

The nature of interaction between Israeli entrepreneurs and investment capital available
within and from outside Israel

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Attestation of Authorship

I, Avishai Friedman, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.



Signature:

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Abstract

Israel is a small country that has rapidly become a global leader in production of high-tech goods. Supporting this industry is strong investment and high levels of entrepreneurship. Some scholars suggest a close similarity between the Israeli Venture Capital industry and that of Silicon Valley. To validate that claim I have closely replicated a network model developed for entrepreneur-venture capital interactions in Silicon Valley and applied it to Israel. This has been achieved through mapping the linkages with a 3D network modelling software (Pajek) between biotech firms created since 2000 and other players in the Israeli market such as venture capital funds, universities and government institutions. Information gathered on the entrepreneurs responsible for the biotech firms creation suggests that the majority are either professors at research institutes or hold a doctorate degree, suggesting strong linkages between the entrepreneurs and their research institutes. Many firms are also found to employ professional management teams. The matrix of inter-connections and supporting institutions suggests that biotech research institutions have a strong focus on fostering commercialization of new technologies. There is also abundant support for high-tech and venture capital from the Israeli government, which is a point of difference between Israel and Silicon Valley. Taken together the strong presence of institutions and of government support may explain, at least in part, the attractiveness of Israel for investors despite the country's precarious and uncertain condition as one of the global war and conflict hot spots.

Introduction

Israel is a small country in the Middle-East surrounded by nations and ideologies which have openly proclaimed and sought its destruction since its inception in 1948. Since that time Israel has been embroiled in numerous international and domestic conflicts:

- 1 1948 the War of Independence
- 2 1956 the Sinai War
- 3 1967 the Six Day War
- 4 1973 the Yom Kippur War
- 5 1976 the Entebbe Raid
- 6 1981 the air raid on Iraq nuclear facilities
- 7 1982 the Lebanon War
- 8 1987 the First Palestinian Intifada
- 9 1991 the Gulf War
- 10 1995 assassination of Prime Minister Rabin
- 11 2000 the al-Aqsa Intifada or the Second Palestinian Intifada

(Herzog, 2004)

Considering these ongoing hostilities one would expect a climate of high economic uncertainty. On the contrary, the Israeli economy has continued to strengthen and is now considered a global leader in the high-tech industry (Schwartz & Bar-El, 2007).

Underlying and sustaining this growth has been an exceptionally strong investment industry (Schwartz & Bar-El, 2007). As a percentage of gross national product (GNP) the level of venture investments over the 1999–2004 period in Israel is much higher than the US and European Union (EU) country averages for the same period (Avnimelech & Teubal, 2004, 2004a), which suggests that Israel is at least a very attractive investment destination. At first glance it appears irrational for so much foreign investment to flow into a nation continually faced with existential threats. The possibility always exists that military conflict will destroy businesses and capital, which logically would pose as a serious deterrent to investors. However, the reality of strong capital inflows suggests that favourable conditions have been created in Israel for investment and the returns are significant enough to warrant bearing the risk. This leads one to question what factors are drawing investors into the market.

Numerous reasons are cited for the high investment focus, amongst them Israel's large civil R&D budget, world-class educational institutions, and an educated and motivated workforce (Levenfeld, Platt, Schapiro, & Tisoni, 2005). Also significant is that investments in Israel are heavily focused on early-stage financing of companies such as start-ups, themselves considered risky forms of investment (Mayer, Schoorsb, & Yafeh, 2005). An explanation is given for these unusual conditions by Schwartz & Bar-El (2007) who note that Israel has for a long time been regarded as "the world's most vital place for entrepreneurship" (Haour, 2005 p. 39). The presence of strong entrepreneurship seems a plausible reason for the high investment levels. However, without access to venture capital (hereafter referred to as VC) entrepreneurship would soon dry out.

Previous work has described the Israeli VC industry as modelled along America's Silicon Valley (Avnimelech & Teubal, 2004) to the point of considering it the most successful transplant of the Silicon Valley model outside of North America (Schwartz & Bar-El, 2007; Avnimelech & Teubal, 2004a; Bresnahan, Gambardella and Saxenian, 2001; Carmell & de Fontaenet, 2004). Work by Castilla, Hwang, Granovetter and Granovetter (2000) highlights the extent to which networks have contributed to the VC industry in Silicon Valley: "The most crucial aspect of Silicon Valley is its networks. There is no proposition so universally agreed upon and so little studied..." (Castilla et al., 2000). Numerous other authors emphasize the value of networks to the finance and entrepreneurial disciplines, and the importance of VC to high-tech more generally: Makela & Maula (2006) show that international cross-border movements of finance are highly dependent on formal networks that exist to facilitate them; Steier & Greenwood (1995) suggest the relationships between investors and entrepreneurs may be more crucial to securing finance than the business plan; Carpenter & Petersen (2002) show that venture capital is often the only source of funding available to high-tech start-ups since they often have insufficient collateral for institutional public lenders (i.e. banks) and have a lot of non-tangible R&D expenditure such as high-tech workers' salaries.

Given the similarity of Silicon Valley and the Israeli high-tech and venture capital markets, as well as the stated reliance on networks, it seems logical to analyse the nature

of entrepreneur – venture capital relations in Israel through the 3D network analysis method used by Castilla et al. (2000) in their research of Silicon Valley. Their paper outlined and described a model which appeared suitable, albeit with a few minor changes, and which has not been applied to the case of Israel before (supported by personal communication with Mark Granovetter, a co-author of the paper by Castilla et al. (2000)).

This leads to my **research question**:

Do networks similar to the ones in Silicon Valley exist among Israeli entrepreneurs and their venture capitalists and do they work as a counterweight to level out the relatively high risk for investors in a region riddled with conflicts? In other words, how are Israeli entrepreneurs and venture capitalists connected? How do networks create a counterweight to investment uncertainty?

A literature review has been conducted by breaking down the focus of the research into the three distinct sections which encompass the research question, namely entrepreneurship, venture capital and network theory. The different literatures are then reviewed and inferences made as to which factors are likely to be important in the case of Israeli high-tech entrepreneur-venture capital relations. Given the broad nature of this research it has been decided to concentrate on theory connected to high-tech studies, particularly given the reliance of the Israeli economy on high-tech industries (Avishai, 1991; Kessel, 2006).

Specific information on the model, data collection methods, data analysis and the results are presented after the literature review in separate sections, along with areas for future study and limitations to this research.

Research objectives:

- Mapping of relationships of entrepreneurs with VCs to demonstrate the

established network ties as a counterweight to investment risks of political insecurity in Israel.

- Explore theoretical explanations of how network relations reduce uncertainty for investors.

Literature Review: A definition of Entrepreneurship

Entrepreneurship, it would seem, is one of those things that everyone acknowledges as essential for a capitalist society yet inexplicable without recourse to a diverse set of reasons. Despite its absolute necessity to business (Shane, 2003, p. 1) and numerous other fields, there are as yet no comprehensive overviews of entrepreneurship (Acs and Audretsch, 2005, p. 9). The academic literature on the topic is considered to still be rather weak (Shane, 2003, p. 2). Also of note is that the definition of what entrepreneurship is has changed over time into three distinctly different forms. The earliest such definition, the classical view of entrepreneurship, is explained by classical economists such as Smith, Ricardo and Marx as being the action of an individual who combines factors of production, generally considered to be land, labour, and capital, in order to create a product (Stanley and Grant, 2007). In the 1920's the work of Knight (1921) led to a different understanding of the role of the entrepreneur as being the individual willing to bear the uncertainty associated with undertaking innovation. His theory showed that entrepreneurs were those individuals willing to guarantee the wages of their workers by putting their own capital at risk (by promising to pay workers irrespective of the ventures outcome), with their own ultimate goal being the generation of profit. A more modern and fairly broad definition of entrepreneurship is given by Shane and Venkataraman (Venkataraman, 1997; Shane and Venkataraman, 2000) as "an activity that involves the discovery, evaluation and exploitation of opportunities to introduce new goods and services, ways of organizing, markets, processes, and raw materials through organizing efforts that previously had not existed". Leading on from this has been the development of more sector-specific definitions of entrepreneurship such as that of the high-tech entrepreneur given by Bernasconi, Harris and Moensted (2006, p. 2). They consider high-tech entrepreneurship to be the creation of value from technical innovation through success in business within an extremely uncertain business environment. Given this emphasis on an uncertain business environment as well as the

focus on high-tech (both considered factors in particular abundance in Israel) it seems logical to include these elements to the working definition of entrepreneurship this paper will use. From a synthesis of the definitions of Shane and Venkataraman (Venkataraman, 1997; Shane and Venkataraman, 2000) and Bernasconi, Harris and Moensted (2006, p. 2) emerges a definition of entrepreneurship particular to Israel and is the definition that this paper will rely on.

Israeli entrepreneurship: innovation in a technical discipline that consists of discovery, evaluation and exploitation of new opportunities to introduce new technological goods and services, ways of organizing, markets, processes, and raw materials, typically in an extremely uncertain business environment.

Entrepreneurship within the classical economic literature

For a long time standard economic theory has relied on explaining a state of equilibrium (Eckhardt and Shane, 2003). Such theories start from the assumption that all actors in the economy have access to the necessary information to make rational, maximising choices (assumption of perfect information). Additionally, economic thought within this discipline has characterized competition between firms as being ‘perfect competition’ - i.e. markets with no barriers to entry or exit, and a large number of small firms producing similar goods competing mainly through product prices. However, as discussed more fully in the review of the development of an entrepreneurial literature (p. 11), entrepreneurship is dependent on a degree of imperfect information. The reliance of classical economic theories on the assumption of perfect information and perfect competition has, by its very definition, excluded the role of the entrepreneur from the field of study (Casson 1982; Herbert and Link 1988; Barreto 1989). Yet as Shane (2003, pg 1) highlights in the opening lines of his book, “almost every explanation for business and, for that matter capitalism itself, relies on entrepreneurship as a cornerstone”. From the outset this highlights the need for a dedicated body of literature to focus on the nature of entrepreneurship, as well as the need for its inclusion within mainstream economic thought.

Classical economic theory relies on a number of assumptions. Firstly, it assumes that prices convey essential information which leads society to allocate resources accurately, resulting in market equilibrium (Hayek, 1945). Additionally, equilibrium theories assume that future expectations of the market can be determined from the current prices bid for resources (Arrow, 1974). However, this creates a unique problem for the field of high-tech under consideration: since such goods are constantly evolving, there can be no current market for goods which will only be created in the future. It is impossible to calculate a present value for goods which do not yet exist. The result of this shortcoming is that equilibrium theories cannot explain how new technologies will alter future demands or costs of a good (Eckhardt and Shane, 2003). A similar and related viewpoint is that the price mechanism in equilibrium theories conveys little information about how opportunities are exploited towards the creation of new markets not yet in existence (Eckhardt and Shane, 2003). So, the price mechanism fails to explain the creation of new goods and the creation of new markets - both issues of importance to the rapidly diversifying high-tech markets.

Eckhardt and Shane (2003) also identify a situation whereby speculation about the creation of goods in the future can destabilise the market in the present. The basis for this idea is solidly rooted in classical economic theory and its predictions. Classical economic theory regards agents within the market (which can be either individuals or firms) as acting in a rational manner and making decisions which maximise their own self-interest. It also holds that the price paid for goods will lead society to allocate resources in an optimal manner; in this way the actions of those willing to pay more for resources will cause the price of those resources to increase until such a point as the supply is just sufficient to meet the demand. To this point the theory has assumed that producers know what resources they will need to produce a good since the theory is considering existing goods and mechanisms of production. However, for goods that are only to be developed in some future period the resource demands are still somewhat unknown. Given that, producers may speculate that they will require a given quantity of a resource for the production of their future goods. If they then enter the market to purchase these resources in the current period they will alter the market price of the

resources. This will happen even though they are unsure if the resources they have purchased are optimal for the production of their future good. The effects of this are twofold: if the good to be developed is not the most valuable allocation of the resources in the economy then the decision of innovators will have led to a non-optimal allocation of resources, which is at odds with the predictions of classical economic theory. Secondly, the change of price for the resources (as an action of the innovating firms demand) may cause resource providers to alter the amount of resources available, leading to an element of destabilization in the resources markets (Eckhardt and Shane, 2003). This highlights the limits to understanding the entrepreneurial process from within classical economic theory.

Equilibrium theories also ignore the case of temporary disruption to the price system, preferring to look at the longer-term in which prices are expected to stabilize (Eckhardt and Shane, 2003). Whilst this provides a useful baseline guide, it also means that the mechanisms for price stabilization are not accounted for. In particular it says little of the opportunities created by price fluctuation for entrepreneurial behaviour - an issue of central concern to understanding it.

Development of a dedicated entrepreneurial literature

Due to the limited scope for understanding entrepreneurship from within the framework of classical economics (as detailed above), a dedicated literature has arisen to explain the entrepreneurial phenomenon.

