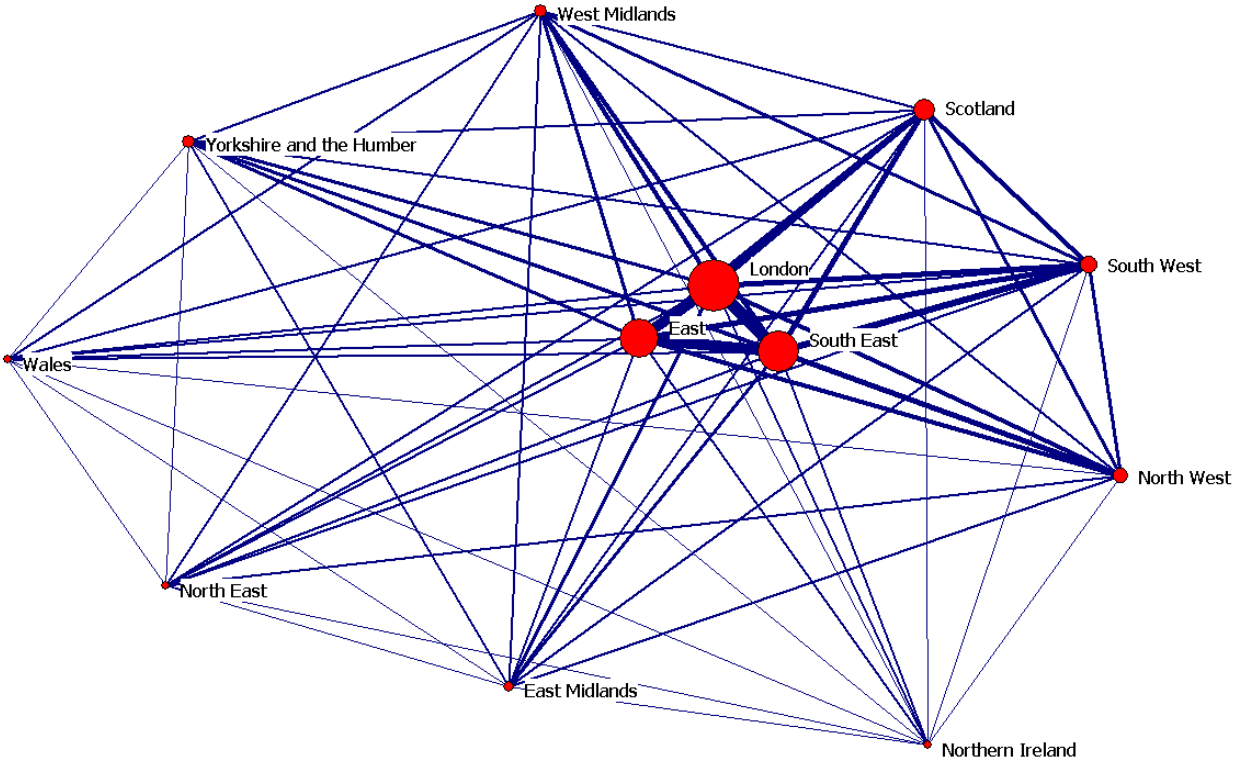
6.1 Regional connectivity

Figure 1 below shows the ties between the different UK regions based on investor activity. The edges (lines) of the sociogram are formed by investors whose portfolio includes firms based in more than one location. For example, an investor with interests in the North East, South West and London will create a link between these three regions. In the sociogram the thickness of the line indicates the number of different investors who link regions together, providing an indication of regional connectivity. The regional nodes are scaled according to the number of different investors recorded as active in each region.

The sociogram in Figure 1 is drawn by grouping ties of a similar strength (i.e. a similar number of shared investors). The South East, East and London regions are shown in the centre indicating a large number of investors are shared between these regions. The sociogram clearly shows the strong investor coverage of the southern areas of the UK. These key southern regions are also connected to all other UK regions. In contrast the remaining regions, away from south, show far weaker links between regions. Irrespective of the physical geography, northern UK regions are most strongly tied to southern regions.

In general we find that each region is tied to all other 11 regions by at least one investor (in most cases many more than one). Thus in terms of the investor network, we can clearly see that all regions are linked by shared investors operating across the UK. However, despite this UK wide coverage and activity, pronounced variation in the strength of relationships are evident.

