Digitalisation and organisational innovation

Lesson 7. The small worlds of creativity and innovation

Introduction

- The first part presents some theoretical and empirical research on the evolution of science of networks, often referred to as **complex network theory**:

1. Six degrees of separation
2. The small-world Small-world effect: MIT experiment, the “Harvard approach”, and the Watts–Strogatz model
3. Scale-invariant networks: a dynamic perspective
4. Affiliation networks

- The second part shows concrete applications of **small-world approach** in social sciences

1. The musicals industry (individual creativity)
2. Strategic alliances and patent partnerships (company)
3. The Silicon Valley hubs (local system)

1. Six degrees of separation

- The expression "**six degrees of separation**" is now widely used in everyday language and in academic studies to show that any person can be reached through a short chain of acquaintances.
- It illustrates the idea that "**the world is shrinking**", because only a few intermediaries are needed to connect us with anyone, even if they live far away or belong to a different social group.
- This idea is not new. It first appeared in **1929** in a short story called "***Chains***" by the Hungarian writer Frigyes Karinthy.
- In the story, a group of friends test the idea that the world has become smaller and more connected. Karinthy suggests that anyone can reach any other person in the world through five intermediaries, starting from someone they know directly

2. It's a small world:

- Why is this literary idea relevant for us?

1. It inspired the first reflections on **social networks**.

2. It was later confirmed by the **small-world experiments**, which led to more scientific and rigorous theories in network studies.

3. The idea of "small worlds" and the ties that connect them has important implications for **Innovation Studies**.

The MIT experiment

- Let us begin with the first point: it inspired the first reflections on social networks.
- In the late **1950s**, two American scholars at MIT in Boston (a political scientist and a mathematician) wrote a manuscript that later became the starting point for scientific research on the “small-world” phenomenon. It was circulated at the time but published only 20 years later.
- The authors wanted to develop an early theory of social and political influence, based on the idea that influence depends on **social ties** and on the ability to reach the **“right” people** through the **right channels**.
- For this reason, they focused on the **morphology of social structure**: how many social ties exist in a population and how they are distributed.

- The answer to these questions is not a simple matter of **probability**. It requires a deeper understanding of the society being studied.
- **Acquaintance networks** are not randomly distributed; they are **socially structured**. This significantly lessens the distance between certain, apparently far-flung, individuals, while extending the distance between certain others.
- Networks of personal contacts tend to cluster around **key social dimensions**: place (local proximity), work (professional ties), family (kinship relations), and leisure (voluntary or interest-based relations).

- Companies and organisations can be seen as **social groups** or **clusters**, where the people inside the group usually know each other well.

- The key question is how **closed** these clusters are (self-contained), and how much they are **connected** (or disconnected) from other clusters.

- Therefore, the chance that two people know each other depends strongly on the network of relations that links (or separates) **different social clusters**.

- The two MIT scholars explored these questions by creating a **mathematical model** of acquaintance networks. The model is based on three main parameters:

1. the total number of people in the population (N);
2. the average number of acquaintances each person has (n);
3. the level of **social structuring** (k), which later studies called the “clustering coefficient”.

- If the level of social structuring were zero (meaning there were no relationship clusters), the probability that two people know each other would depend only on the first two parameters (N and n).

- This situation, however, is only theoretical. Real societies are different.

- Friends usually live in the same city, have similar jobs, interests, and lifestyles. They belong to the same **social circles**, so it is easy for them to know one another.

- This means that each friend can introduce us to fewer new people, and this tends to extend (and complicate) the social ‘chains’.

- In other words, it is the **k** parameter (the level of social structuring) that decides how many intermediaries are needed to link two people. And it is the distribution of relational capital (**social capital**) between the various groups and individuals that conditions their social opportunities.
- So, to understand how many steps are needed to reach a certain person, simple probability is not enough. What we really need is knowledge of the relational structure of the population we are studying.

The “Harvard approach”

- The mathematical model created by the MIT group was interesting in theory, but it was based on **weak empirical evidence**.

- This encouraged other researchers to explore new methods. In 1967, social psychologists Milgram and Travers published the results of an experiment, known as the “Harvard approach” to the small-world phenomenon.

- Milgram and his team studied social structure and acquaintance networks through two ingenious empirical experiments.
- They selected some “random” people (starting persons) and gave them basic information about someone living in another state (the target person).
- These participants had to send a letter to the target person by traditional mail. The rule was: if they did not know the target directly, they had to pass the letter to someone they personally knew (a friend, relative, or acquaintance), who would then continue the chain.

- Initially, the researchers were sceptical about the experiment’s chances of success, but the results were surprising and offered four useful insights.

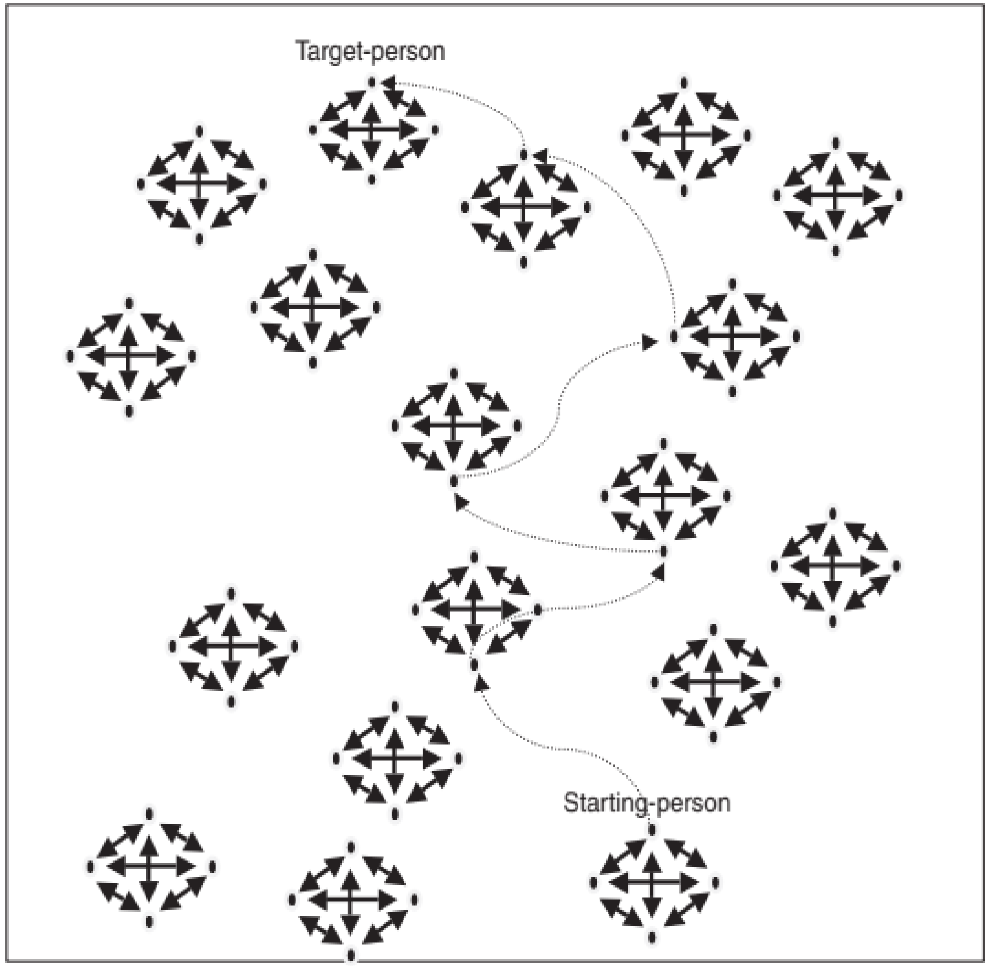
1. First, they discovered that the main barrier to sending information was **social distance**, not physical distance.