This literature has generally focused on two core areas. Firstly, on identifying members of society who can be considered as naturally predisposed towards entrepreneurial activity due to their personal attributes, such as an ability to cope with ambiguity (Scherer 1982), a need for achievement (McClelland 1961), and being able to operate under conditions of uncertainty (Khilstrom and Laffont 1979). Secondly, the literature regards entrepreneurship as the outcome of a favourable business environment, which suggests that all business environments are not equally appropriate for entrepreneurship (Shane 2003, p. 3). A combined view of these literatures is given by Shane (2003) in his

'individual-opportunity nexus' theory which explains how different individuals will be suited to identify different opportunities, exploit them, acquire the necessary resources, and protect their activities sufficiently to extract a profit from them (Venkataraman, 1997; Shane and Venkataraman, 2000; Eckhardt and Shane, 2003). The development of this literature is particularly important in understanding what factors contribute to entrepreneurs' overcoming the high levels of uncertainty inherent to entrepreneurial activities.

Entrepreneurship theories move away from the price mechanism of classical economic theory by asserting that the equilibrium is either never achieved in the market (Kirzner, 1985) or is disrupted by the profit-seeking actions of individuals (Schumpeter, 1934). Entrepreneurship theories consider the interaction of individuals and market opportunities (Shane, 2000); entrepreneurs can foresee a higher price being paid for a recombined mix of resources or the creation of a new good. For this foresight to be effective (i.e. enable the entrepreneur to generate a profit) it cannot be a universally shared belief, or the opportunity for entrepreneurship is eliminated as everyone in the economy would be equally likely to exploit the opportunity (Casson, 1982). By assuming that entrepreneurs have the creativity to envisage a different, more valuable product being produced from the same resources that are currently producing some other good, entrepreneurship theory does away with the need to explain the future in terms of current prices (Shane, 2003). Since the mix of resources to be used for the future good are the same as those used for the current good, there is assumed to be no change in current period prices of the resources.

In regards to how such discrepancies can exist within a market and be exploited by entrepreneurs, Eckhardt and Shane (2003) hold that the literature identifies 3 different mechanisms through which entrepreneurial opportunities can be generated:

- 1) The locus of the changes that generate the opportunity (Eckhardt and Shane, 2003). Schumpeter (1942) holds that a change in product or service can occur through any one

of five possible mechanisms or 'new combinations' thereof: a creation of new products/services, discovery of new geographical markets, creation/discovery of new raw materials, the continuing production of the same product but utilizing a new way of producing, and products generated through a new organizational form.

2) By the sources of the opportunities themselves (Eckhardt and Shane, 2003). From a synthesis of previous research Eckhardt and Shane (2003) identify four ways that the source can create opportunities, an idea which is supported by research conducted by Bhidé (2000) on the sources of opportunity for start-ups:

1. From asymmetries in information due to access to different information by some actors (Hayek, 1945),
2. Supply and demand side opportunities,
3. Productivity-enhancing (e.g. mergers, which may also create new markets) and
4. Rent-seeking opportunities (i.e. those opportunities which are exploited with the goal of increasing the entrepreneurs personal wealth but are of no social value (Baumol, 1990) e.g. crime).

As to how information can act as a source of opportunity (the first point given above), Hayek (1945) and Kirzner (1973) explain that it is the differential access to this information that truly generates an entrepreneurial opportunity. Some people, due to their particular situations and their social ties (Shane, 2003, p. 49) may be able to access information that other people cannot, creating an information asymmetry which allows them to exploit opportunities not visible to others by engaging in entrepreneurial behaviour with the ultimate goal of generating a profit. Alternatively, Shane (2003, p. 45) suggests that different individuals may be able to identify an opportunity from exactly the same information that others have access to due to their superior cognitive abilities.

In regards to the second point a distinction should be made between supply and demand side opportunities, to which Kirzner and Schumpeter have offered different opinions

(Shane, 2003, p. 22). Kirzner holds that demand-supply disequilibrium is a result of errors made on the part of existing market players creating an imbalance in the market which can then be exploited by opportunistic behaviour. Schumpeter considers the same demand-supply side opportunities to be the result of the creation of a new business environment (and its associated information) through changes in technology, policy, or the regulation of the social/demographic spheres. In Schumpeter's view it is change in the environment which leads to new demands and makes new sources of supply available (Shane, 2003, p. 23).

3) By the initiator of the change (Eckhardt and Shane, 2003). Shane and Cable (2001) consider the initiators to be the investors that back the formation of new companies and thereby finance the creation of new goods. They show that such investors are more likely to make seed-stage investments (invest in new companies) if they have direct or indirect social ties to the entrepreneurs who approach them. This suggests that a large part of entrepreneurial innovation can be understood from the perspective of the network of contacts between entrepreneurs and their financiers'. In addition to the networks between the entrepreneurs and financiers, Castilla et al. (2000) suggests that many sub-networks may operate within both the entrepreneurs' network and the financiers' network. The strong focus on network forces by these authors supports this research paper by highlighting the relevance and importance of networks as an area of study in the entrepreneurial and financial literatures.

Having considered the sources of entrepreneurial opportunity, the literature then considers different ways through which entrepreneurs can exploit these opportunities. Venkataraman (1997) suggests that entrepreneurs evaluate opportunities not on their relative performance, but rather on the opportunities relative to their personal alternatives such as opportunity cost, premium for uncertainty and liquidity. This suggests that entrepreneurs will engage in an opportunity if they personally did not have any superior alternatives; if that holds, it means that individuals with fewer alternatives (and thus presumably lower skilled) will be more likely to engage in entrepreneurial activities.

This can be a source of agency problems for investors if they back those individuals least likely to succeed.

Another issue to entrepreneurs is whether new firms or existing firms are better suited to exploiting opportunities. In connection with this, research by Cohen and Levin (1989) indicates that new firms will tend to be started more in industries that have easy access to venture capital, or are not in industries that require significant economies of scale or first-mover advantages since these typically favour established producers (Shane and Venkataraman, 2000). Additionally, new markets are best exploited by small start-ups since the small market size is insufficient to interest larger or incumbent firms (Shane, 2001). Eckhardt and Shane (2003) also found that low capital demands required to exploit an opportunity will increase the likelihood of a new firm being used to exploit it.

The ability for entrepreneurs to patent their products also encourages new firms creation (Teece, 1987). If entrepreneurs can protect their products from imitation for a sufficient period of time to generate a suitable profit then they will have an incentive to innovate. Conversely, if they cannot patent their products then their source of opportunity will be exploited by numerous firms producing imitating products, thereby diminishing the profits the entrepreneur can expect to earn and thus lowering their incentive to engage in entrepreneurial activities. Patenting also gives the entrepreneur time to fine-tune the innovation to market needs, and to implement the value-chain needed to exploit the opportunity (Shane, 2001a). Interestingly, the majority of Israeli innovations are patented through the USA patent office in preference to the Israeli patent office (Kessel, 2006), which may be partly due to most of the goods being destined for the large US markets and requiring strong legal copyright in those markets. There is also evidence that the process of patenting in the US is simpler and faster (Kessel, 2006) – both factors of concern to entrepreneurs operating in the typically fast-moving high-tech markets.

Another reason for starting a new firm to exploit an opportunity is that a new firm would be more able to focus on R&D activities than an existing firm (Henderson, 1993). As

Henderson notes, the routines of existing firms tend to focus their attention away from new information and activities in order to concentrate on production of existing products. Established firms also presumably have invested in physical capital to produce their current products, so have little interest in developing new products that would require additional outlays of capital to facilitate production (the '*sunk-cost*' effect) (Henderson, 1993). Additionally, new firms are often better options for pursuing entrepreneurial opportunities since they are generally more flexible than existing firms (Holmstrom, 1989). Existing firms often seek to minimize flexibility once production has started to enable them to concentrate on monitoring of operations (Holmstrom, 1989). As this highlights, existing firms may not be flexible enough to the R&D activities that entrepreneurs must undertake in order to innovate.

When an opportunity depends more on human capital than on physical assets, spin-off companies will tend to be more common for the simple reason that entrepreneurs cannot take the physical assets with them when they exit an incumbent firm to start their own business, but they can take their own human capital (Eckhardt and Shane, 2003). Since a new firm is likely to be cash-strapped, at least initially, little capital is expected to be available for the purchase of physical assets. At this early stage the majority of a firm's assets will be in the human capital of its founders, which suggests that the more industry specific knowledge the entrepreneurial team has, the greater the initial wealth of the firm (Eckhardt and Shane, 2003). As such it seems prudent for entrepreneurial teams to have sufficient industry experience to be able to market their human capital to investors willing to invest in the physical capital necessary for the human capital to reach its full potential.

Entrepreneurship: risk and uncertainty

The idea of entrepreneurs as risk-takers seems pervasive and numerous theories attempt to explain this. Crucial to this endeavour is a working definition of risk and the closely related uncertainty. Risk is defined as a situation where the probability of a given occurrence is distributed over a given range (Knight, 1921). In such a case the

probability of a given situation can be statistically calculated using past and present market signals as data. Uncertainty differs from this however, in the sense that the existing information is considered an unreliable guide to the future; the probability of a given situation occurring in the future is essentially unknowable (Keynes, 1936). Hence it can be said that under conditions of uncertainty and unknown probabilities, individuals have to base decisions on some factor other than logical calculation (Thaler, 1994).

Gifford (2003, p. 37) holds that entrepreneurs can only operate in an economy which contains an element of uncertainty (in the form of imperfect information about the future), since if everyone had perfect information then all profit opportunities would be instantly explained and there would be no further role for rent seeking/entrepreneurial behaviour. As such the role of the entrepreneur pre-supposes an element of market instability and the existence of risk (Gifford, 2003, p. 37). Although at first glance this may suggest that entrepreneurs are high risk-takers (Kihlstrom and Laffont, 1979; Knight, 1921), empirical findings by Cramer, Hartog, Jonker and Van Praag (2002) suggest this is not the case. Their findings show that entrepreneurs tend to invest more in acquiring the necessary knowledge to make decisions which others without this specialized information would consider risky (Cramer et al., 2002). Although entrepreneurs can readily be depicted as individuals possessing certain natural characteristics such as being success-focused (Cooper and Artz, 1995), optimistic about their business (Hayek, 1945) and over-confident in their own abilities (Simon, Haughton and Aquino, 2000), Gifford (2003, p. 45) suggests a lot of the necessary tools can be learnt. More specifically, individuals can better their chance of success through the acquisition of specific venture-related knowledge (Fiet, 1996). Although this specific knowledge can account for some of the perceived risk, Shane (2003 p. 40) holds that many of the decisions entrepreneurs must make regarding recombining resources through a new means-end framework to generate a profit are intrinsically uncertain since the entrepreneur is assuming a future price of the product (which is indeterminate in the present) greater than the cost of the inputs: the entrepreneur is making decisions based on unknown future demands and prices of the product. As such the entrepreneur is valuing differently to the majority, since if he/she were not, everyone would perceive similar

prices and the source of opportunity would not exist. It would seem that central to entrepreneurship is a decision making process that results in judgments at odds with the judgment of others (Shane, 2003, p. 41). The pioneering spirit of entrepreneurship can therefore be considered to carry a fundamental element of uncertainty.

The entrepreneurs' decision to invest in knowledge is also a calculated one. Gifford (2003, p. 48) suggests that individuals with a lower current value for their skills will be more likely to invest in learning/upgrading their skills than those with higher skills, who would face a larger opportunity cost for not using the skills they already have. This is relevant to the investor also, since entrepreneurs may be undertaking a venture not because they have great knowledge about the subject but because they have low opportunity cost (Gifford, 2003, p. 48).

Entrepreneurship as innovation: a review of common techniques used to quantify entrepreneurship

Without being able to gather statistical data on entrepreneurship it is difficult to disprove or validate theories, conduct inter-regional studies, or view the impact of policy change on entrepreneurship in the economy (Acs and Audretsch, 2005, p. 57). Since entrepreneurship by definition must involve an element of new business, a measure of entrepreneurship is akin to a measure of the durability/self-generating ability of an economy, and hence a vital statistic to governments. Any study of the field of entrepreneurship requires an accurate measure of the level of entrepreneurship, whether taken directly or by proxy. Without this measure it is impossible for policy makers to know the effect of policy changes designed to stimulate entrepreneurship in the economy. However, given the wide range of entrepreneurial actions available to individuals it is difficult to find a measure that encapsulates all possibilities. One way this issue has been dealt with is considering the entrepreneur as an innovator (Acs and Audretsch, 2005, p. 57).