Figure 1 Sociogram of dyadic ties between regions based on shared investors



The left hand side of Table 1 shows the top ten regional dyads by the number of investors active in both regions. As the dyads are undirected the order of regions within each pairing is insignificant. The regions sharing the highest number of common investors strongly relates to the area known as the 'Golden Triangle', here we find investors operating between London, the East and the South East are the top three dyads. Within the top 12 dyads we also find the involvement of other regions such as the South West, Scotland and the North West, with one of the core regions.

Table 1 Top 12 regional dyads and total number of active investors in each region

Top tied regions		Shared investors	Region	Active investors
South East	London	162	London	612
South East	East	141	South East	478
London	East	140	East	433
South West	South East	81	Scotland	210
South West	London	73	South West	154
South West	East	71	North West	145
London	Scotland	71	West Midlands	108
Scotland	East	68	Yorkshire	89
South East	Scotland	68	East Midlands	67
South East	North West	59	Wales	59
North West	London	57	North East	55
North West	East	53	Northern Ireland	46

However, we have found a reliance of northern regions on investors operating in the south, but what about the local level of investor activity? The right-hand side of Table 1 shows the number of different investors making at least one investment in each region. We still find the northern UK regions have relatively small numbers of investors active locally, compared to London, supporting our assertion of a general dependence on a core of investors circulating in the southern UK regions.

Next we extend our analysis of investor networks in the UK by analysing the ties between individual investors in greater detail, in order to understand the organisation of the national network through the lens of structural and relational social capital.

6.2 Investor networks

In this section we analyse the network created by investors funding the same firms, the affiliation network. We look in detail at the organisation of investment activity according to the geography coverage of investors. However, as we show in section 6.1 many investors operate across different geographies and therefore cannot be labelled according to a particular place. As described in section 5 we code the vertices by colour to represent the regional coverage of each investor. As we are interested in the network of investors created when different investors provide finance to the same firm, we exclude isolated investors from our analysis. These isolated investors (degree = 0) have no ties to the network, and therefore are not included in the analysis of network structure.

Figure 2 (page 12) shows the network formed from shared affiliations between all investors in the dataset. The network clearly shows a single large dense component at the centre. In line with the expectations from the literature, at the centre of the main network component are the national investors having interests across several regions. Conversely as we move from the centre to the periphery we move from investors with a multi-regional presence to those operating solely in one region.

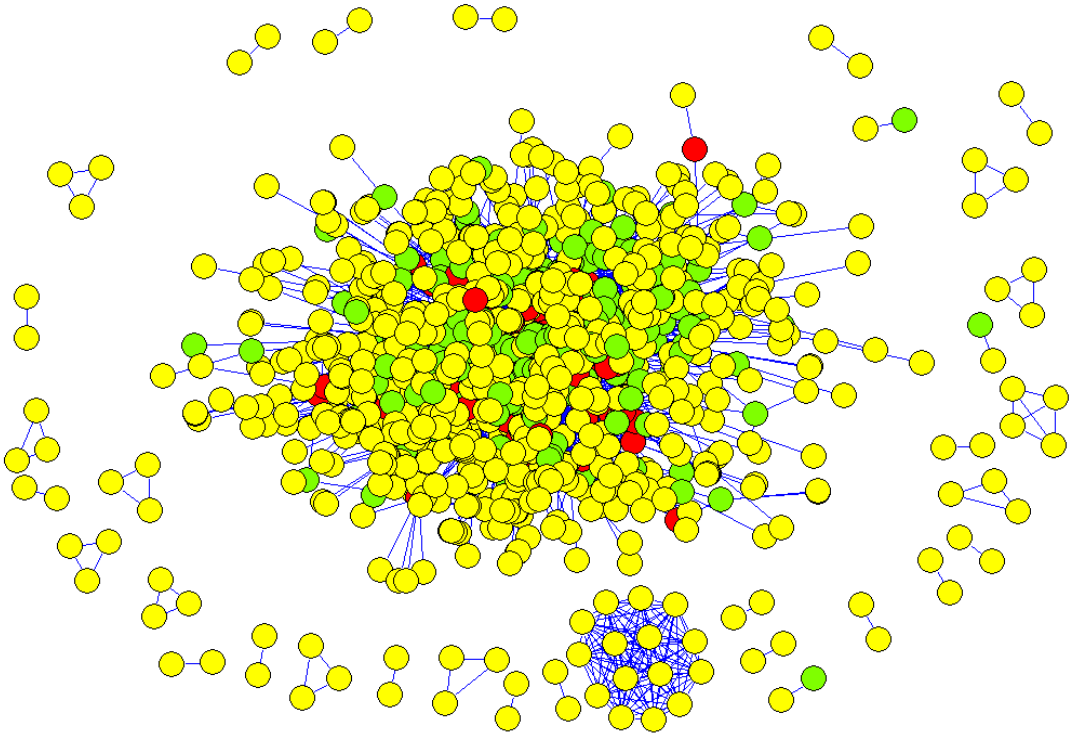
We find Figure 2 is predominantly formed from local investors. Over 70% of investors in the network operate in only one region; the largest presence of single region investors is in London and the South East. However this representation does not account for the contribution of investors. If we were to represent the approximate contribution of each investor we would find that the core national group of investors contribute over 40% of the value of investment, based on only a 109 investors[iv] from the total of 1518.