2. Second, they found the existence of **relational hubs**: many different chains of people ended up passing through a small number of key individuals who finally delivered the message.

3. Third, these hubs were **specialised**: some belonged mainly to professional chains (people connected through jobs), while others belonged to territorial chains (people connected through place of residence).

4. Fourth, the experiment showed clear **gender segregation**: men and women often sent the message to someone of the same sex, and they preferred to use friends and acquaintances rather than relatives.

- The figure helps us understand the real meaning of the Harvard experiment.



- The researchers also noted that these social patterns were typical of the United States in that period, and could be different in other societies.

- In short, the experiment offered interesting indications about how people are socially connected and, even more importantly, about the social mechanisms that shape **how information circulates**.

The millennium email experiment

- Almost 40 years later, in **2003**, a group of researchers at Columbia University (a mathematician, a physicist, and a computational social scientist) repeated the test on a larger scale, using the **internet**.

- The goal was to replicate the **small-world** test at a global level, tracking how messages moved from person to person and what kinds of social links were involved.

- However, the results were disappointing, and the researchers explained this by pointing to a simple reason: participants had **no real incentive** to take part and continue the chains.

- This conclusion, although it may seem obvious, is important: it shows that a **network structure** alone does not produce social effects.

- It only becomes meaningful when the people inside it have **specific motivations** and **strategies** (agency)

What we have learned?

- These initial studies highlight three key aspects:
- First, saying that two people are separated by five intermediaries does not mean that they are socially close.
- For example, any ordinary citizen could be only five steps away from the President of the United States or from Nelson Rockefeller. But this does not mean that their everyday life is connected in any real way to the President or to a billionaire.
- The distance is not just “five people”, but five whole “**circles of acquaintances**” – and that still represents a very large **social gap**.

- The second point: the **small-world** phenomenon must be understood in the **plural**. Society as a whole, scientific communities, and technological sectors all constitute a series of small worlds, highly internally integrated internally.
- Because networks are strongly clustered, the number of steps needed to reach a given person is higher than it would be in a world where relationships were randomly distributed.
- This **internal closure** of social networks has an important consequence: it limits access to new and non-redundant information, making it harder for actors to reach resources and ideas outside their own circle.

- The third point: close acquaintance cluster (family, close friends, colleagues, etc.) are internally well connected through direct links, but they are not isolated. They are linked to the outside world through **indirect** or **weak ties**, and it is precisely these bridges that **connect different “small worlds”** and make the small-world phenomenon possible.
- However, the experiments also show that even if people are theoretically connected by only a few intermediaries, **searcing**, **selecting** and **transmitting** reliable information across these links is not automatic.

The transaction costs in the use of networks

- These observations highlight the transaction problems and costs involved in using networks.

1. **Motivation**: even if connecting two acquaintances is easy, people will only do so if they have a good reason. Without motivation, the chain does not start or breaks quickly.

2. **Chain length**: the longer the chain, the greater the probability it will break or fail to deliver the expected benefits.

- As Ronald Burt notes, networks generate advantages in terms of information (access to new knowledge that creates favourable opportunities). It is evident that each additional step in the chain tends to diffuse (and disperse) new information amongst multiple subjects and, above all, it delays access (thus reducing the benefits related to timing).

3. **Accreditation**: each intermediary also acts as a “filter” that validates both the information and the person who provides it.

- The longer the chain, the weaker the credibility effect becomes: “a friend of a friend of a friend” is less convincing than a direct contact.
- It is then evident that the more this function of accreditation is dependent on a long chain of ‘acquaintances of acquaintances’, the more it tends to lose power.

3. Small-world networks: the Watts–Strogatz model

- Researchers repeated the **small-world experiment** many times to test the impact of different variables, such as gender, ethnicity, organisational setting, and the use of different media (for example, telephone or email).

- Many of the **problems** reported were already visible in Milgram and Travers' studies (the "Harvard approach"): small samples and arbitrary selection criteria reduced both randomness and representativeness.

- Low response rates and many incomplete chains made the experiments unreliable for mapping social networks and for estimating real path lengths.

- Participants often chose **unsuitable intermediaries**, which created longer chains than the shorter routes that were actually available in the network.

- In addition, the rise of **large-scale digital data** allows scholars to analyse the small-world phenomenon with more robust and alternative methods (**agent-based model simulation** and **big data**).

- Interest in the topic has revived thanks to **new mathematical models** of small-world networks found in social, biological, and technological systems.

- In the late 1990s, two researchers from Cornell University (Watts and Strogatz) published an article that had a strong impact across many disciplines.

- Their study showed that if we start from an <u>ordered model</u>, made of local clusters (short-range links between nearby points) and then add a few **random long-distance links**, the average distance between all points in the network becomes much shorter.

- They show that this process creates a network that combines some properties of the **regular network** (the high clustering of local relations) with those of the **random network** (high reachability of all nodes).