Since innovation is an outcome of successful entrepreneurship, attempts have been made

to measure the levels of innovation as a proxy for the prevalence of entrepreneurship in an economy (Acs and Audretsch, 2005, p. 57). Measurement of innovation has been fraught with difficulties, which has led to several different methods being used. Initially and possibly most simply, innovative activity was measured by a count of the inputs of innovative activity, taken as labour involved in R&D (Acs and Audretsch, 2005, p. 61). However, although this provides a relatively accurate measure for inter-country comparisons it says nothing of the efficiency of the innovation process.

Another way of measuring innovation is through counting the number of patents registered over a given time period in an economy (Acs and Audretsch, 2005, p. 58). However, the existence of a patent is no guarantee that the product or service under patent is truly innovative. Conversely, many unpatented products and services may be innovative (Acs and Audretsch, 2005, p. 58). As a result the use of patents within an economy is a relatively poor measure of innovation, although it is of use in inter-regional studies.

A third measure of innovation, considered more accurate than those already mentioned, is gained by directly measuring the number of innovations produced in an economy through the use of industry experts and their subjective decisions' of whether any given new product or service is truly innovative (Acs and Audretsch, 1990, chapter 2). This is typically conducted per industry sector with input from a panel of experts to give a measure of the level of innovation in each sector. The advantage of this measure is that it circumvents the problems of the two previously mentioned methods i.e. measuring by proxy. Given that this is conducted at a firm level, and the labour of each firm is known, it is possible to calculate the number of innovations-per-unit of labour employed in each industry sector (Acs and Audretsch, 1988, 1990), which can be of benefit when measuring the different levels of entrepreneurship in different sectors of an economy. Nevertheless, this measure still has shortcomings since the definition of 'an innovative product or service' is somewhat subjective (Acs and Audretsch, 2005, p. 61). Different panels of experts (for example in different countries) may measure innovation differently,

leading to unreliable inter-country comparisons. This method assumes (as do the other two) that the units of measurement are homogeneous (i.e. each innovation is of equal importance) although in reality this is not necessarily the case (Acs and Audretsch, 2005, p. 61).

In general, using innovations as a proxy measure for latent entrepreneurship is problematic since in many instances entrepreneurial activity is more about assembling knowledge already acquired in a new way to exploit an opportunity rather than conjuring up a totally new innovation (Shane, 2000). In addition none of the methods of measurement considered above account for all the failed entrepreneurial attempts (Shane, 2003, p. 9). In regard to this point Aldrich and Martinez (2003, p. 363) have argued that the almost exclusive focus of programmes for entrepreneurs on successful business cases encourages entrepreneurs to merely attempt to reproduce similar business structures with little thought about what business structure best suits their needs. As Shane (2003, p. 9) has suggested, given the large number of start-ups that fail, entrepreneurial success may be more due to a departure from the norms of entrepreneurship than to its adherence. Findings that most of the Inc. 500 firms were not started in the most popular industries for start-ups back up this assertion (Bhide 2000).

This paper avoids the issue of whether a firm is ultimately successful or not by considering only the source of funding start-up firms receive, irrespective of whether they have undergone an IPO (or other VC exit strategy) or not. For a firm to have raised capital it must have entered into some form of dialogue with investors, and it is the modelling and interpretation of this network that this research seeks to undertake. The justification for this selection mechanism is that it avoids the bias of only considering successful firms (as mentioned above), as well as any bias resulting from a quantitative measure of entrepreneurship.

Entrepreneurship and the firm: The effects of firm size on innovation

Until the 1970's it was understood that technological innovation was the domain of large corporations (Chandler, 1977; Schumpeter, 1942; Galbraith, 1956) since they were the ones capable of acquiring the quasi-rents that funded R&D and innovation (Acs and Audretsch, 2005, p. 62). This was the result of having some degree of monopoly power (Schumpeter, 1942, p. 101). However, later research shows that smaller firms may actually have an innovative advantage (Rothwell, 1989) since they are not encumbered with the bureaucracy of corporate R&D (Scherer, 1991). Small firms also do not reward innovation by promoting excellent individuals to management positions to the degree that large firms do (Scherer, 1991), presumably because the organizational structure is flatter. They also have less bureaucracy to deal with in bringing new innovative products to market, and so can presumably do this faster (Link and Rees, 1990). The actual mechanism underlying the innovativeness of small firms may be the result of what Hirschman (1970) terms an 'exit' strategy: an individual working for an existing firm discovers an opportunity to innovate. However, given the uncertainty of the future innovation the firm values this opportunity lower than the individual does and is consequently prepared to pay the individual less for this innovation than he/she thinks it is worth. Thus the individual decides it will be more profitable to exit the firm and produce the innovative product on their own. The other alternative, the 'voice' strategy, occurs if the individual chooses to dispute the fee the company is willing to pay or otherwise enter into dialogue with the firm until they are satisfied that they will extract the value of their innovation from within the firm. In such a situation the individual chooses to exploit the opportunity their innovation has created from within the firm (Hirschman, 1970).

Another explanation for the innovativeness of smaller firms and of particular relevance to high-tech is given by Saxenian (1991), who views firms as interacting with networks of supplier firms, themselves specialised in niche markets, and collaborating with the producer to supply innovative inputs which result in the small firm being able to innovate at a much faster rate than a large firm would be able to.

A paper by Dibiaggio (2006) highlights some of the reasons believed to underlie the shift in technological innovation to SME's in recent history. The emergence of industries that do not require economies of scale for innovation (such as biotech R&D firms) allows smaller firms to enter a market. Additionally many researchers have chosen to work in the close-knit team of small firms in preference to larger, more hierarchical and bureaucratic firms (Link and Bozeman, 1991). This may account for some of the innovation occurring in small firms. However, in industries that do require economies of scale and large capital outlays (e.g. military research), it can be expected that a lot of research will remain with the larger firms (Dibiaggio, 2006). Research that is time consuming or long term may also be better carried out within larger firms since they typically have more resources and time to allot to projects than smaller firms. Larger firms are also likely to have a greater number of inter-personal connections between their workers and outside contacts since the number of inter-personnel connections is a function of the number of personnel a firm has. These contacts can allow a large firm to have access to a larger and more diverse set of contacts than a small firm, which directly impacts on their resource access. In addition larger (and presumably older, more established) firms have also passed the crucial start-up phases and are thus more likely to be considered as reliable and long-term potential business partners than new firms. Such firms have had more time to establish a reputation than start-ups, which the literature identifies elsewhere as a crucial factor to firms seeking funding (see pp. 47-48 for more detail on the effect of reputation).

Lazerson and Lorenzoni (1999) observe that firm size is really somewhat irrelevant when network ties are considered. In their view what are really important are the networks that connect small firms to large firms, which in turn connects them to global partners and suppliers. Castilla et al. (2000) suggest that this would be an important factor in Silicon Valley, and given its stated similarity to the Israeli markets (Avnimelech & Teubal, 2004, 2004a; Bresnahan et al., 2001; Carmell & de Fontaenet, 2004) it can be expected to also play a vital role in Israel.

Geographic effects on entrepreneurship and firm clustering

Another pertinent set of ideas to explain Israel's persistently strong capital inflows is the 'regional economic' theory as expounded by Breschi and Malerba (2005 p. 1). Central to this viewpoint is that variations across regions in economic growth and performance are ultimately dependent on a set of factors and resources such as knowledge, skilled human capital, institutional and organizational structures which are specific to certain locations and relatively immobile in space. The justification for this is that borders, whether national or of the city, tends to limit movement between regions to some extent. So in any given region the resulting mix of factors are expected to lead to differential rates of growth, thus essentially creating 'clusters' of activity in favourable places. As the paper notes, an increasing number of research papers are focusing on this approach, particularly within the technology-based or high-tech industries (Breschi and Malerba, 2005, p. 1). Central to regional economic theory is the idea that entrepreneurial firms will attempt to group together in a location due to the benefits of information availability from their contemporaries. Empirical work by Breschi and Malerba (2005, p. 3) supports this logic since their findings indicate that firms in clusters tend to be more innovative than isolated firms. The actual mechanism through which this transfer of knowledge occurs is named *localized knowledge spillovers* (Breschi and Malerba, 2005 p. 2) in reference to the idea that knowledge will be diffused faster amongst geographically close actors than through more geographically distant actors. This knowledge transfer can occur through either formal or informal means. For example, for knowledge to diffuse locally may require nothing more than a casual conversation between professionals at a lunch meeting, whereas an inter-regional diffusion of knowledge would require either the movement of one of the workers to the new region or a means of transmitting the knowledge such as email or phone. Jaffe, Trajtenberg and Henderson (1993) show that workers tend to move between firms within the same region rather than move regions. This seems intuitive; it is simpler for individuals to change jobs locally without having to uproot and move to a

new location.

In addition to regional clustering, work by Feldman and Audretsch (1999) shows that clustering varies across industries within a region, depending to a large extent on the stage of the industry life cycle and the importance of tacit knowledge. In the field of high-tech, Breschi and Malerba (2005, p. 3) identified several major common elements responsible for firm-clustering. Since this is of direct relevance to the research question each item has been considered in detail below.

1. Learning through networking and interacting is regarded as the crucial force pulling firms into clusters and the essential ingredient for an ongoing innovative cluster i.e. more generally, a key feature of successful high-tech clusters is related to the high level of embedding of local firms in a very thick network of knowledge sharing, supported by close social interactions and institutions building trust and informal relations amongst actors. (Breschi and Malerba, 2005, p. 3). The ability of firms to tap into the localized body of knowledge is largely dependent on their ability to maintain effective social links (Breschi and Malerba, 2005, p. 3). Collectively, the existence of social norms, conventions and codes of exchange and interpretation of knowledge eases the transmission of knowledge between actors.
2. 'Evolutionary theory' has added the ideas that learning and knowledge are key elements in the change of the economic system. This theory holds that the learning, behaviour and capabilities of agents are constrained by the technology, knowledge base and institutional context in which firms act (Breschi and Malerba, 2005, p. 4). So, firms in the same region, industries and using similar knowledge bases could be expected to behave similarly and follow similar organizational forms. More importantly, these similarities affect the basic processes of variety generation and selection and therefore the dynamics of evolution of firms (Nelson and Winter, 1982; Malerba and Orsenigo, 1997).
3. 'Innovation System' (Freeman, 1987) considers innovation as an interactive

process among a wide variety of actors I.e. firms do not innovate in isolation but as part of a collective process. This idea holds that firms interact both amongst themselves and with universities, research centres, government agencies and financial institutions. Since often firms form a sort of national community first, it leads to the idea of the 'national innovation system' (Nelson, 1993). This idea seems to have two different sub-branches: it is possible to identify a regional innovation system based on the borders defining the set of relevant actors/interactions (Braczyk, Cooke and Heidenreich, 1998). Also, the way in which actors are connected to each other may differ significantly across industries, leading to different dimensions in different sectors (Malerba, 2004).

4. The most recent approach to the analysis of clusters of innovations is the 'social network' approach. All of the different theoretical perspectives hold that it is the interactions between the actors within a network that are primarily responsible for driving innovation within a cluster of firms. This approach draws strongly on social network analysis and graph theory. "The number of papers that are taking, more or less explicitly, a network approach to the study on innovative clusters (and not only) is taking off" (Breschi and Malerba, 2005, p. 5). Given that this method essentially encapsulates all the other, separate drivers considered for innovation, it should provide a sound framework in which to draw broad conclusions of entrepreneurship and innovation. The approach taken in this paper in modelling Israeli start-up companies follows this theory and is explained in more detail in the network literature review and methodology sections.

Another idea pertinent to the study of clusters is the idea of a shared culture. In a study of Chinese businessmen abroad, Redding (1990) finds that a shared culture and family ethic linked entrepreneurs in numerous regions, effectively rendering the geographical distances irrelevant. This shared culture may explain a certain amount of the US based investment in Israel since Israel has strong diplomatic and military relations with the US as it's staunchest middle-east ally, and cultural relations with the large US Jewish population, as well as a strong affinity with US popular culture (Galily and Bernstein,

2008). However, in the authors' opinion it does not explain the attraction of such large quantities of capital to Israel; if profits were not substantial, no amount of shared culture would interest investors. Hence, whilst a shared culture may contribute in some measure to Israel's capital influx it is unlikely to be on a scale to compete with more profit-centred theories.

The entrepreneurship literature presented above highlights some of the issues pertinent to this field. Entrepreneurship is found to be largely inconsonant with classical economic theory, which has led to the development of a separate literature dedicated to explaining the entrepreneurial phenomenon. The definition of entrepreneurship itself has changed over time and leads to a specific and unique definition of Israeli entrepreneurship being developed for use in this research paper. The process of exploitation of opportunities is detailed, as well as a brief overview of the dedicated entrepreneurship literature. In general entrepreneurship theories have attempted to explain entrepreneurship through either the personal characteristics of the entrepreneur or the extent to which the business environment is conducive to entrepreneurship. Research within the field of high-tech suggests that entrepreneurship in this industry is particularly uncertain due to the constant need for innovative products and the rapidly changing global markets. The literature suggests that innovation varies across firm size, although it is not clear-cut whether large or small firms are more innovative. The level of innovation has also been shown to vary across regions, despite the stated difficulties in the literature of obtaining empirical measures of entrepreneurship.