In the core group of national investors we find established large investors such as 3i Group, Aberdeen Asset Managers, and YFM Group. However, we also find other types of investors, such as companies solely managing VCT (Venture Capital Trust) funds such as Oxford Technology Management, and Government related initiatives including direct grants, as well as investment from charities such as the Wellcome Trust.

We have frequently referred to centrality as an important aspect of network structure. Who are these central investors? We examine the betweennessv centrality to understand who the most important intermediaries in the network are. We find that in line with their high degree statistics two investors consistently have central positions as measured by the betweenness centrality in the

all sector network. The most central venture capitalist is 3i Group[vi] being an intermediary in 18% of geodesics in the total investor network. However, the most central intermediary in the affiliation network is the UK Government (labelled DTI[vii]). UK Government direct investment, typically in the form of grants, is involved in 19% of the pathways between investors overall.

Figure 2 Sociogram of syndication network of all investors (degree =>1)



Colour code: Investor operating: Yellow = single region; Green = Multi-regional; Red = National (coverage of 4 regions or more)

The centrality of Government funding runs against our expectations. We predicted that the most central investors would be the established names of venture capital. Government funding, typically via grants and other public investment schemes (excluding professionally managed funds), are provided as seed capital finance. We can see that the Government (DTI) as a provider of seed capital has many affiliations with other investors who have provided funds to the same firms. However, it is not clear what type of intermediary role the DTI plays at a network level beyond providing finance. Clearly as a central investor in the network it has strong potential in terms of the informal circulation of information or participation in VC networking events. Finally we note that its central position in the network suggests it fulfils an important role in the financing of firms. However, in terms of the financial significance, or the estimated value contributed by each investor, we find that the DTI is approximately 29 times smaller than 3i. This is in agreement with the DTI's report in to Venture Capital provision in England (2005). This report finds that the DTI is one of the main providers of capital in the sub £500k market.

Through common affiliations the UK Government (DTI) is connected to most major investors such as 3i Group, Oxford Technology Management and YFM group. We also find that the DTI has repeated affiliations that link it to other public institutions, such as NESTA, Carbon Trust, Scottish Enterprise

and University affiliated bodies such as Cambridge Enterprise. In approximately 25% of cases the DTI money was used as the first recorded investment, rising to over 50% of cases within the first two rounds. However, the range of participation includes the 10th round suggesting that DTI funding is provided across a range of development stages.

6.3 Repeated ties

We have consistently referred to repeated ties between investors as indicating the strength of affiliation between investors. An m-core analysis highlights the distribution of the strength of ties within the total network. An m-core is a network representation where only line values equal to m are shown. As the value of m increases, weakly tied investors become isolates and are removed from the representation. By counting the number and type of investors in the network across different tie strengths, the m-core analysis in Figure 3 shows how the network is structured by different types of investors as well as by different tie strengths.