- In other words, the randomly added links (which in real life may be friends with long-distance networks) act as **shortcuts** that reduce theoretical distance.

- The two researchers also show that this kind of network reflects patterns that exist in reality: the collaboration network of Hollywood actors (a social network); the electricity grid in the western United States (a technological network); and the system of 302 neurons in the organism Caenorhabditis elegans (a neural network studied in developmental biology).

- All three of these “**real networks**” turned out to be small-world networks.

- Therefore, two surprising results emerged from this experiment.

1. The first is that the **small-world effect** does not exist only in social networks.
2. The second is that only a **few local changes** (a small number of long-range links) are enough to produce **strong global effects**, such as an exponential drop in average distance.

4. Scale-invariant networks: a dynamic perspective

- Other studies expanded the mathematical modelling of networks and helped us understand their **dynamic evolution** (how they evolve over time).

- Almost at the same time as the research on small-world networks, Albert-László Barabási, a physicist at the University of Notre Dame in Indiana, and two collaborators, Réka Albert and Hawoong Jeong, published two highly influential articles on “Science” and “Nature”.

- These studies revealed the existence of **other types of networks**, which follow different rules from those described by Watts and Strogatz.

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Internet

Diameter of the World-Wide Web

Réka Albert, Hawoong Jeong & Albert-László Barabási

Nature **401**, 130–131 (1999) Cite this article

Abstract

Despite its increasing role in communication, the World-Wide Web remains uncontrolled: any individual or institution can create a website with any number of documents and links. This unregulated growth leads to a huge and complex web, which becomes a large directed graph whose vertices are documents and whose edges are links (URLs) that point from one document to another. The topology of this graph determines the web's connectivity and consequently how effectively we can locate information on it. But its enormous size (estimated to be at least 8×10^8 documents[1]) and the continual changing of documents and links make it impossible to catalogue all the vertices and edges.

- Many real networks do not follow a normal distribution of links but rather a **power law**, where many small events (nodes with few links) exist together with a few large events (nodes with many links).

- In real-world networks, this means that most nodes have only a small number of links, while a few nodes have an extremely high number of connections: these are the so-called connectors, or **hubs**.

- In random networks, all nodes have, on average, the same number of links. In networks that follow a power law, however, it is useless to talk about an average value, because there is no ‘typical’ node that represents and that can summarise the characteristics of the others.

- Since these networks do not have a characteristic scale, they are called **scale-invariant networks**.

- Barabási and his collaborators used the World Wide Web as the starting point for their observations. With special software, they mapped the pages (nodes) and the links connecting them.
- Their exploration produced a surprising result: the enormous web had a relatively limited diameter, since all documents were on average only 19 clicks away from one another.

- They also showed that global connectivity is not ensured by all nodes equally, but mainly by the hubs. This led them to conclude that the web depends on a small number of highly connected nodes.

- The same pattern appears in many other **real-world networks**. Hubs make the small-world effect possible because their high connectivity links many nodes and keeps the paths between them short.

- Models based on random networks are **static and egalitarian**: the number of nodes stays constant and each node is treated as equal.

- The scale-invariant model relies on two opposite assumptions, which explain the emergence of power laws through two generative mechanisms found in many complex systems:

1. **Growth**: networks constantly expand by adding new nodes;
2. **Preferential attachment**: new nodes tend to connect to nodes that already have many links.

- Real-world networks are therefore **dynamic systems**: the number of nodes increases, and new nodes usually choose to link to existing hubs.

- From these initial reflections, and subsequent contributions by physicists, mathematicians, sociologists, biologists, and computer scientists, a new field of research has developed on how networks evolve.

- The **topology of networks** and their **different forms of change** increase their variety.

- For example, the ways in which nodes age, disappear, or are replaced, the rules for creating new links, and whether links are costly (in terms of time) or not, all strongly affect the number and size of hubs in real networks.

- In these advances in **network evolution theory**, the scale-invariant model appears as a special case. Nevertheless, when growth and preferential attachment exist, power laws and hubs still appear “most of the time.”

From non-human networks to actors’ agency

- However, in **socio-institutional contexts**, the resources needed to build social ties are very different from those required to create or maintain web page links and, most importantly, they change depending on the **type of interaction**.

- In a logic of complex and **mutual interdependence**, networks both shape and are shaped by the socio-institutional environment in which interpersonal and inter-organisational relations develop.

- In the **social sciences**, there are then many more sources of variability and contingency, which limit the possibility of applying the same “natural laws” that govern the structure and evolution of non-human complex networks.

- Social networks are made up of **nodes**, and each node carries a **social identity**.
- The key point in this argument is that the **different identities** of actors shape both the **map** and the **compass** they use to act.
- These identities also structure networks through the **principle of homophily**, which leads people to connect mainly with others who share similar traits: “***similarity produces connection***”, so networks tend to be homogeneous along many dimensions.
- This principle of homophily restricts the individual’s social world, limiting interaction to a circle of “similar”, and therefore reducing access to new information and diverse experiences.

- These small worlds of “similar” are also **layered** and **interconnected**, which opens windows onto different social worlds. Identities and interactions are indeed multi-dimensional, allowing individuals to move across various contexts and even bridge large distances.

- This dual nature of social identities shapes networks through two opposite principles:

1. Homophily makes local worlds small, because people cluster around similarity;
2. Multi-dimensionality makes the global world small, because it enables people to cross the boundaries of their local worlds.

- In conclusion, the distinctive feature of social networks is that they are composed of actors who **deliberately use** and **manipulate** their relationships (agency) and this feature conditions the properties that the social networks deploy.

- This step introduces the last type of network we will see: the **affiliation networks**

5. Affiliation networks

- We call two social actors affiliates when they belong to the same group.

- Examples of affiliation networks in innovation include: two technicians working on the same project in a firm, two inventors who file a patent together, or two university researchers who co-author a paper.

- Mark Newman, a physicist at the University of Michigan, shows that these **collaborative partnerships** also tend to form small-world networks.

- The same logic also applies to another type of affiliation network, often analysed in economic sociology: **interlocking directorates**.

- Scholars study the overlap of managers sitting on the boards of different firms to understand how economic activities are coordinated in both manufacturing companies and financial and credit institutions.