Venture Capital: A definition

As in the entrepreneurship literature above, a good starting point in understanding the venture capital (termed VC) literature is clarifying exactly what we consider VC to be. Since venture capital is a relatively recent phenomenon, in existence since 1946 in the USA (Bylinsky, 1976) and in Israel since 1966 (Avnimelech and Teubal, 2004a) a single

definition of venture capital is considered by the author to be sufficient. Gompers and Lerner (2003, p. 267; 1999, p. 349) defined venture capital as “independently managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high growth companies”, which is the same definition as that used by Avnimelech (2008, p. 82) for VC in Israel and hence considered applicable to this research.

The venture capital investment process

Previous research on the VC industry by Tyebjee and Bruno (1984) and supported by other authors (Avnimelech & Teubal, 2004a) has found that there are several separate processes undertaken by venture capitalists when deciding which venture to back, which have been considered in detail in this review. Although Tyebjee and Brunos' (1984) work is somewhat dated it appears that the venture capital process they describe is similar enough to that encountered in the present to validate using their paper for a broad process outline. Where changes have occurred the review refers to more recent literature.

Tyebjee and Bruno (1984) found that venture capitalists typically undertake five separate processes when undertaking to invest in a new venture. The first process undertaken is that of *deal origination* (Tyebjee and Bruno, 1984), which determines how venture capitalists become aware of potential investment opportunities. The main issue faced by venture capitalists at this stage is that the environment in which they are searching for potential deals is very poorly defined; the typical investment candidate is a small company that is not obviously identifiable as a potential investment. Given this limitation, several mechanisms exist which can match start-up firms to VC firms: entrepreneurs can cold-call the VC firm with details of their enterprise, the firm can receive a referral to a potential investment, or the firm can actively seek for ventures to back. By far the largest source of potential deals (65%) were achieved through referral (Tyebjee and Bruno, 1984), either from within the VC community (of which the majority were lead investment firms requiring other firms to join in on their deal, a process known as 'syndication'), or from prior investors and personal acquaintances. Around 25% of

investments were the result of entrepreneurs' cold-calling the venture capitalist; the remaining 10% was the result of VC firms actively searching for suitable investments.

The second stage of the investment process is that of *screening* (Tyebjee and Bruno, 1984). Since the VC is only willing to invest in a relatively small percentage of the deals that come to its attention it needs some way of limiting its in-depth study of potential deals to types of firms that it is willing to back. By providing a set of conditions as a template for potential investments the VC firm can reduce the number of firms that it needs to consider in detail to a more manageable level, which is particularly necessary given the small staffs most VC firms have (Tyebjee and Bruno, 1984). Tyebjee and Bruno identify four characteristics commonly used for screening:

1. Size of the investment and the investment policy of the fund - given the limited staff of most VC funds, investing in a large number of small firms is not feasible since each investment will still require a certain amount of support. VC firms concentrate on limiting their new investments to a few select firms and reasonably sized investments, which allows them to maintain a portfolio of about nine firms at any one time (Gorman and Sahlman, 1989). However, investments are only limited by their minimum size. If a large firm seeks investment the VC fund may syndicate with other VC funds to provide the necessary amount of capital. In a large-scale US study of venture capital firms in the US over 1995-1999 it was found that around 50% of all VC portfolio companies received syndicated funding involving two or more venture capitalists (Hochberg, Ljungqvist and Lu, 2007). The same study found that around 10% of VC firms never syndicated any investments, preferring instead to invest on their own (Hochberg et al., 2007).
2. Industry and technology of the venture - Tyebjee and Bruno (1984) have suggested that VC funds specialize in a few technological sectors since it is not feasible for the fund managers to be well versed with all available market sectors and technologies. For US funds over the 1995-1999 period funds were found to specialise in sectors as follows: roughly 46% specialized in computer related companies, 19% in Non-high-technology, 16% in communications and media, 9% in medical, health and life sciences, 6% in biotechnology, and 4% in

- semiconductors and other electronics (Hochberg et al., 2007).
3. Geographic location of the venture - since the VC managers want to have regular contact with the investors they tend to limit their investments to within easy travelling distance of their headquarters. The only time this was found to be ignored was when the investment was syndicated with another VC firm and the venture was located close to the other VC's headquarters (Tyebjee and Bruno, 1984). Tyebjee and Bruno also suggest that often it is the entrepreneurs that choose to seek funding from VC firms in their local area since their banking, accounting and legal contacts are strongest there.
 4. Stage of financing - most VC funds at the time of Tyebjee and Brunos' (1984) study were believed to prefer later stage financing since it is considered inherently less risky. However, their study also found that some VC funds were unwilling to commit funds to later stage financing unless they have been involved in the previous rounds of funding, suggesting that the issue of early versus late-stage financing is not clear-cut. Recent research has found that early-stage funds performed about 4% worse than later-stage funds (Hochberg et al., 2007). However, the prevalence of seed funding in the Israeli VC market (Mayer, Schoorsb, & Yafeh, 2005), as well as the focus on mostly young (usually between 1 and 5 years old) high-tech companies whose main activity is R&D up to the initial sales stage (Avnimelech and Teubal, 2006) suggests that this literature is somewhat outdated in the modern, high-tech economy. It appears that VC companies in Israel are actively targeting seed-stage companies and other early-stage investments.

The third process in the chain of investment is that of *evaluation*; since most of the firms seeking capital are start-ups with little operating history, the venture capitalist has few indicators of the firms' ability to succeed. As such the VC is forced to undertake an in-depth assessment of the firm to determine the likely levels of risk and return from investing with it. Given the lack of historical data, much of this assessment will be based on factors determined subjectively by the VC. Tyebjee and Bruno's (1984) study found

that over 60% of the evaluation process can be explained by five factors:

1. Market attractiveness, which considers whether the venture fulfils a market need, as well as considering the size of the market and its accessibility and growth potential
2. Product differentiation, which considers whether the product to be developed is suitably unique to gain a market share and well protected enough (through use of patents) to realize a significant profit
3. Managerial capabilities, which other studies have confirmed are a crucial concern to venture capitalists (Gorman and Sahlman, 1989; Lerner, 2002).
4. Environmental threat resistance, which considers whether the product is robust enough to maintain a market share in the face of a change in the business environment, such as a change in the technology in use, a lowering of barriers to entry or a change in government policy
5. Cash-out potential, which is a measure of how easily the venture capitalist can foresee exiting the venture in the future. In pre-1994 Israel VC firms traditionally exited by selling their portfolio companies to large international firms rather than through IPO since the deal structuring of such a sale is considerably simpler (Avnimelech and Teubal, 2004a). However, post-1994 there has been a constant increase in the number of Israeli IPO's (Avnimelech and Teubal, 2004a).

After evaluating the deal on offer the VC will decide whether to invest or not. Only a very small number of potential deals will actually receive funding, historically only one percent of all business plans submitted to VC firms are approved for funding (Fenn, Liang and Prowse, 1995). Many VC firms at this point make investment conditional on whether another VC firm is willing to co-invest in the business (Lerner, 1994).

The fourth stage is that of *deal structuring*, where the venture capitalist, after having decided that a particular firm represents a good investment opportunity, needs to enter into negotiation with the entrepreneur to determine the details of the investment. The main element here is negotiating the equity share of the firm that the entrepreneur is willing to surrender to the VC firm in exchange for a specific amount of capital (Golden, 1981). A 2004 study by Berg-Utby, Sorheim and Widding (2007) found that amongst Norwegian VC companies roughly one-third held between forty and sixty percent of the equity of their portfolio firms. In addition to the amount of equity the entrepreneurs are willing to surrender, the deal structuring stage involves establishing a legal framework for the investment (Gorman and Sahlman, 1989). This typically limits managerial salaries, establishes the conditions under which the venture capitalist can take control of the firms' board or force a change in management or alternatively liquidate the investment. Replacing management was found to be reasonably common: VC managers had on average replaced three CEO's from their portfolio companies over the course of their careers (Gorman and Sahlman, 1989). During the deal-structuring stage several mechanisms may be employed to ensure the motivation and loyalty of the entrepreneur. One such mechanism is an 'earn-out arrangement', whereby the entrepreneurs' equity share of the firm can increase if performance targets are met. Since the performance targets need to be mutually agreed to, this also provides an indication to the VC of the entrepreneurs' expectation of the venture succeeding (Leland and Pyle, 1997; Ross, 1977).

The fifth and final stage of the investment process is that of *post-investment activity*, which considers the venture capitalists involvement with the firm after having invested financially in it. It is at this stage that the venture can expect to benefit from the support of the venture capitalist, either through the venture capitalists human capital such as their experience and expertise, or through their social capital such as access to resources from other firms/organizations and providing contacts in market, supplier and creditor networks (Berg-Utby, Sorheim and Widding, 2007). Research suggests that VC funds provide several critical but non-financial services to their portfolio firms (Widding,

2005): VC's can search for co-investors and help raise additional funds on behalf of the business, help the business to formulate and review its business strategy, and recruit any necessary additional management to strengthen the management team. In addition VC's provide a more general form of business knowledge to complement the specific knowledge of the entrepreneurial team (Berg-Utby, Sorheim and Widding, 2007), including help with such activities as product development and marketing (Widding, 2005). For example, with respect to marketing VC funds' specialization within different markets or market sectors allows them to develop detailed knowledge about potential customers, the structure of the market and its idiosyncrasies (Sapienza, Manigart and Vermeir, 1996; Giudici and Paleari, 2000), as well as likely sources of competition and threat which can help better position a start-up firm. Several researchers have found that having VC funding increases the future profitability of firms: Lukomet (2001) compared start-up firms in Israel and found that VC backed firms had three times the rate-of-return of firms that had not received VC backing, three years after issuing stock publicly. These findings are broadly supported by similar findings by Jain and Kini (1995) and Hochberg et al.(2007), suggesting a higher rate of return for VC backed firms as well as greater likelihood that such firms would eventually be sold to another firm or become publicly traded (Ber, 2002).

Despite being involved in many areas of the venture during the post-investment stage, VC's were found to prefer to leave the day-to-day management of the firm to the management team (Tyebjee and Bruno, 1984). Their face-to-face time commitment with their portfolio firms was found to be roughly four to five hours per month, although if they felt that there was a high level of information asymmetry between themselves and the entrepreneurs/management they tended to monitor the performance of the firm more closely (Admati and Pfleiderer, 1994; Amit, Glosten and Muller, 1990, 1990a; Chan, 1983). Research also suggests that VC firms may allot their time in unequal portions between their portfolio companies, due largely to their own limited time resources. Two diametrically opposed views emerge from the literature on this topic, one view suggesting that VC firms will put the most effort into the relatively poorer performing

firms in their portfolio (Fredriksen, Olofsson and Wahlbin, 1997) and the other suggesting that they will concentrate on generating as much value as possible from their well performing portfolio firms (Sapienza and Gupta, 1994). Although this debate is non-conclusive as yet, one relevant issue emerges: the high rate of failure for VC portfolio firms (Gorman and Sahlman, 1989, p. 238). A three decade study of over seven hundred VC investments by Gompers (1995) suggests that only slightly over twenty-two percent succeeded in becoming publicly traded, which was the form of exit most sought by VC's, typically sometime between five and seven years after first investing in the firm (Gorman and Sahlman, 1989, p. 233).

According to Hochberg et al. (2007) the average VC fund writes off around 75% of its investments. This implies that VC funds earn their capital gains from a small subset of their portfolio companies, namely those they exit via an IPO or a sale to another company (M&A). This high failure rate has been attributed, in part, to the funding habits of VC's, who typically provide capital in discrete intervals depending on the performance of the venture. This allows them to stop funding a venture if it appears to be failing, thereby minimizing their losses. However for the entrepreneurs this means that most new ventures are extremely cash strapped during the start-up phase and therefore not well placed to overcome unexpected problems or expenses that may occur (Kirchhoff, 1994; Greene and Brown, 1997; Brush, Green and Hart, 2001).