Figure 3 Distribution of ties strengths by investor coverage

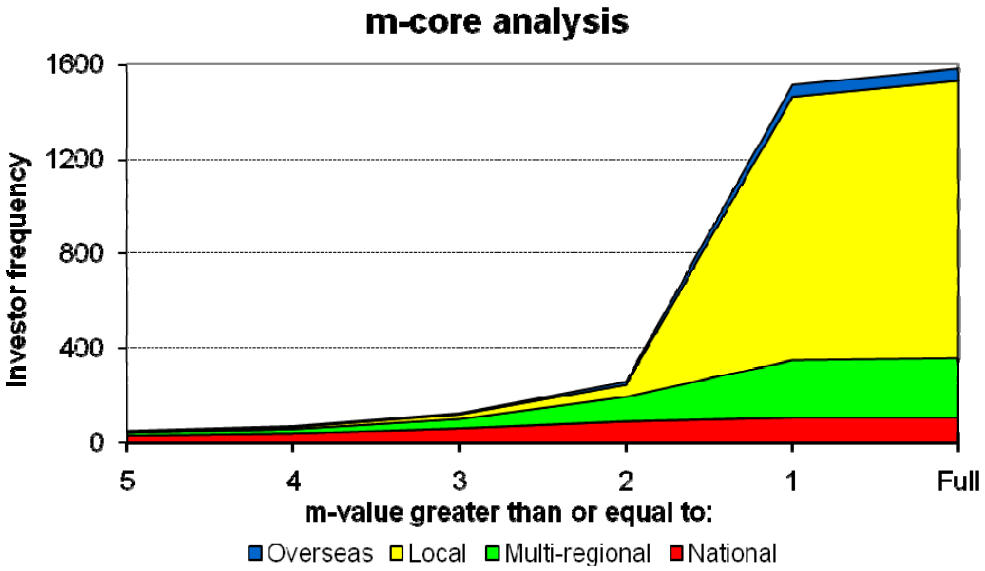


Figure 3 clearly shows the venture capital network in the UK is predominantly comprised of weak ties. We find that 92% of the relationships between investors involve a single common investment in a single firm and can be viewed as relatively weak. There are also small number isolated investors[viii], shown by the small change of investor frequency moving from the full network to a network involving nodes with at least one tie (m>0). In agreement with Bygrave (1987, 1988) the high proportion of weak linkages in UK networks suggests the main role of syndication networks is to help manage uncertainty. Figure 3 clearly shows investors operating in a single UK region generally have weak ties to other investors. In our network only a small minority of investors are affiliated to more than one firm and can be viewed as potentially trust based relationships. The number of investors present in each m-core network representation decreases rapidly as the strength of ties increases.

Our literature review also notes that investors favour trust based ties to organise their relationships, particularly established investors who routinely invest with other similar status investors. The higher

m-cores are made up from predominantly national investors. In fact examining the network representations for each m-core state (see appendix) demonstrates that national investors form an important part of the structure of relational social capital in the network. It is mainly national investors that have strong ties within the network and form a strongly tied group. A minority of overseas and locally based investors also have strong ties, but frequently this tie is with a nationally active investor. The largest number of repeated affiliations is found between Oxford Technology Management and the DTI. They are linked by 15 common affiliations. Again, this is not expected, this links the UK Government with a Venture Capital trust management firm.

To understand the relational structure and detailed involvement of investors with strong links, we can remove the weak relationships in the network and concentrate on investors that have repeated common affiliations. The result is network formed from a core of 248 strongly connected investors (from a total of 1586) of which 205 operate in more than one UK region shown in Figure 4.