- Cross-shareholding, shared board positions, and co-optation practices, together with personal ties between corporate executives, act as regulatory mechanisms for firm relations that go beyond simple market rules.
- Sitting on the same board creates channels through which management practices and business strategies circulate. This promotes innovation through the exchange of ideas and through organisational isomorphism, meaning the spread and imitation of similar innovations.
- In this sense, interlocking directorates work as a powerful mechanism of coordination and transformation among large American corporations.

- **How does this mechanism actually work?**
- **Is it the result of deliberate planning or does it emerge spontaneously?**
- **Which actors and institutions play the main role?**
- Research on the largest US companies across different historical periods (from the early twentieth century to the 1970s) shows a high level of concentration and interconnection within business structures.
- Networks of interlocking boards made it possible to reach any member of the American managerial élite in only a few steps—usually four or five, depending on the study.
- In addition, until the early 1980s, the main commercial banks (such as J. P. Morgan and Chase Manhattan, later merged in 2000) played a key role in maintaining this high level of connectivity within the corporate elite.

- After the 1980s, however, this stable system began to break down.
- As internationalisation increased, the recruitment criteria and management practices of the elite changed, and corporate governance shifted more strongly toward the interests of shareholders.
- With the rise of shareholder capitalism, boards of directors became smaller on average, less interconnected, and included fewer internal managers (see VoC).
- Managers were paid in company shares and faced stronger performance pressures, including tighter monitoring from institutional investors. These heavier responsibilities made it harder for them to sit on multiple boards at the same time.

- **How did the integration of the American business elite change after these developments?**
- **What happened to the connectivity created by interlocking directorates?**
- The data shows that the overall structure of the network does not depend on specific managers or firms, nor on the stability of inter-organisational ties, nor on which institutions are central (such as commercial banks).
- The high level of integration within the American business elite is an emergent property of the small-world network. It does not require intentional design, a central authority, or a coordinating group.
- Network connectivity is highly stable over time (path dependence) and remains strong even when key nodes disappear (resiliency).
- The authors show that even when the main actors are removed, the network stays connected and the average path length increases only slightly.

1. The musicals industry

- **What is the relationship between small-world networks and innovative capacity?**
- Brian Uzzi and Jarrett Spiro (2005) explore this question in their study of the world of artistic creativity.
- They argue that creativity and innovation emerge from combining different ideas or mixing influences from several artistic fields.
- Creative tension does not come from the solitary efforts of isolated individuals, but from a system of social relations.

- The authors ask whether the dual nature of small-world networks — strong local clustering combined with wide global reach — influence creative performance.
- Most research on these networks focuses on classifying them or showing where they appear in the real world. Few studies link the structural properties of these networks with their performance.

- Networks shape the behaviour of actors by influencing the level of connection and cohesion in their relational world.
- Cohesion builds trust and reputation, so that material coming from a specific cluster acquires credibility and value in different environments.
- The strong connectivity of small-world networks allows a larger number of subjects to interact, helping information move across different clusters of relationships.

- Uzzi and Spiro tested these hypotheses by studying the Broadway musical industry.
- Their dataset included information on more than 2,000 people involved in 474 original musicals produced between 1945 and 1989.
- The core team of each musical usually included six roles: the composer, lyricist, librettist (who writes the story), choreographer, director (who coordinates the team) and producer (who provides financial support).

- Collaboration starts when one or more artists develop new material and invite others to join the team.
- Box office revenue defines commercial success, while critics' reviews determine artistic value.
- Success depends largely on the originality of the product, which, in turn, rests on two factors:

1. The team's access to a wide and diverse set of artistic resources;
2. The belief that new experiments do not involve excessive risk.

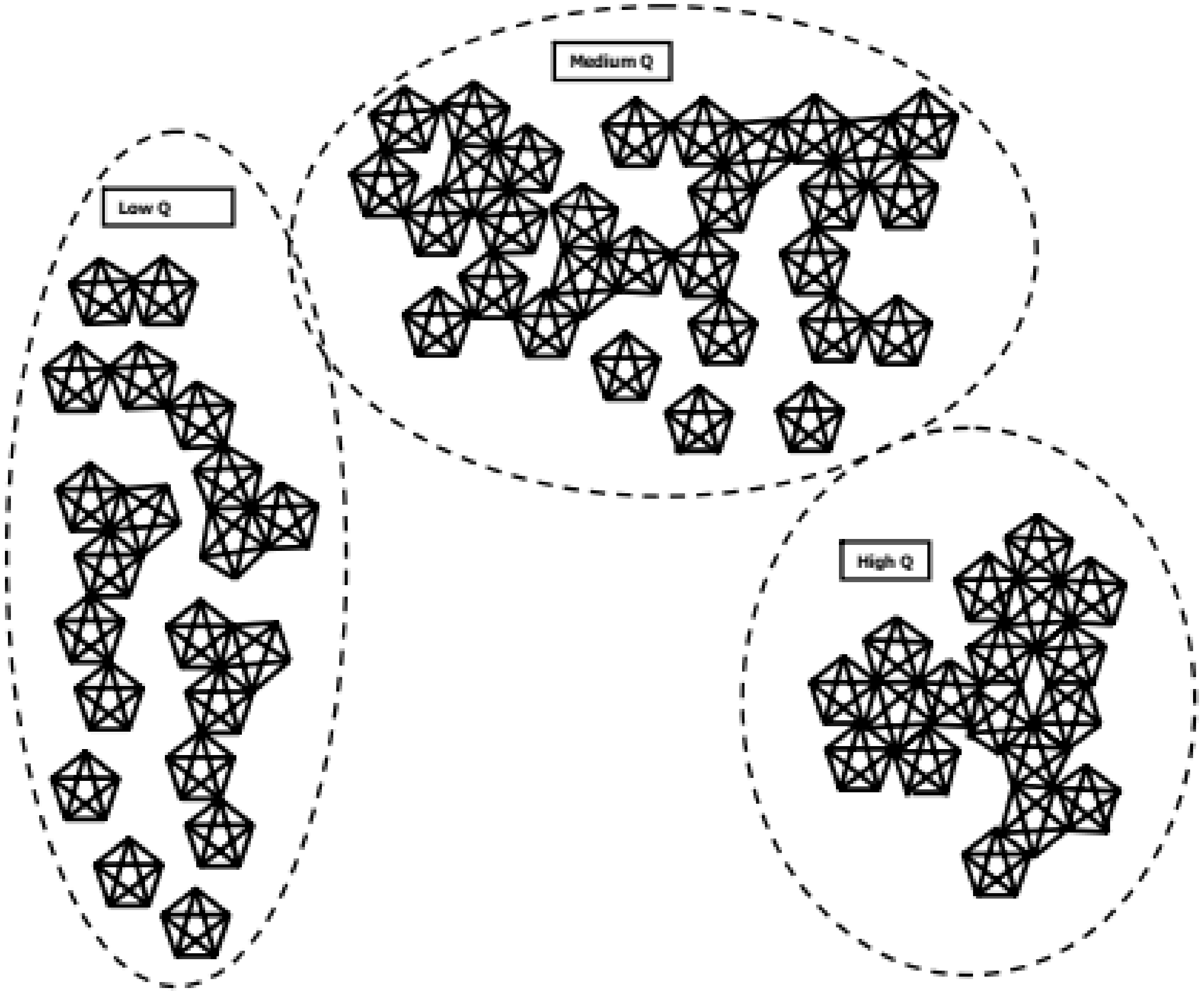
- Creative work is based on shared conventions, which give artists common rules for effective collaboration and help them predict how audiences and critics will react (see Domain and Field).
- Original artists adapt and tailor these conventions to their own requirements, develop a personal style, and introduce innovations that, once accepted and copied, later become part of the conventions themselves.
- Innovation relies on access to “uncommon” creative material, which comes from working with other artists.