Sources of capital: Implications for the VC firm and entrepreneur

Crucial to the understanding of why certain VC's back particular entrepreneurs is the mechanisms with which the VC raises its capital (Barnes and Menzies, 2007, p. 4). This is, in essence, a similar issue to the one faced by the VC's themselves: whilst VC's must search for suitable ventures to invest in, the original holders of the capital that VC's rely on must search for a suitable VC firm to invest with. The source of the VC's funds has been shown to influence VC's interaction with their portfolio companies. For instance,

Van Osnaburg and Robinson (2001) found that VC's dependent on external fundraising activities behave more diligently with their investments (e.g. monitoring their portfolio firms performance more frequently) than VC's who received and invested funds on-behalf of other large financial organizations such as banks and pensions funds. Also, and of direct interest to entrepreneurial teams, VC's who have to raise funds from investors have been found to provide more direct value-added to their portfolio companies than VC teams who manage funds on behalf of other institutions (Barnes and Menzies, 2007, p. 10). The reason for this is that the investors who provide capital to VC funds typically want secure, high-yield investments and one way of ensuring this is making sure that the funds they back contribute directly to the growth of their portfolio firms. Given that the VC funds future abilities to raise capital is dependent on investors being satisfied with its operations, successful VC's will ensure they take an active interest in developing the abilities of their portfolio firms (Barnes and Menzies, 2007, p. 10).

The stringencies associated with privately raising capital would seem to indicate that VC funds should shy away from this activity in favour of investing on behalf of donor organizations (e.g. retirement funds). In reality however, most VC funds prefer to raise their own capital since the remuneration packages available to them from such activities are generally better than those available from investing on-behalf of other financial organizations (Barnes and Menzies, 2007, p. 7). In connection to the Israeli VC industry however, Avnimelech (2002) found that more successful VC's were those who received funding from a global investment bank that had connections to strategic investors. Whilst this seems somewhat at odds with the findings of Barnes and Menzies (2007, p. 7), it appears that the presence of strategic investors makes it more favourable to invest on-behalf of a donor organization in Israel than to raise capital privately.

With regards to remuneration, investors have also been found to look at the incentive structures of the younger VC team members when deciding whether to invest in a

particular VC fund or not since they reason that these are the personnel involved in day-to-day operation of the fund and if they were insufficiently motivated the fund would be unlikely to perform well (Gompers and Lerner, 1999). The implications of this is that for VC funds to generate any profits they need to ensure the calibre of their staff is extremely high and able to generate revenues commensurate to the high wage-packets that the firms investors typically expect it to provide. For start-ups, this suggests that if they can obtain VC financing they will receive support from a team of very business-savvy individuals.

Investor Types: stereotyping VC fund managers

Of interest to this research paper is a study conducted by Clarysse, Knockaert, Lockett and Van Eeskhout (2007) that considered the specific criteria that venture capitalists look for when backing early-stage high-tech entrepreneurial companies. Previous studies around VC venture selection found that VC firms base a large part of their decision to invest on a few key criteria: the ability of the entrepreneurs (Tyebjee and Bruno, 1984; MacMillan, Seigel and Subbanarashima, 1985, 1987; Shepherd and Zacharakis, 1998), the market environment of the new venture (Hisrich and Jankowitz, 1990; Muzyka, Birley and Leleux, 1996), or some other financial criteria such as exit opportunities or the product the firm will offer (MacMillan et al., 1987). However, in their study of European VC's investing in high-tech Clarysse et al. (2007, p. 19) found that the investment criteria ultimately depend on the background of the VC fund managers who will make the decision on whether or not to invest in the venture. This finding is significant since it suggests that the background and professional interests of the VC managers may have as large an influence on whether start-up firms receive funding as the traditional measures already mentioned.

Clarysse et al. found that VC fund managers could be stereotyped into one of three distinct types of early-stage VC investors: 'technological investors', 'people-investors' and 'financial investors'.

1. 'Technological investors', explained as those individuals that consider the ability to protect the uniqueness of a new technology as paramount (Clarysse et. al., 2007, pp. 19-22). Such VC managers (all of whom held technical degrees) often came from a technical work background and believed that their own contacts could be of benefit to the entrepreneur and add-value to the venture. Such investors were found to be only willing to undertake an investment if they had supreme confidence in the lead entrepreneur, although it was somewhat surprising to the author to discover that this applied even when the ventures team may have no commercial experience. This finding suggests that technological investors expect the lead entrepreneur to be able to surmount any difficulties arising within their team due to lack of commercial experience. They expected to be able to have frequent contact with the lead entrepreneur. Technological investors were also found to place a higher emphasis on the ability to protect a new innovation and their relationship with the entrepreneur than either of the other two investor types.

Also interesting was that technological investors tended to invest in the seed stage of a company more than the other investor-types. They also tended to have privately raised (i.e. independent) funds that were smaller than average, frequently the result of patronage by angel investors (wealthy individual investors). They invested predominantly in local firms, and typically had no previous VC experience in other funds, having come straight from a technical position themselves.

Given the dominant focus on high-tech of some form within the Israeli VC market (Schwartz and Bar-El., 2007) it seems likely that a large proportion of VC fund managers have come from technical backgrounds. This is supported by work by Avnimelech (2002) that found evidence that technological investors have contributed strongly towards high-tech start-up formation within Israel's VC industry. This finding is similar to that of Wilson (1985, pp. 50-51) that during the early years of Silicon Valley the VC industry was dominated by individuals who had migrated from industry rather than from backgrounds in finance.

I propose that this mechanism, whereby former technologists enter the realm of financing new technologies, may explain some of the dynamism underlying venture investment in Israel. Since ‘technological investors’ are well versed with the available technologies after having been in industry themselves, they can be expected to be better educated on innovations that truly represent a new technology than other financiers with non-technological backgrounds. As such they may be better able to advance technology through concentrating their investments on new and novel technologies, which is in their own best interests since such technologies will also allow them to create new markets and their associated opportunities for profit. Their specific technological knowledge makes them aware of the technological boundaries, and hence enables them to identify the opportunities that expand these boundaries, thereby opening new markets and creating an opportunity to generate profit in an environment where they are the sole player.

2. ‘People-investors’ were defined by the study as those investors who were primarily concerned with the leadership capabilities of the lead entrepreneur and the quality of their team (Clarysse et. al., 2007, pp. 22-25). The basic assumption of such investors was that a highly performing team should be able to develop and position the necessary product in the marketplace correctly and make accurate business predictions. The typical ‘people-investor’ came from a banking or financial background and had worked in other VC funds, but had no technical experience. Their investment interest was across the spectrum, from after a company had been started until well into the later stages of the lifecycle, although they tended to concentrate on those firms that had already passed the seed-stage and its associated period of uncertainty. The people-investors also placed the least importance on the ability to protect the technology and a lower amount of importance on regular contact with the lead entrepreneur than the technological investors; perhaps even more crucially, these investors had on average the least amount of commercial experience of any of the investor types. As such they are

probably less well-placed to directly add-value to a firm due to their lack of commercial experience and contacts. Given this, and their tendency to shy away from seed-stage investments, entrepreneurs starting out would do well to look to one of the other investor types when founding a new business.

Also noteworthy was that such investors were active in non-technological industries and also in late-stage investments, both techniques they considered necessary to diversify their portfolio's risk away from their early-stage high-tech investments. This was the most common type of VC in continental Europe where the study was conducted.

3. 'Financial investors' was taken by the study to mean those individuals who were mostly interested in the potential returns as stated on the business plan (Clarysse et. al., 2007, pp. 25-27). These investors tended to only invest in well-built teams entering fast-growing markets. They were predominantly funded by other financial institutions such as banks, and their degree of seed-stage funding was intermediate between the high of the technological-investor and the low of the people-investors. Most financial investors held technical degrees. They tended to invest globally and placed the least emphasis on meeting regularly with the entrepreneur of all the investor-types. Countries such as France, where the majority of venture capital was provided by banks, had a high representation of this type of investor.

With knowledge of the different investor types and the funds they represent, it seems that entrepreneurs in high-tech start-ups would do well to concentrate their efforts on the 'technological investor' type since they would be those most likely to have useful contacts and to add value to the business beyond the limits of finance. This also highlights that all sources of finance cannot be regarded as equal from the perspective of the entrepreneur. Beyond the necessity of securing the needed amount of funding, entrepreneurs should look at what additional non-monetary assistance they can expect to receive from the VC

fund and attempt to gain maximum leverage from the VC's contacts and industry experience.

The venture capital literature highlights that VC funds follow a routine mechanism in seeking out new investments, which appears to have changed little over the last fifteen years and is dependent to a large degree on the VC funds network of contacts. VC funds tend to maintain a portfolio of approximately nine companies, preferably close to their headquarters, and invest resources beyond capital in ensuring that these companies grow and can be either sold to other firms, or else traded on the stock market. Such assistance is typically through seeking additional sources of funding, identifying potential business partners and recruiting suitable management personnel. The background of the managers of VC funds was found to be a crucial factor in determining their investment strategies, including their willingness to invest in high-tech and start-up companies. Similarly the source of the VC firms' capital was found to influence the investment strategies of the firm.

Venture Capital in Israel: A Historical perspective

A detailed paper by Avnimelech and Teubal (2004) provides much of the background detail on the development of Israel's high-tech and venture capital industry. Prior to the Six Day War in 1967 Israel engaged in little R&D development. During this period R&D within Israel was virtually synonymous with the military, most of whose hardware was sourced abroad. After the war however, an arms embargo forced Israel to develop its own military hardware, leading to the development of an advanced military-related R&D sector. Running parallel to this was a growth in civilian business R&D, fostered by the creation in 1969 of the Office of the Chief Scientist (OCS) at the Ministry of Industry and Trade (Avnimelech, 2008). The aim of this office was to stimulate innovation and technology-related businesses. In terms of its effect, Avnimelech and Teubal (2004) argue that the creation of this office was probably the largest and most significant action taken by the Israeli government to foster innovation and the growth of high-tech

industries. Under the auspices of the Innovation and Technology Policy (ITP) the first 'R&D Penetration' period ran till about 1990 and generated the basic R&D capabilities of Israel's business sector, largely through the creation of the 'R&D Industrial Fund', essentially a government VC fund which provided more than 90% of the government funding for civilian R&D projects until well into the 1990's (Avnimelech and Teubal, 2004).

The army played a crucial role in developing Israel's R&D facilities. In addition to providing the economies-of-scale needed for advanced R&D it fostered strong networks between researchers who worked together on the military R&D. The army became the incubator of talented young researchers, providing the training and resources for them to realize their potentials (Avnimelech and Teubal, 2004). Then, starting in 1985 a large-scale restructuring of the military took place, resulting in many spin-off companies sub-contracted to the military for R&D. It was during this phase of Israel's history that the 'Silicon Valley' model of innovation began, as venture capital flowed into the country to back the new military spin-off companies as well as the numerous engineers made redundant by the restructure who sought to start their own businesses in the civilian sector (Avnimelech and Teubal, 2004). In addition a large number of engineers from the former Soviet Union immigrated to Israel during the 90's, many of whom started their own companies and required finance. With the dual objective of stimulating R&D and successfully absorbing these immigrants into the workforce, Israel undertook a series of government programmes to make business finance available for high-tech business ventures (Avnimelech and Teubal, 2004).

The first programme was Inbal (1992), a Government owned Insurance company which provided a 70% guarantee to publicly traded VC funds, which was aimed at reducing the risks associated with investing in the Israeli economy (Avnimelech and Teubal, 2004). Under this programme four VC companies were established. However, overall the bureaucracy required to register individual funds and the start-up ventures they were

backing was considered excessive and the open market valuations of the Inbal-backed funds were low. As a result the fund was terminated shortly after opening.

Following Inbal in 1993 was the creation of the \$100 million Yozma fund, widely credited with being the forerunner of the Israeli VC industry today (Avnimelech and Teubal, 2004). Under the Yozma programme, government invested eight million dollars into ten privately held VC funds operating in Israel and the remaining twenty million directly into high-tech start-up companies. The terms of the Yozma fund stipulated that if each privately held fund could get a foreign investment partner and an existing Israeli financial institution involved, then government would invest up to forty percent of the funds raised. In this way Yozma succeeded in drawing more than double its own value of capital into the Israeli VC market (Avnimelech and Teubal, 2004). Also significant was that it allowed the inexperienced Israeli VC funds to learn the investment process from their more experienced foreign co-investors, which collectively triggered a learning process within the Israeli VC industry. Yozma did not act to protect VC funds from existing investments that had soured as did the Inbal programme (a process known as 'downside support'); Yozma's main incentives were on the upside (i.e. when investments succeeded) by allowing the VC funds to purchase government bonds at cost for a period of five years. The profits Yozma-backed VC funds accrued led to the entry of numerous non-Yozma VC funds also seeking a share of the profits (Avnimelech and Teubal, 2004), all of which ultimately resulted in investments in numerous start-up companies. The initially high profits generated suggest that an excess demand existed for VC in Israel at the time of the creation of Yozma; at Yozma's creation, numerous start-up companies were not associated with any VC due to its scarcity in the Israeli market, which allowed the first wave of VC funds in the transforming Israeli market to secure deals with the best available start-up companies. Many of these firms ultimately went public or were purchased and generated attractive profits for their financiers.

Israel's VC industry became one of the largest VC industries in *absolute terms* (second only to the U.S.) and the largest in *relative terms* (in terms of VC expressed as a percentage of GNP) over the course of the 1990's (Avnimelech and Teubal, 2006).