Figure 4 Sociogram of affiliation network for all investors where m-core > 1

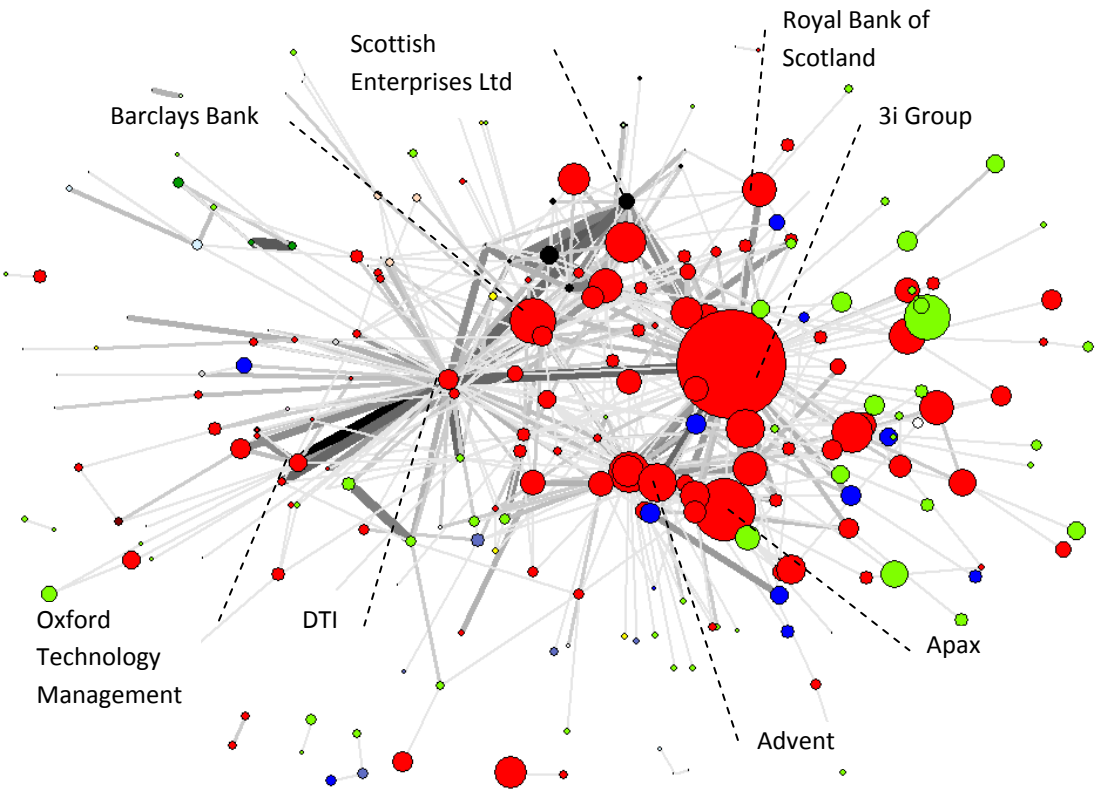


Figure 4 shows only repeated ties between investors. The vertices are colour coded to reflected investors with national activity (red), multi-regional (green) and international investors without a UK office (blue). We also indicate which investors which operate in a single region. In addition we also weight the size of the vertices according the estimated investment made (see footnote iv).

At the centre of network of repeated ties we still find a range of different types of investors, ranging from direct public finance (DTI), public-private initiatives (Scottish Enterprise Ltd), International

banks (Royal Bank of Scotland), Venture Capital Trusts (Oxford Technology Management) and the top venture capital firms (3i, Advent, Apax, plus several others). As in the centrality analysis the core of the network features the established names of UK VC who are repeatedly tied to one another. However, we still find the presence of public based investment sources within the core structure

From a geographical perspective the results only partially matches our expectation for local investors. We find a low presence of investors with locally bounded operations in Figure 4 and relatively few investors that operate in one region have strong ties to other regionally restricted investors. As we found in Figure 2, investors with a presence in a single region are located in the periphery, but often linked individually or in small weakly groups to national investors at the centre of the network. Scaling the vertices by financial contribution, shows that regional investors contribute relatively small amounts of finance. Only Scottish investors (e.g. Scottish Enterprise) making a sizable contribution.

In line with our expectations, investors with specific single location presence appear connected to the main network with repeated ties to larger national investors. However, contrary to our expectations we find little evidence of strong ties between locally bounded groups of investors. In fact there are few strong links between single location investors.

In contrast overseas investors are featured in Figure 4. It was not predicated that investors without a UK base would be strongly tied to the network, as well as to other overseas investors, as indicated by the blue vertices. It is likely that these strong ties help reduce information asymmetries presented from being located outside the UK. Given the distances involved in US investing, the relationship between UK and overseas investors may be similar to the type of boundary spanning relationships found in the US syndication networks.