- A successful show is based on a combination of convention and innovative material.
- Without the first (shared standards) the product would be incomprehensible; while without the latter it would be boring and repetitive.

- Groups of artists who work together repeatedly over time (local clusters) tend to share the same artistic repertoire.
- By contrast, bridge-links formed between different clusters (through certain artists who connect them) create two positive effects: they allow different conventions to come into contact, and facilitating the validation of new material.
- Small-world networks provide the ideal setting for this successful combination.
- These networks not only create bridges that overcome structural gaps, but also build the trust needed for innovators to accept the risks of new experiments.

- Uzzi and Spiro showed with empirical data that changes in the balance between local cohesion and global connectivity also changed creative performance.
- However, the relationship was not linear: it followed an inverted U-shape.
- When the small-world quotient (Q) was too low or too high, it produced opposite problems: too much variety made artistic products hard to share or use, while too much homogeneity reduced options and led to standardised conventions.
- The highest creative performance appeared at intermediate levels of the small-world quotient.

Figure 2 (cont.) Variation in Small World Network Structure



- When Q is low there are few links between teams (clique) and there is low connectivity and cohesion in the global network.
- As Q tends towards a high level, there are many between team links and these links are disproportionately made up of repeated and third party ties – there is high connectivity and cohesion in the global network.
- At medium levels of Q the small world network has an intermediate amount of connectivity and cohesion.

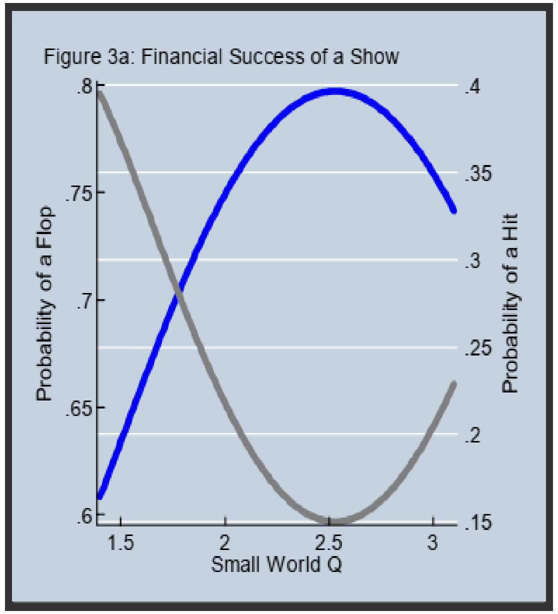


Figure 3a: Financial Success of a Show
.8
.75
.7
.65
.6
Probability of a Flop
.4
.35
.3
.25
.2
.15
Probability of a Hit
1.5
2
2.5
3
Small World Q

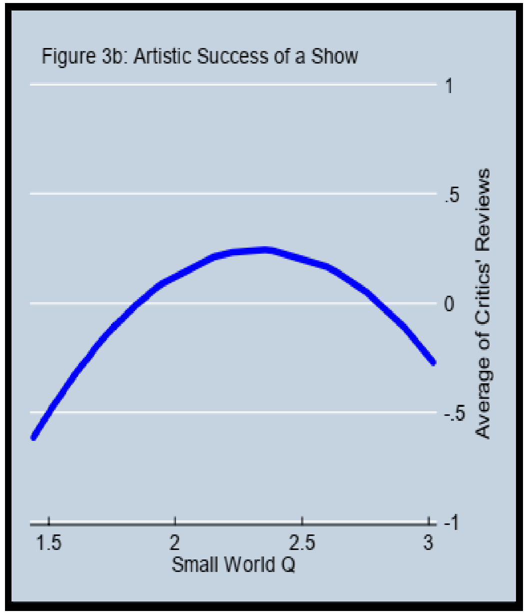


Figure 3b: Artistic Success of a Show
1
.5
0
-.5
-1
Average of Critics' Reviews
1.5
2
2.5
3
Small World Q

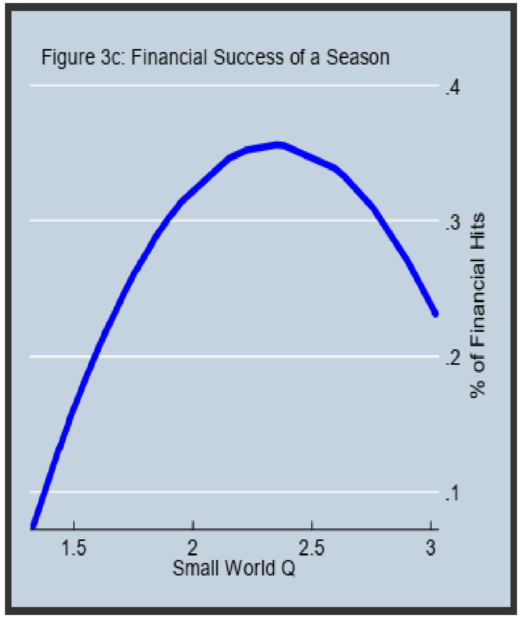


Figure 3c: Financial Success of a Season
.4
.3
.2
.1
% of Financial Hits
1.5
2
2.5
3
Small World Q