Besides Yozma several other government programmes have been widely considered as successful (Avnimelech and Teubal, 2004). The Magnet Programme, started in 1992 and still active, was designed to foster R&D between firms and universities, and under its terms and conditions requires a cooperative partnership of two or more firms and one university before it will consider providing funding. The Technological Incubators Programme (\$30 million PA, also started in 1992) was a government backed network of business incubators started to provide funding and support to firms during the seed phase for a period of two years. It has been credited with contributing strongly to the transformation of the Israeli high tech industry over the 1990's and is still in use as of 2008.

Apart from the formal government programmes, numerous background conditions have been cited as contributing to the success of Israeli high-tech. Among them the presence of multi-national enterprises (hereafter MNE) such as Motorola, IBM and Intel, the initiation of a Peace Process with the Palestinians in the wake of the Gulf War which made Israel less isolated politically, and the general global revolution in IT taking place at the time all contributed to the transformation of the Israeli high-tech industry (Avnimelech and Teubal, 2004).

It appears to the author that central to Israel's VC growth was the role of the Israeli government. The impact of the Israeli government on partial funding of new firms suggests that it exists as a separate investor type similar to the three already identified by Clarysse et al. (2007). The provision of partial funding to start-ups by the Israeli government means that it essentially acts as a syndication partner to VC firms and likely structures deals on more favourable terms with VC funds than would other VC companies. The fact that governmental support offices are not motivated by generating a profit suggests that VC firms which manage to syndicate with the Israeli government on deals will be able to retain the bulk of the investments profits for themselves. Through this mechanism VC funds can expect to extract a greater profit than would be possible if they were dependent only on their own funds. The result of this is that VC firms that receive government support can expect a relatively higher rate of return than would have

otherwise been possible without this support. This supporting action by the Israeli government can be expected to have boosted confidence amongst foreign investors, which may partly explain the large capital inflows to the Israeli market.

Another side to this issue is that VC funds who decide to back firms already receiving partial government funding will be able to do so with less of their own resources (assuming the firms requirements are the same with or without government assistance), which means they will suffer smaller losses if the investment soured than would be the case if they were the sole financier of the firm. This combination of an increased rate of return and a reduced liability suggests that the Israeli government has acted both to stimulate interest in VC investment in Israel by making the deals more profitable to investors, as well as reducing the risk, both factors which can be expected to dramatically increase the interest in Israel as a global investment destination.

Network Theory: Defining a network

In the process of reviewing network literature it becomes apparent that the term network research has been applied to a wide range of different research and analysis methods (Shaw, 1997). This may be partly due to the lack of any core network theory or the constructs and definitions that would predicate such a theory (Hoang and Antoncic, 2003). Given these limitations it is understandable that research within the field of entrepreneurship from a network perspective has remained somewhat limited (Hoang and Antoncic, 2003) although more generally usage of networks has surged in popularity in recent years to the extent where network research is now referred to as "the new science of networks" (Barabasi 2002, Buchanan 2002, Watts, 2003).

A broad definition of networks would be that they are comprised of a set of nodes (termed *vectors* in the Pajek software program used for this research paper) and connections between these nodes (O'Donnell, Gilmore, Cummins and Carson, 2001; Brass, 1992). Within social science research the nodes may represent an individual or a

group of individuals (such as a firm, which is the grouping that this paper uses) and a set of direct and indirect links between the nodes to represent the social ties between them (Davern, 1997).

Important to network research is the understanding that its' analysis techniques differ to those of classical statistical analysis. Network theory considers the connections between interrelated units, as opposed to classical statistical analysis which assumes that individual units are independent (Iacobucci and Zerrillo, 1996). As a result statistical analysis is not well suited to the type of data collected in this research paper. Pajek's analytical tools have been used in place of standard statistical techniques.

The development of the networked firm

Prior to the concept of inter-organizational networks economists explained how resources were allocated between firms through one of two possible mechanisms: the *market mechanism* or the *vertically integrated firm* (O'Donnell et al., 2001). The market mechanism as postulated by Williamson (1975), building on work by Coase (1937), was that firms would resort to trading resources between themselves when the transactions required by the firms were simple and non-repetitive. Under such a system the firm will search amongst a set of suppliers who supply similar products and compete on the basis of price: since all resources are assumed to be intrinsically equal, the rational firm will act to minimize costs by selecting resources at the lowest price. Once these resources have been exhausted the firm will have to re-enter the resource market and undertake another search for resources at the lowest price. In such a scenario the firm has few loyalties to any specific resource supplier. As a result the firm encounters an ongoing cost associated with searching for resources. For firms that engage in frequent resource transactions, buying resources on the open market is likely to be more costly over the lifespan of the firm than engineering the entire production chain from raw material to final product in-house, a type of firm structure termed vertically integrated (Williamson, 1975). Under the vertically integrated mechanism organizations source their own raw materials and develop them into the inputs needed for production of their final goods. By keeping the

entire process within a single structure and bearing the costs and inefficiencies associated with open market transactions, such a firm is likely to be able to produce goods at a lower price than would one operating through the market mechanism (Williamson, 1975).

However, both these production mechanisms rely on the classical assumption that individuals (and firms) engage in self-interested behavior which is minimally affected by social relations (O'Donnell et al., 2001). When work by Granovetter (1985, 1992) showed that organizations are in fact largely constrained by their ongoing social interactions with other organizations, the idea of inter-organizational networks emerged as a widely accepted third mechanism through which firms operate (Eccles, 1981; Mariotti and Cainarca, 1986; Thorelli, 1986; Johansson, 1987; Jarillo, 1988; Blois, 1990; Powell, 1990; Larson and Star, 1993). Under this mechanism firms have long standing agreements with key partners such as supplier firms to provide specific goods over an extended period (O'Donnell et al., 2001). This ensures firms are not constantly searching for needed resources as they would if modeled along the market mechanism, nor are they investing in an entire production chain from raw material to final product as they would if they were vertically integrated. Implicit to the network mechanism is the understanding that firms will establish long-standing relationships with their customers and investors and can expect frequent exchange of information between themselves and these actors (O'Donnell et al., 2001; Galaskiewicz, 1996). The study of such networks of interdependent firms as well as the inter-personal web of relationships has led to the broad field of research termed *network research*, which includes the study of new firms and the entrepreneurs who create them.

A distinction is made in the literature between networks between individuals and networks between organizations (O'Donnell et al., 2001; Brown and Butler, 1993). Since this research paper is undertaking a modeling of start-up/entrepreneurial firms and their supporting institutions its focus is primarily inter-organizational. The inter-organizational network literature is further sub classified into vertical networks and horizontal networks (O'Donnell et al., 2001): *vertical networks* are those that include the members of the production chain ranging from the suppliers of the raw materials to the

end users of the products (Piercy and Cravens, 1995; Elg and Johansson, 1996; Achrol, 1997). *Horizontal networks* are those between actors who have the potential to be competitors or may already be competitors (Elg and Johansson, 1996; Piercy and Cravens, 1995). A typical example is organizations within the same industry, which is the view that this paper takes. By its inclusion of biotech start-ups, venture capital firms and other institutional actors such as universities and governmental offices which act in a supporting role to individual biotech firms this research paper is conducting a horizontal network review of the Israeli biotech industry.

Implications for network analysis

It is widely accepted that any attempt at social network analysis should consider both the structure of the network, as well as the nature of the interactions between network actors (Mitchell, 1973; Granovetter, 1973, 1985; Powell, 1990; Burt, 1992; Spekman, 1996; Olkonnen, Tikkanen and Alajoutsijarvi, 2000). Crucial to understanding the nature of the relationships is the idea of *direct* and *indirect ties*. Actors who are directly in communication are considered to be linked by direct ties. Indirect ties are considered to be the linkages in information flow between actors who do not exchange information directly with each other but through at least one intermediate actor.

Within the entrepreneurship literature three elements of networks emerge as critical to understanding the impact networks have on entrepreneurial activities (Hoang and Antoncic, 2003; Amit and Zott, 2001):

- (1) The nature of the information that is exchanged between actors;
- (2) The governance mechanisms that exist to monitor behavior within relationships; and
- (3) The network structure created by the crosscutting relationships between actors

Despite being introduced separately these elements are essentially different facets of the same network construct (Hoang and Antoncic, 2003). As such it has been decided to combine their explanation below.

Work by Granovetter (2005) highlights the ways in which these elements interact within

networks to impact on economic outcomes. Firstly, the flow and quality of information passed between actors will be dependent on the strength of their contact/relationship. Since a lot of information obtained from external sources to the actor is difficult to verify, it makes sense for actors to trust the information received from well-known and reputable sources to a greater degree than they would the information from an unknown third-party. In addition, with a close and reputable network associate an actor is likely to exchange more sensitive information than they would with an unknown network actor (Granovetter, 2005). Actors who manage to have a large number of relationships with other actors not closely associated with them have also been identified as more likely to gain access to novel and hence potentially useful information through a process Granovetter (1973) terms the *strength of weak ties*. The crux of this theory is that more novel sources of information are available from sources different to those already widely available to network actors. This is discussed more fully on page 50.

Implicit to actors exchanges of information is that each actor knows that if they defaulted (i.e. by publicly disclosing sensitive information entrusted to them) they would lose the element of trust with their associate and thus will likely not be privy to such information in the future. This will also damage their reputation, which limits the extent to which other actors will choose to interact with them (Portes and Sensenbrenner, 1993; Jones, Hesterly and Borgatti, 1997). The number of network contacts an actor has poses a constraint to the amount of resources that will be available to the actor from the network in the future (Hoang and Antoncic, 2003; Saxenian, 1991; Lorenzoni and Lipparini, 1999; Hite, 2000). Seen this way networks are largely self-governing since non-conformity with the social norms will result in an actor being ostracized from the network. Actors comply with the norms to maintain their network contacts and associated access to resources.

Actors also have a financial incentive to maintain good social standing: if they are considered reputable they can largely replace detailed legal contracts with other (reputable) network actors with more general contracts, backed by an element of trust (Larson, 1992; Lorenzoni and Lipparini, 1999; Granovetter, 2005). The use of a more

general contract allows the actors to minimize the legal costs associated with generating and enforcing each contract. The result is that trust creates a self-governing mechanism between network actors which allows them to produce at a lower cost than the open market or the vertically-integrated firm, and with a degree of security despite the lack of contractually complete agreements (Thorelli, 1986; Jarillo, 1988; Starr and Macmillan 1990; Lipparini and Lorenzoni, 1993; Jones et al., 1997).

The presence of networks of actors has been widely documented as beneficial for entrepreneurs attempting to gain ideas and gather information on entrepreneurial opportunities (Birley, 1985; Smeltzer, Van Hook and Hutt, 1991; Singh, Hills, Lumpkin and Hybels, 1999; Hoang and Young, 2000). For example, ties to venture capitalists and professional service organizations have been recognized as a means for entrepreneurs to tap into key talent and market information (Freeman, 1999). Due to the extremely uncertain environment in which entrepreneurs operate, having well-regarded network associates acts as a signal of legitimacy to as-yet-unrelated resource providers as to the potential of the entrepreneurs venture (Hoang and Antoncic, 2003; Deeds, Mang and Frandsen, 1997; Stuart, Hoang and Hybels, 1999; Higgins and Gulati, 2000; Shane and Cable, 2001). As a result savvy entrepreneurs will attempt to associate with well-regarded individuals and firms to better their chances of obtaining beneficial resources in the future (Hoang and Antoncic, 2003). One example of this process would be that of a well-regarded venture capitalist recommending a certain entrepreneurial deal to their associates; given that the associates are more closely linked to the venture capitalist than they are to the unknown entrepreneurial venture, they are more likely to trust information received from the venture capitalist than that received directly from the entrepreneurial firm.

Of particular interest to this research paper were the findings of Stuart et al. (1999) that biotechnology firms with prominent strategic alliance partners were likely to become public faster and at higher market valuation than biotech firms with less highly regarded associates. This was supported more generally by the findings of Hochberg, Ljungqvist

and Lu (2007) that better-networked VC firms experienced significantly better fund performance and were more likely to successfully exit their investments. In the context of this research paper it suggests that biotech start-ups that have gone public over the course of the research (2000-2008) are likely to be linked to more highly regarded venture capital firms or institutional actors (e.g. universities).

Measures of network structure

Several measures exist for determining the structure of a network and these are detailed below.