6.4 Co-investment vs. affiliation networks

To this point we have considered the network formed from common affiliations to early stage firms. An alternative and more direct form of networking that occurs is through co-investment. If we restrict relationships to only those formed through co-investment in each round, (and so use the investment round as the joining property) do we still observe similar properties?

Overall we find the co-investment and affiliation networks are very similar, the overall importance of investors does not change whether we consider affiliation or co-investment networks. For example the centrality scores of individual investors in each network highly correlated (0.80) indicating that the national players in the affiliation network are central in the co-investment network.

There are three main differences between affiliation and co-investment networks in terms of network structure. Firstly we find that co-investment networks have a smaller core component. We find the size of the core component is reduced from 1423 to 1038 investors. This result confirms that many investors are weakly linked to the centre of the network through participation in funding the same firm, but not at the same time. A smaller core component size in co-investment networks suggests a smaller network of dedicated VC's who formally work together. Our expectation was that the network would be developed through the addition of investors operating at network periphery. In an affiliation type network, these investors would increase the size of the main component, investing in the same deals as other investors indicating that it is likely they create informal

relationships with the other investors. However, in the co-investment network we find many of these peripheral investors are isolated, including for example business angels, regional development agencies, and large blue chip companies (e.g. Vodafone, Microsoft). It indicates that these actors have different strategies to the core investors which result in them not working directly with other investors, despite contributing resources to the same firms.

Secondly, the results show public finance and seed funds are not an important feature in co-investment networks. Although major national investor's co-ordinate the network co-investment through connections to smaller investors, many of the seed investors identified such as Government grants (DTI), Bloomsbury Bioseed fund and University based funds are not central players. Instead these investors are located on the periphery of the co-investment network or absent. As this indicates they often invest alone or in rounds without the national investors, a likely explanation is that they often invest in early rounds at higher risk, where private investors may not prepared to provide funds.

Finally, in contrast to the results of the core size, the co-investment network formed of only repeated ties is larger than the affiliation network representation. We find a core of 391 investors (compared to 248 in Figure 4) who have opted to syndicate in more than one round in the same firm. As investors repeatedly syndicate together to provide rounds of finance, it indicates that these relationships are characteristic of strong ties, representing a tight core of investors who frequently work with each other. This result indicates that relational social capital is strong at the centre of the co-investment network.

7 Conclusion

This analysis finds agreement with the US literature and our expectations regarding syndication networks. Analysis of the UK affiliation investor network shows a minority of central actors, with a national presence, forming a dense network core. To operate at the centre of the network investors must be able to invest nationally (potentially internationally), and not be constrained to a particular location. We find that national investors repeatedly work together being affiliated to the same firms. Although national investors form strong relationships between different types of investors, predominantly the large private investors form the core network structure. Thus, in contrast to our expectation, we find little support for regional concentration in networking activity, networks are organised only on a national basis.

Our analysis also indicates that syndicate network structures reflect characteristics of structural social capital. For instance we find that the networks are organised around key players, demonstrating the importance of investors with high structural positions. Similarly we find evidence to suggest that strong relationships are formed between these important national level investors, indicating the presence of tightly linked groups. However, groups of strongly linked investors are not geographically bounded. We find evidence to suggest that the structure of syndication networks in the UK is co-ordinated at a national level by a central group of investors. The contrast between the core and the periphery of the network, as well as the lack of established investors groups within the periphery, indicate a hub type organisation of the network. In contrast to the classic type hub and spoke organisation (Barabási 2002), the investor hub is formed from a core of ties representing

strong relational social capital. The larger overall structure of the network, or spokes, are formed from weaker ties, independent of geography.

In contrast, the more formal co-investment network demonstrates a weaker organisation of the network periphery, indicating weaker relationships between investors in UK SME. The co-investment network is more dispersed and has a smaller core component. Public investors in the co-investment network are less prominent and lack direct investment links to the established players. Similarly large corporate investors are also shown as peripheral players in the co-investment network. At the core of the co-investment networks, however, relationships are shown to be very strong, formed from repeated investments between the major UK investors. Investors at the centre of the co-investment network have national or international reach and large investment funds. These top investors repeatedly share the financing of the same firms.