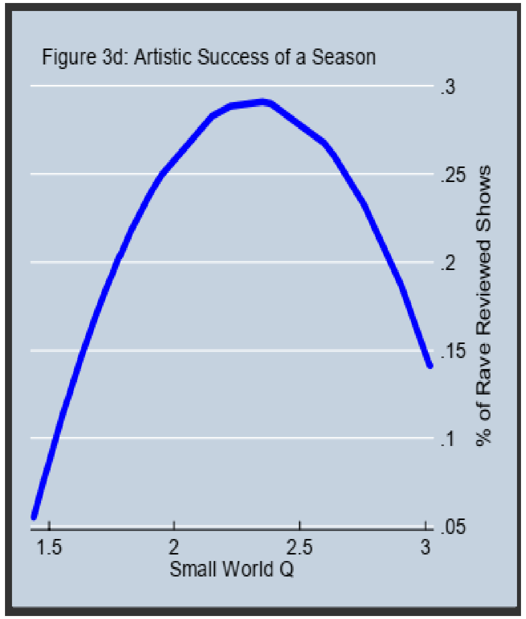


Figure 3d: Artistic Success of a Season
.3
.25
.2
.15
.1
.05
% of Rave Reviewed Shows
1.5
2
2.5
3
Small World Q

2. Strategic alliances and patent partnerships

- In recent years, research on small-world networks has been extended to a number of economic phenomena: agreements between investment banks; collaborations between companies in the fields of research and technology transfer; and partnerships between inventors.
- Studies have emphasised their efficiency in terms of information flow, as well as the transfer and increase in level of knowledge.
- In particular, small-world networks appear to positively influence the innovative capacity of companies through mechanisms similar to those identified for the artists of the Broadway musical.

- A study by Melissa Schilling and Corey Phelps (2007) analysed strategic alliances made between 1990 and 2000 by more than 1,000 US firms in 11 high-tech sectors.
- The authors view innovation as a recombinatory problem-solving process, where firms develop new solutions by creatively combining elements that are already partly known.
- In this view, small-world networks create a favourable structure for innovation. High local clustering increases the ability of firms to exchange information and builds the trust needed for knowledge sharing and joint problem-solving.
- At the same time, bridging ties, that link different clusters, allow non-redundant information to circulate, expanding the range of possible recombinations available to firms.

- The research data confirms the hypothesis. First, strategic alliances show strong clustering: firms tend to form alliances with other firms that are already linked through cooperation agreements.
- In addition, in industrial sectors where the distance between clusters is low (that is, where a small-world effect exists), firms show higher innovative capacity, measured by the number of new patents produced in the years after the alliance.
- In other words, Schilling and Phelps show that the overall network structure of an industrial sector affects the performance of individual firms, and similar effects have been found by other scholars in partnerships between inventors.

3. The Silicon Valley hubs

- Michel Ferrary and Mark Granovetter study a well-known innovative cluster: Silicon Valley.
- They distinguish this type of cluster (innovative clusters) from “industrial clusters”, which are mainly based on incremental innovation within an existing specialisation.
- In contrast, innovative clusters stand out because they can radically reconfigure their value chain through breakthrough innovation, that creates new industrial sectors.

- The competitive advantage of these clusters lies in their constant ability to generate cutting-edge start-ups.
- Innovation is not created by single firms, but by the whole local system: it results from the interaction of many actors embedded in a complex network of social relations.
- For this reason, Ferrary and Granovetter argue that the sociological study of networks can strongly improve the analysis of innovative clusters.

- Complex networks have three specific characteristics.

1. First, they are composed of a plurality of nodes that interact without any form of hierarchical coordination.
2. Second, the structure of relations and the forms of coordination that emerge affect the efficiency of the actors.

- Their performance depends not only on their own resources and skills, but also on how they interact with the surrounding environment.
- In other words, there is a systemic interdependence between the nodes and the network, and the ability of both to survive depends on the variety of the nodes and the connectivity of the network.

3. Another key feature of complex networks is their robustness, meaning their ability to resist external shocks. Robustness does not imply that the network stays stable (unchanged), but that it can reorganise itself when faced with major threats to its survival.

- This resistance comes from the completeness of the network, where many heterogeneous actors interact in a decentralised way.
- This structure makes it possible to integrate different modes of learning, stimulating the creativity of firms and innovation of the system.

- Ferrary and Granovetter describe Silicon Valley as a paradigmatic case of an innovative cluster based on a complex network.
- In this area, many different socio-economic actors interact: not only firms, universities and research labs, but also law and consulting offices, investment and commercial banks, venture capital funds, service companies and recruitment agencies.
- These actors create a dense web of relations, where organisational and economic links combine with personal and social ties (multiplex ties).
- The region's innovative strength depends on the completeness of this network, which brings together diverse but complementary actors.

https://www.google.it/maps/place/Silicon+Valley,+California,+Stati+Uniti/@37.5708555,-122.319814,78316m/data=!3m1!1e3!4m6!3m5!1s0x808fb68ad0cfc739:0x7eb356b66bd4b50e!8m2!3d37.387474!4d-122.0575434!16zL20vMDZwdzY?entry=ttu&g_ep=EgoyMDI1MTExMi4wIKXMDSoASAFQAw%3D%3D

- Other areas with strong innovative potential perform less well because their networks are less complete.
- In fact, Silicon Valley was formed historically through several stages, each adding new actors who reinforced the systems of relations.
- The presence of a top university like Stanford, the creation of companies such as Hewlett-Packard, and the arrival of major external firms like General Electric, IBM and Lockheed in the 1930s were not enough on their own to make the area highly innovative.

- In the late 1950s and early 1960s, with the rise of the semiconductor industry, Silicon Valley became an innovative cluster that continued to evolve and expand. Only later, in fact, were other essential elements added:
- Private research laboratories (Stanford Research Institute in 1946 and Xerox PARC in 1970);
- The first investment banks in the late 1960s;
- The creation of major venture capital firms in the 1970s;
- The growth of law firms specialising in high-tech industries in the 1980s.