1. **Centrality:** with regards to the amount of resources any given actor in a network can access, network theory suggests that the more centrally an actor is positioned within the network, the greater the degree of resources they will have access to. This idea assumes that by positioning centrally within a network an actor ensures that the majority of resources must flow through them to other actors in the network (Hoang and Antoncic, 2003). This has led to the quantitative measure known as *centrality*, a measure of an actor's ability to access (or control) resources (Hoang and Antoncic, 2003). Centrality is used in this paper to find those actors who are controlling the bulk of the resources, an idea supported by Castilla et al. (2000) as being particularly applicable to networks computed for a single point in time, as it is in this research.
2. **Structural Holes:** another factor to consider is the presence of *structural holes*, explained as areas of a network where actors are not connected to one another through direct or indirect ties even though they are operating within the same environment (Hoang and Antoncic, 2003). Network theory suggests that actors who can bridge structural holes by creating a conduit for information between the otherwise unconnected actors (through creating mutual ties with actors on each side of the structural hole) stand to profit since this bridging position creates an opportunity to influence firms on either side of the structural hole (Burt, 1992;

Krackhardt, 1995). This can also be a position of strength to the bridging actor since it allows them to gain access to a more diverse source of information than would be available from within a single network (Hoang and Antoncic, 2003). From a Schumpeterian understanding of entrepreneurship as creating new economic opportunities from combining previously unconnected resources, Granovetter suggests that unconnected resources have remained so by being in separate networks (Granovetter, 2005). If actors can act to bridge networks they can make more resources available for combination (Granovetter, 2005), thereby increasing the opportunity for entrepreneurship. Despite the obvious strategic importance of structural holes to entrepreneurship and network theory, identifying them has proven difficult, which may partly explain why little empirical work has been conducted in this field (Hoang and Antoncic, 2003).

3. Density: another quantitative measure of an actor's ability to gain resources within a network is the degree of network *density*, defined as the extent to which an actor's contacts are interconnected (Hoang and Antoncic, 2003). When there is a high level of interconnections between network actors (i.e. high density) it becomes increasingly likely that resources will circulate within the group instead of new resources being introduced to the group (Hoang and Antoncic, 2003). Although from a resources perspective high network density seems undesirable, from the perspective of regulating social norms within the network it is considered to be advantageous (Granovetter, 2005). This idea is based on the assumption that the more network actors are interconnected, the more difficult it will be for those flouting the social norms to go by undetected. Additionally the social norms will be encountered more frequently in a closely knit network than in a more loosely integrated one, which suggests that network actors will be better educated about them.
4. Strong versus weak ties: in relation to network ties Granovetter has suggested that more novel information is expected to travel to actors through *weak ties/connections* than through strong or close connections, since close connections

typically move in the same social circles as the individual and have much the same knowledge as the individual (Granovetter, 2005). Conversely, weak connections move predominantly in other social circles and hence have access to novel sources of information (Granovetter, 1973). This suggests that a certain amount of weak ties will be beneficial to actors in allowing them to access new sources of information. Singh et al. (1999) found evidence that entrepreneurs with more weak ties were privy to a greater number of opportunities than those with fewer weak ties. However, in the early start-up stage the presence of strong ties was still found to be important since they appeared to influence the persistence of entrepreneurs to continue in their start-up formation activities (Honig and Davidsson, 2000). In general a mix of ties has been considered most valuable to a start-up firm's growth and longevity (Uzzi, 1996; Stearns, 1996; Zhao and Aram, 1995) since it allows the firm to synthesize the benefits from the different external actors, a process termed *network complementarity* by Uzzi (1999). The basic idea here, derived from portfolio theory, is that assets in a portfolio have a value that depends on the other assets in the portfolio, not only on the value of the individual asset (Uzzi, 1999). However, this matter is not conclusive since other researchers have found networks to have little bearing on the growth rates of start-up firms (Aldrich and Reese, 1993), so although it remains a useful conceptual tool no specific analysis has been undertaken in this regard.

5. Social embeddedness: also identified as having a strong influence on the dynamics of networks is the interpenetration of economic and non-economic actions (Granovetter, 2005), a situation Granovetter terms the *social embeddedness* of the economy (Granovetter, 1985). The crux of the issue here is that personal and economically motivated relationships are expected to overlap and become intermixed with each other to a varying degree. In such a situation the non-economic relationships will have an effect on the costs and available means of economic activity which is dependent on the degree of mixing between the different relationships (Granovetter, 2005). A typical example is that of a

regional culture that considers bribery the norm. In such a case there is an additional hidden cost to doing business (Granovetter, 2005). Like strong vs. weak ties, no quantitative measure was found for social embeddedness which somewhat limits its practical research application. Nevertheless, it remains a useful conceptual tool in explaining regional differences.

6. Inter-firm mobility: another important cultural element of social networks is that of inter-firm mobility. Saxenian (1994) has already noted that inter-firm mobility tends to be a self-perpetuating mechanism. For example, in areas with low inter-firm mobility, when a worker leaves one firm to enter another they are much less likely to have already worked with an employee of their prospective firm than would be the case in an area with higher inter-firm mobility levels. Assuming that the likelihood of someone being hired at any given firm is better when an extant employee can vouch for the applicant from having worked with the applicant at a previous firm, in areas with more people moving between firms the likelihood of a firm hiring new staff is greater. Findings by Montgomery (1991) that approximately fifty percent of all currently employed workers found their jobs through friends and relatives lends strong support to the idea of inter-firm mobility.

The network literature highlights first and foremost the limits to network research as a result of the lack of formal theory and qualitative techniques. A few qualitative measures are available (e.g. centrality and density) which have been used in this research paper. Despite the lack of empirical tools the use of networks across numerous disciplines has increased drastically in recent years.

Research Design

The original intention of this research paper was twofold: to generate a network map of entrepreneur-VC firm relations in Israel, and to create a genealogy tree of VC companies active in Israel. This would mirror the research conducted by Castilla et al. (2000) in

their study of Silicon Valley VC companies and thereby enable a direct comparison between the developments of VC in the two regions. However, given the large number of VC firms currently listed on the Israel Venture Capital Research Centre website and given the time limitation of a masters dissertation, a full-scale genealogical model of Israeli VC's is unfeasible. Instead a brief overview of the development of the Israeli venture capital industry has been given to place this research in historical context.

The network map used in this paper to model entrepreneur - VC relations in Israel is based on that used by Castilla et al. (2000) in modeling the firms involved in an IPO in Silicon Valley. In their paper all law firms, accounting firms and venture capital firms involved in an IPO were considered to be interconnected and were modeled within a 3D network map using the software program MAGE. This allowed them to determine who the dominant actors were within the study, as well as highlighting the degree of interconnections between the different industries in Silicon Valley. As they explained, each IPO is typically comprised of “at least five firms from four different institutional sectors: the new industrial firm (issuer), a lead underwriting investment bank (usually as part of a syndicate), the issuer-side law firm, the underwriter’s law firm, and an auditing accounting firm” (Castilla et al. 2000, p. 242). Their method of data collection was to analyze all IPO’s within a single industry class (SIC code) over the course of 1999.

The actual dynamics to be considered in this paper are slightly different to those considered in Silicon Valley. Whereas Castilla et al.(2000) considered the inter-industry linkages and the dominant players within each (related) industry, this paper is concerned primarily with the dynamics between venture capital firms and the entrepreneurs/entrepreneurial firms they back, as well as whether networks between these actors would provide a counterweight to investment uncertainty (refer to the research question) . A paper by Hochberg, Ljungqvist and Lu (2007) has been used for making general comparisons between US-based high-tech firms and those in Israel to see what similarities or differences exist between the two regions. Several interesting dynamics identified in their paper have already been introduced in the literature review; in the network analysis comparative data from Israel will be introduced and inferences made.

Due to the differences between this study and that of Castilla et al. (2000) a slightly different method of data collection has been used in this paper, although the methods of modeling and analysis remain similar. For this paper suitable data need only include the venture capital firm, entrepreneurial firm and any other firm or institution that can be considered as providing a significant amount of business support. Whilst no strict definition of 'significant business support' has been followed, the paper has endeavored to include all institutional actors such as universities, hospitals, research centres, business incubators and government offices involved with the entrepreneur and their start-up firm or the venture capital firm. In similar fashion to the study by Castilla et al. (2000), data has been collected within a single industry class: biotech. All biotech firms listed on the MATIMOP (2007) website as of the end of March 2008 and listed as incorporated since 2000 have been included within the dataset. This time limit was enforced for two reasons: the dataset used by Castilla et al. (2000) and using IPO data from 1999 can be considered as a similar time period to post-2000 data from Israel for the sake of any inter-regional comparisons. Secondly, in their paper on the emergence of VC in Israel, Avnimelech and Teubal (2004) considered that the current mode of VC activity which is likened to Silicon Valley first emerged in 2000. In terms of sourcing information on these firms, only publicly available websites were used.

The selection of the biotech industry was done on the basis that it is of a suitable size, given the time limitation of this dissertation, to include all relevant actors within the model. The software package used for modeling purposes is Pajek, a dedicated network modeling package with analysis abilities and which is publicly available free of charge.

Data Collection

As stated in the research methodology section above, data collection has been limited to that set of firms listed as biomedical high-tech firms on the Israeli Industry Centre for R&D (MATIMOP) database as of the end of March 2008. In total 181 firms were listed as biotech, of which 68 were incorporated between 2000 and 2008 (dates inclusive).

Most of the biotech firms were found to have a company website, the address of which (URL) was frequently listed on the MATIMOP database. Whenever a website was listed it was analyzed for investor relationships and any specific information that may lead to details regarding who had provided the start-up finance, as well as who the entrepreneurs were. If a VC fund was mentioned then its' Webpage (all the VC funds were found to have WebPages) was analyzed to see if it collaborated with any other VC firms or institutional actors. This was a valuable step in the process, since several funds were found to jointly back individual business incubators, or to be closely aligned with research institutions. Several VC funds were also found to be backed or fully owned by larger funds, in which case both funds have been included within the network map. Most VC company websites were found to have a portfolio page which detailed their current portfolio companies, as well as successful past ventures. Of particular note was the large number of VC firms found to be actively promoting their interests in targeting start-up firms. The portfolio pages frequently had additional information on start-up firms that was not listed on the MATIMOP database. It also provided a valuable check against the accuracy of the MATIMOP listings. Besides MATIMOP, company websites and VC firms' websites, suitable data was collected exclusively from publicly available internet sources through the use of the GOOGLE internet search engine. If after a general search no information was found regarding the ventures financiers or institutional support, the venture was listed as privately funded and appears on the network map as an isolated point with no linkages to other actors.

Due to the capabilities of the modeling program used a slightly different graphical method was employed that that used by Castilla et al. (2000). Instead of using an inversely proportional relationship between the number of links between actors and the distance between them on the graphical interface (which shows actors coming closer together as the number of joint-ventures they are involved in increases), the lines connecting actors has been made thicker as the number of linkages between the actors increase. This was chosen purely for ease of modeling and coding of the input file for the Pajek program. The appearance is considered by the author to sufficiently convey the same essential information as the techniques used by Castilla et al. (2000) to be

comparable.