It is clear from this analysis that large nationally mobile investors are essential for the provision of finance. We find that these investors predominately co-invest together, but obtain support from a myriad of other smaller investors, indicating that information regarding opportunities spreads relatively well, but is reliant on a core national structure for efficient transfer of information around the UK. For example we find that smaller local investors are present in the networks, but generally peripheral, contributing to a small number of investments, often investing alone. Although we expected regional networks to be visible; even in regions such as the East, investors operate on a national basis. We expected to find large national investors acting as 'spanners' linking locally tied groups of investors, this was not shown in co-investment network, and only weakly shown by affiliation. Instead we find that strong relationships occur between large national or international investors, who also link weakly to a range of smaller investors. In agreement with Hochberg et al (2007b) our findings suggest large investors have greatest control over opportunities. Although seed investors exist, they lack strong co-investment relationships to major investors.

These observations of syndication have some implications for policy. For example many public funds have been created as a means to seed opportunities for exploitation by large private investors. Oakey (2003a) expects that the deliberate integration of public sources with private investor networks, from the outset, can prevent funding gaps for SME firms and help supply critical follow-on funding for early stages businesses. In the Israeli Yozma program, public investment was made into private funds; under the condition that each fund must be partnered with a foreign VC to ensure only credible managers got access to public finance. The Yozma program has been very successful and able to identify promising start ups. There is also evidence that local Israeli Yozma investors have learnt from foreign investors, improving the national VC competences. Many of the original Yozma funds have gone on to raise new private funds (Avnimelech et al, 2004).

Thus a lack of integration between different types of investors may signal a warning that public funding has attracted further public finance, or that public funds have been directed into businesses which are unattractive to private investors. We observe a high level of integration in the analysis of the affiliation network suggesting some integration of public and private funds. On a co-investment basis we observe the structural weakness in the network, albeit over a relatively short period, that may restrict the development of the total UK venture capital industry. This is a cautious assessment as many public schemes are only a few years old, and new entrants may naturally be excluded from

the main network. One alternative interpretation is that our results may indicate the beginning of the integration of new forms of investors, rather than the continued exclusion of them. Finally we note from a policy perspective that constraining funds to a local region may be a strong disadvantage, as even investors based in Cambridge seek opportunities elsewhere and we find little indication of strong networking between groups of local investors.

Our analysis has demonstrated a giant network, including all regions, but it is worth highlighting the tendency for investors to concentrate their operations across southern UK regions. This suggests that whilst investment networks are co-ordinated by investors who are nationally active, relationships between investors are supported by a physical concentration of investors around London, linking with previous research. This paper provides a relatively statistic analysis, more research is required to link our understanding of the dynamics of investor location, proximity and investment distribution in the UK in order to provide appropriate long term policy recommendations.

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[i] Here the structure refers to Lin (2002) theory of social capital, that valuable social capital is not distributed evenly, but along a 'structural' scale, with the most valuable social capital held by a minority of people at the top of the scale.

[ii] See Stuart and Sorenson (2001) for an extensive review of literature on social and geographical space and interaction.

[iii] Library House has since been sold to DowJones

[iv] We don't have information on the exact contribution of investors in each deal, so we calculate the amount individual investors contribute by assuming each investor contributes evenly in every investment round, and then sum the total contribution.

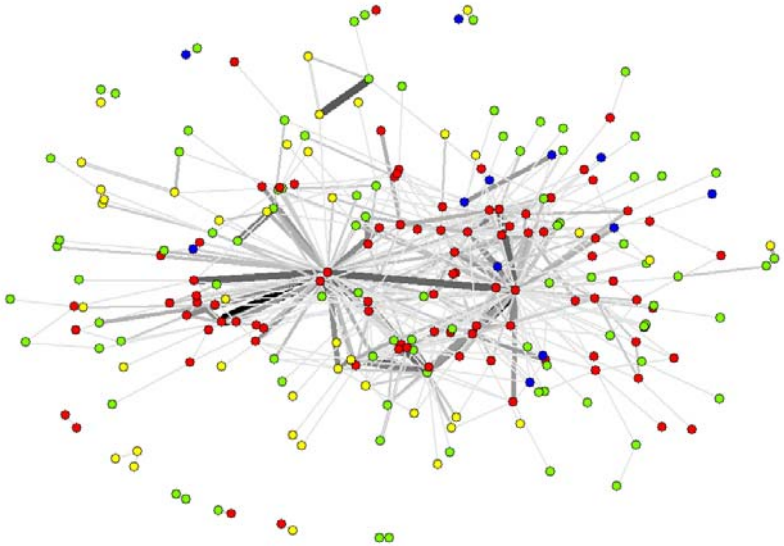
[v] Betweeness centralities are calculated by Pajek