- The complexity of the network gives the system its special ability to change organisational architecture and areas of specialisation through major innovation.
- The area was given its initial boost through semiconductors (with companies such as Fairchild Semi-conductor, Intel etc.) but subsequently went on to specialise in personal computers (Apple), software (Oracle, Sun Microsystems, Symantec, etc.), telecommunication systems (Cisco System, Jupiter Networks, 3Com), and the internet (Netscape, Excite, eBay, Yahoo!, Google).

- As we have seen, certain actors in complex networks can act as hubs. In Silicon Valley, venture capital firms (VCs) play this role by investing risk capital in the most promising local start-ups. This strong VC presence distinguishes this area from many other technological districts.
- In 2006, 180 of the 650 US VCs were based in Silicon Valley. Between 1995 and 2005, investments flowing into the Californian VC cluster made up about one-third of all VC investments in the US and Europe.

- The presence of these investment companies improves the innovative capacity and the overall robustness of Silicon Valley, and carries out five specific functions.

1. The first, and most famous, is the financing of technological start-ups.
2. The second is selecting them.

- The VCs fund a small part of the Valley's startups (about 9 per cent of the more than 2,000 new companies that are created every year). However, almost all of those that have been successful have received support from the VC.
- The VCs' high level of competence in the leading sectors allows them to identify the most promising entrepreneurial projects, fostering their survival before market mechanisms come into operation.

3. The third function is signalling the most promising start-ups. When a VC – especially a well-known one – decides to invest, this creates a ripple effect of legitimacy among other actors in the system, which in turn facilitates the subsequent development of new businesses.
4. The fourth function is embedding new companies in the local system. VCs use their own networks to help start-ups enter the wider regional network. In this role, VCs act as key hubs that integrate and coordinate relationships in Silicon Valley.
5. The fifth function is collective learning. VCs help build a shared pool of entrepreneurial knowledge and experience that new firms can use.

HOW THE VENTURE CAPITAL INDUSTRY WORKS

The venture capital industry has four main players: entrepreneurs who need funding; investors who want high returns; investment bankers who need companies to sell; and the venture capitalists who make money for themselves by making a market for the other three.

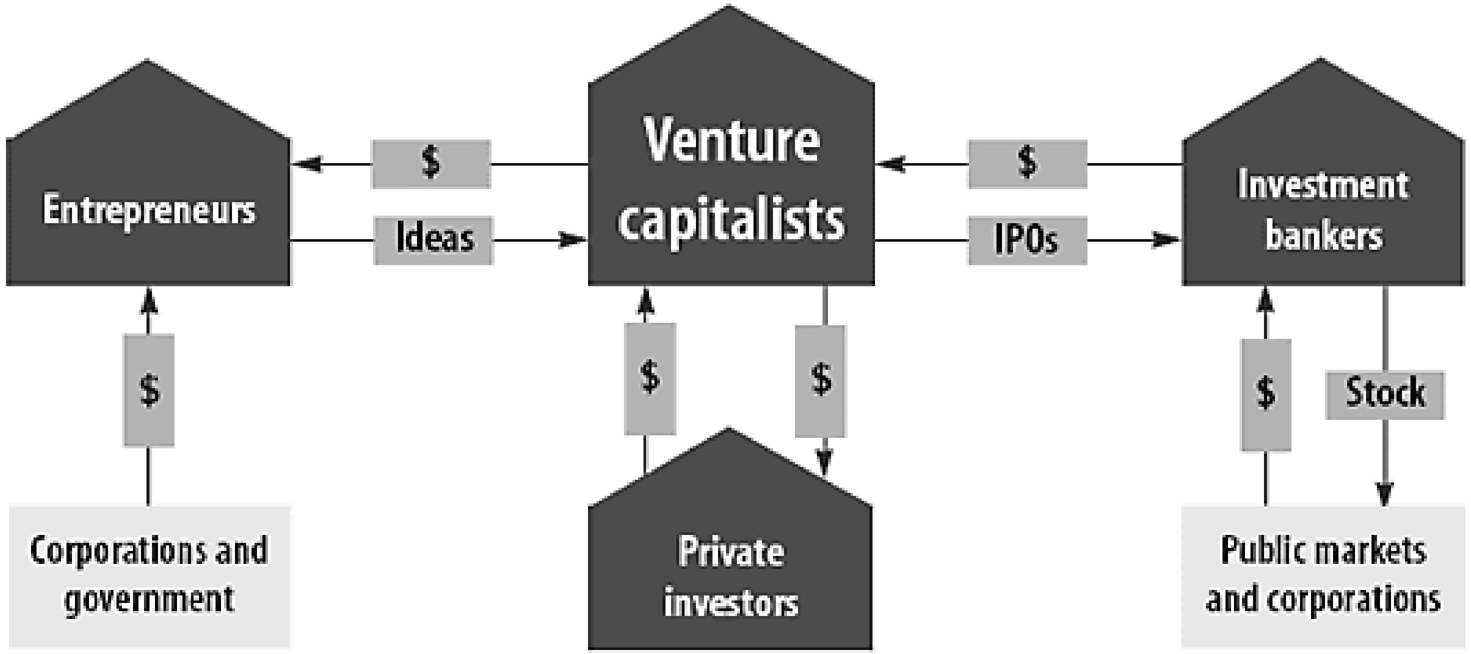


Figure 1. The complex network of innovation of Silicon Valley

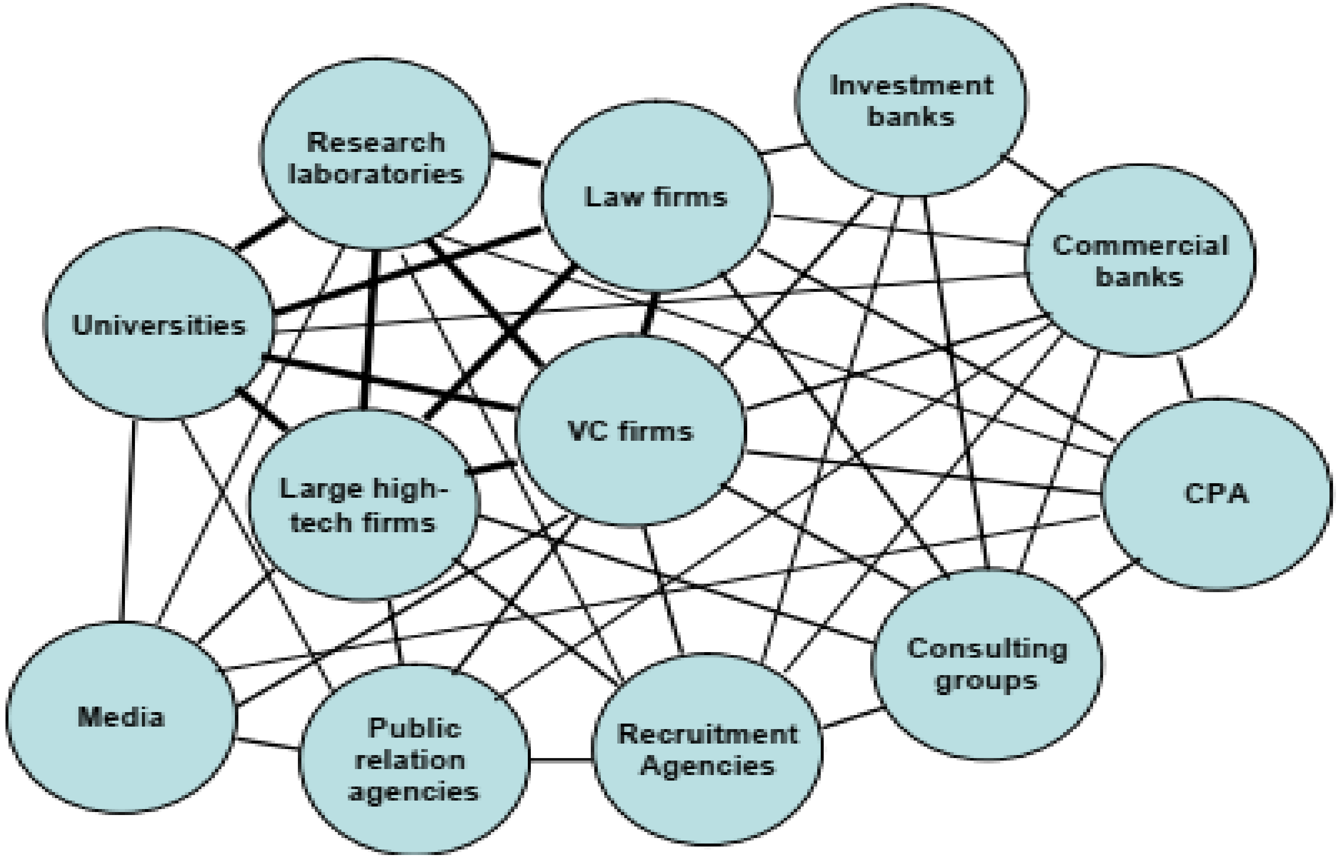


Table 2. Economic functions of agents of Silicon Valley

Agents	Formal functions	Informal functions
Universities	Nurture innovations Accumulate expertise Provide trained workers	Incubate start-ups Socialize agents
Large firms	Nurture innovations Develop innovations Accumulate expertise	Incubate start-ups Acquire start-ups Partner with start-ups Provide trained workers Socialize agents
Research laboratories	Nurture innovations Accumulate expertises	Incubate start-ups Socialize agents
VC firms	Finance start-ups	Select start-ups Accumulate entrepreneurial knowledge Embed start-ups Signal start-ups Network the cluster
Law firms	Accumulate legal expertise Handle legal issues	Embed start-ups Network the cluster
Recruitment agencies	Favour labour market	Network the cluster
Public relations firms	Publicize start-ups	Network the cluster
Media	Circulate information	Publicize start-ups Sustain an entrepreneurial culture
Consulting groups	Accumulate business expertises Supply expertise to start-ups	Provide trained workers
CPAs	Accumulate accounting expertise Handle accounting issues	
Investment banks	Organize IPO of start-ups Organize acquisitions of start-ups	Signal start-ups
Commercial banks	Enable financial transactions	

Table 3. Initial VC funding of large high-tech companies

Company	Employees	Founded	First funding	Investors
Adobe Systems	5734	1982	1982	JP Morgan Partners
Advanced Micro Devices	9860	1969	1969	Sequoia Capital, Bixby Associates, Bank of America
Agilent Technologies	21,000	1999	*	*
Apple Computer	14,800	1977	1978	Sequoia Capital, Venrock Associates, Arthur Rock
Applied Materials	12,576	1967	1969	Partech International, Adler & Co., Frederick Adler, General Electric Venture Capital
Atmel	8076	1984	1987	Institutional Venture Partners
Cadence Design Systems	4900	1988	1988	TA Associates
Cisco Systems	38,413	1984	1984	Sequoia Capital, Stanford University, Indosuez Ventures, Vencap, Inc.
Cypress Semiconductor	5100	1982	1983	Sequoia Capital, Mayfield Fund, Stanford University, KPCB, Merrill, Pickard, Anderson & Eyre, Dietrich Erdmann, Whitney & Co., Sevin Rosen Funds
eBay	22,000	1995	1997	Benchmark Capital
Electronic Arts	6819	1982	1982	Sequoia Capital, KPCB, Sevin Rosen Funds
Google	5680	1998	1999	Sequoia Capital, KPCB
Hewlett-Packard	150,000	1938	*	*
Intel	99,900	1968	1968	Venrock Associates, Grinnell College

Conclusion

- In conclusion, Ferrary and Granovetter use the new science of networks to show the strong interdependence between the performance of single actors and that of the whole network.
- As they point out, the theoretical contribution provided by their study is to highlight the relevance of the actors in the system (agency).
- Complex network theory often explains emergent properties by looking at the structure of links, not at the nature of the nodes. Yet, as we have seen, in social networks the identity of the actors is important.

- The specific characteristics of venture capital firms explain their central role in the network and influence the performance of the whole system.
- This point also highlights the importance of the institutional and regulatory setting in which actors operate. The rules of the financial market and contract law in the US, together with Silicon Valley's particular cultural environment, are key to understanding both who the actors are and how they interact.
- This argument opens the way for empirical and comparative studies of complex networks, paying more attention not only to actors and their strategic use of networks (agency), but also to the institutions that shape the context of interaction (see comparative political economy and growth models).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Thanks for the attention

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