[vi] Although towards the end of the analysis period 3i had committed to reducing its involvement in early stage investment activity, we find it to be the most centrally tied actor to the network, frequently syndicating on investment deals with a large range of other investors. For example, 3i, following its public flotation in 1994, re-positioned the company as a development capital firm, preferring to do deals of at least £1m in size (Sunley, Klagge, Berndt and Martin, 2005). More recently in March 2008, 3i and a number of other international investors have confirmed their complete shift from all early stage investment in the UK (Fortson, 2008). Whilst this has an impact on the network structure, there is significant redundancy in the network and the overall network structure statistics, such as overall network centralities, average distance remain similar. Also the core structure remains a single component.

[vii] During the period analysed the Governement department responsible for grants and SME investment was the Department for Trade and Industry (DTI). However, due to several Government re-organisations within a relatively short period, SME investment now falls under the Department for Business Innovation and Skills (BIS).

[viii] Isolated investors were removed from Figure 2.

9. Appendices



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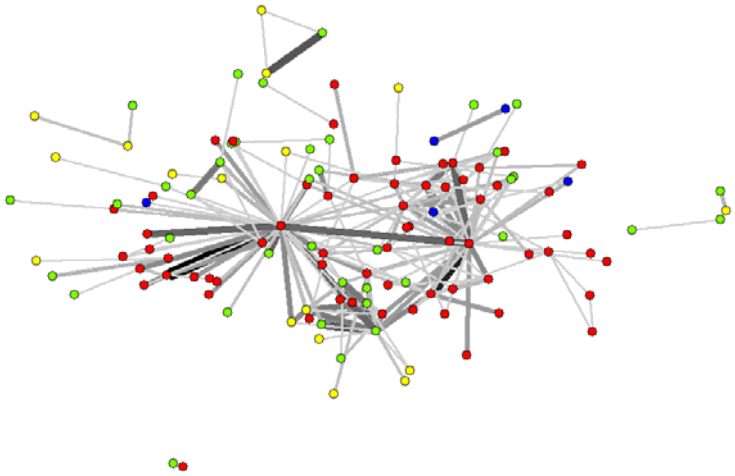

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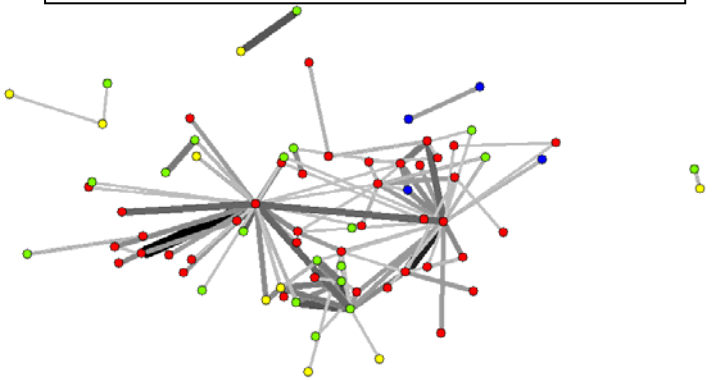

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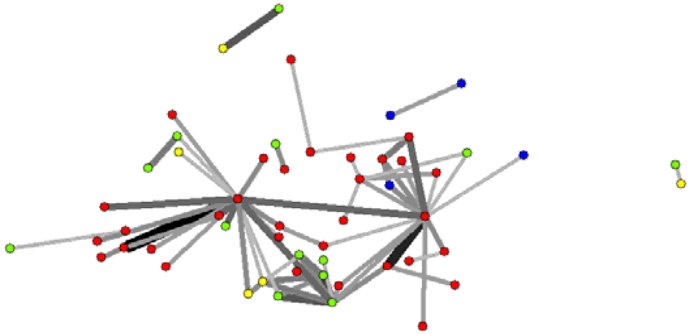

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