Network Analysis

Diagram A – Israeli Biotech Industry

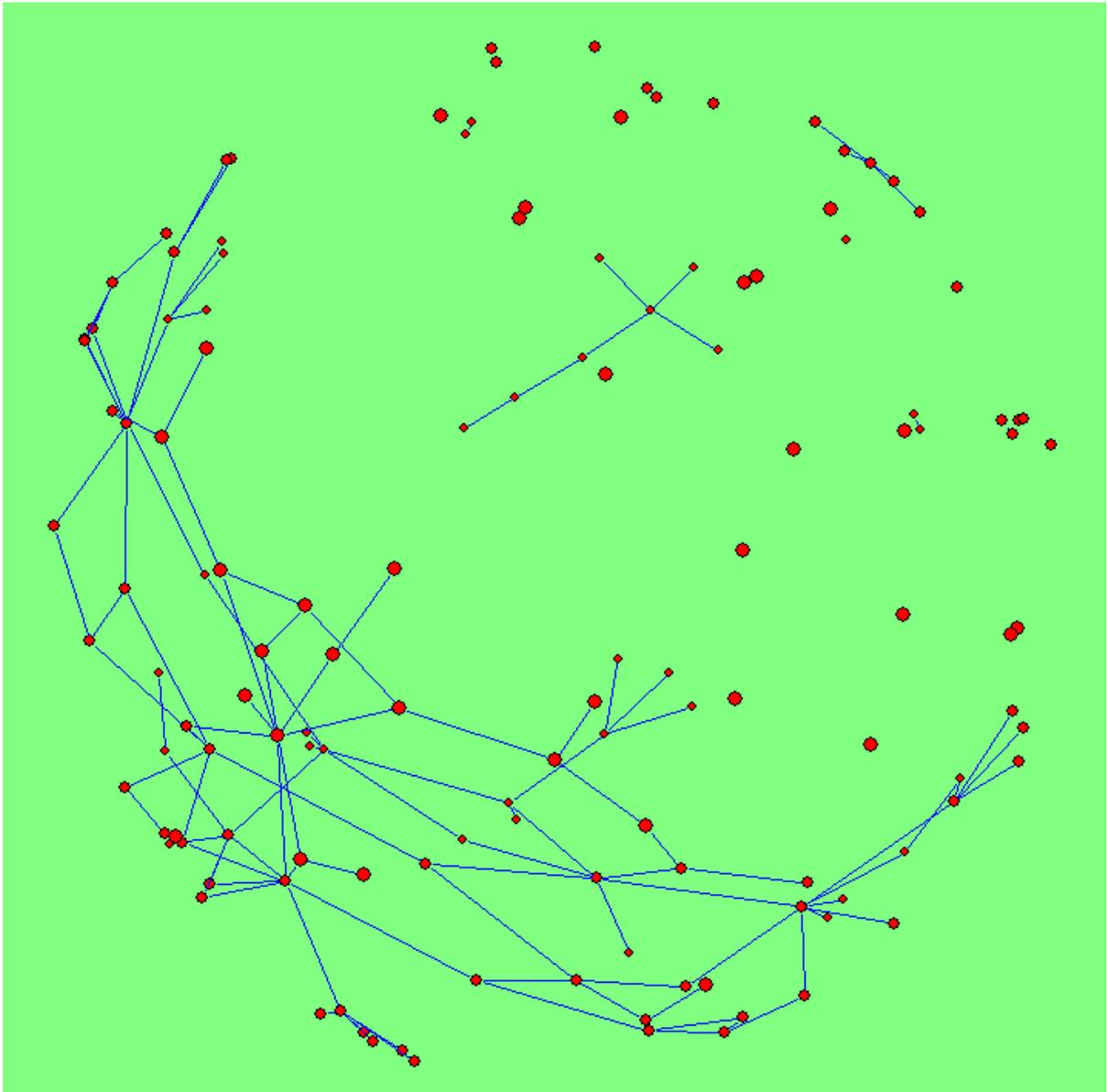
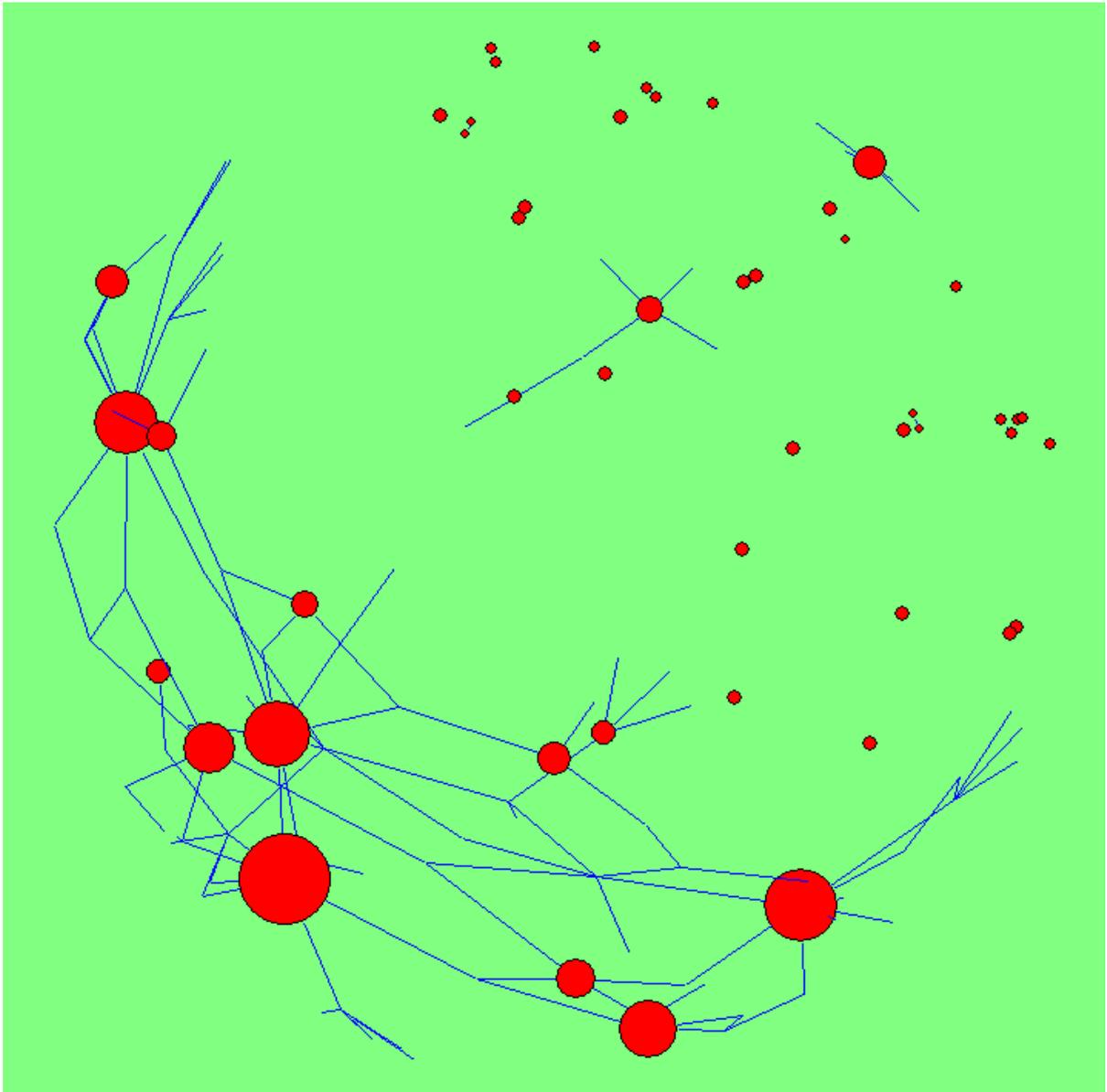
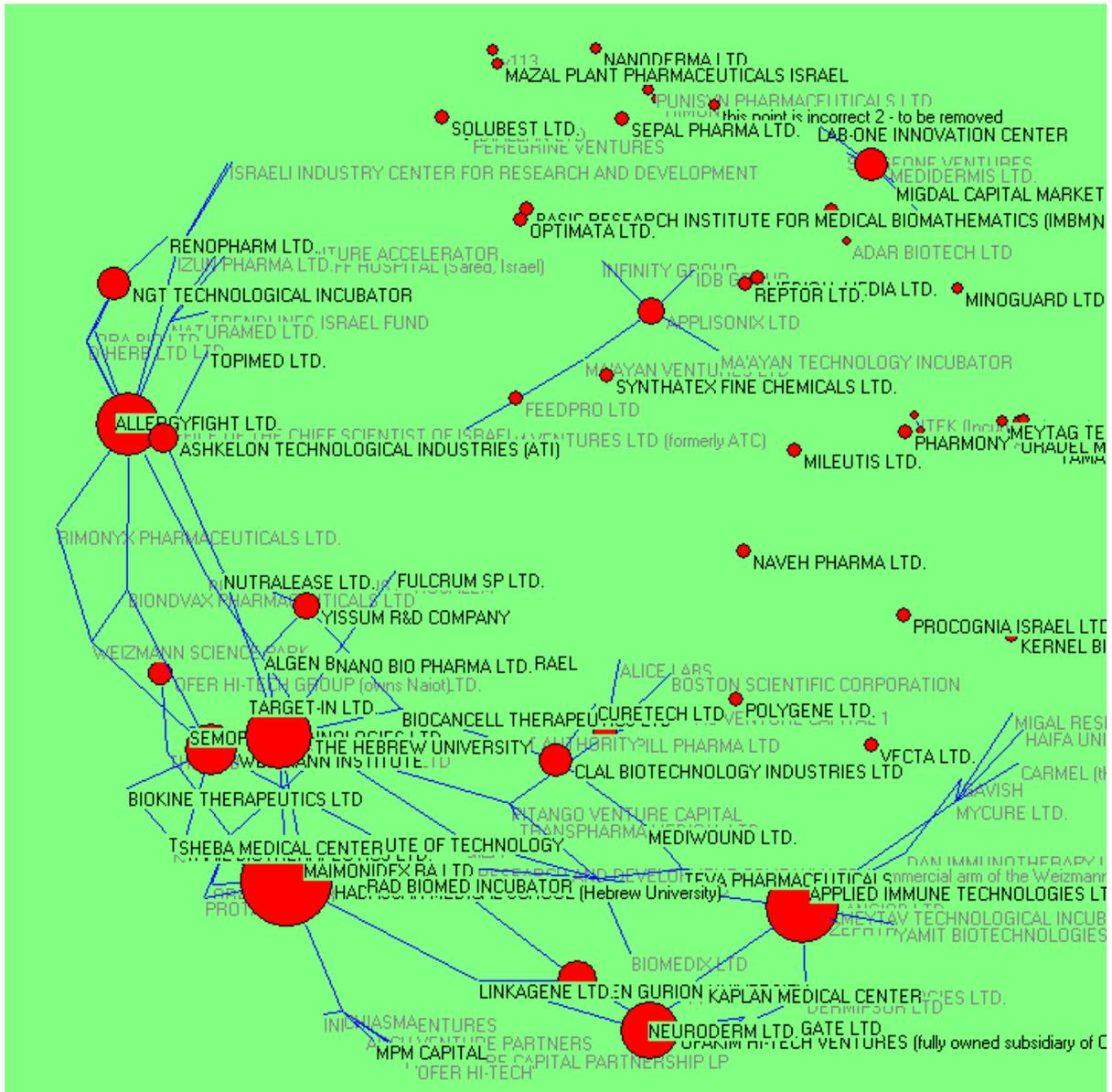


Diagram B - Key Actors in the Israeli Biotech Industry



Additional Diagram - Important actors in the Israeli Biotech industry (labels included)



In addition to the 68 biotech firms included in the dataset, numerous venture capital organizations, technology incubators, governmental organizations, universities, hospitals

and research organizations have been included in the network map, resulting in a total of 132 different actors being included in the network. This has resulted in a network roughly the same size as that of Castilla et al.'s 129 actors (2000, p.238). The resulting network was spatially arranged through the use of the Fuchterman-Reingold 3D algorithm.

Of the 68 start-up biotech firms that were included within this dataset, 13 (representing 19% of the start-ups) were found to have no links to other network actors, either because they were listed on the MATIMOP database as privately funded or no data was available to indicate where they had received funding or business support from.

Avnimelech and Teubal (2004) mention that fifteen start-ups between 1991 and 1992 achieved IPO without any venture capital intervention, which suggests that numerous start-ups in Israel at that time did not gain venture financing. If this has continued then a number of the thirteen biotech firms in this dataset may have not received any external financing, although no details around this was found from the publicly available websites reviewed. As a result of these thirteen ventures not being linked to any other actors within the network, the remaining (approx.) 81% of biotech firms provided all of the observed network linkages.

Seven start-ups (or slightly over 10% of all the start-ups) were only linked to a single other network actor, which itself was unlinked to any other network actors. This resulted in seven pairs (for a total of fourteen) network actors who were unrelated to the remainder of the network. This is consistent with the findings of Hochberg et al. (2007) for the US that around 10% of VC firms choose not to syndicate their investments.

Also possible is that these firms were new start-ups and their financiers would be seeking additional VCs' to syndicate with in future funding rounds. However, since five of the seven firms were incorporated over the 2000-2002 period and have not added any additional network partners in the intervening six years to 2008, it seems tenuous to

consider this an intermediate state. The effect of the pair-wise partnerships on the network is that an additional fourteen network actors are not connected to the main Israeli biotech industry. In conjunction with the thirteen start-ups not connected to any other network actors, this leaves 105 from a potential 132 (or roughly 80% of actors) as forming the backbone of the biotech industry network. In terms of number of start-up firms, $68 - (13 + 7) = 48$ firms or 70% of all the biomedical start-ups formed the industry-wide network of connections. Thirty-six start-ups (or roughly 53% of all the start-ups) were found to have received funding from two or more sources. This result is similar to that found by Hochberg et al. (2007) that around 50% of all VC portfolio companies in the US received syndicated funding from two or more venture capitalists. The rate of VC deal syndication in Israel, as well as the rate of VC firms that choose not to syndicate, is approximately the same as in the US. Given that around half of the venture capital firms in the United States are now active in Silicon Valley (Castilla et al., 2000) this finding suggests that deal syndication between VC firms within Israel operates in the same way or a very similar way to their operation in Silicon Valley.

Another factor to consider in the network analysis is the presence of mini-networks which are not related to the main network of actors. Two such networks are found here, namely that centred around Medidermis Ltd. (Lab-One Innovation Centre, Migdal Capital Markets, StageOne Ventures, Tel Aviv Economic Development Authority), shown to the right of the main network in Diagram A, and that centred around Applisonix Ltd. (Maayan Ventures Ltd., Ma'ayan Technology Incubator, Infinity Group, IDB Group, Ma'ayan Ventures) and Feedpro Ltd. (Rotem Ventures Ltd., which was bought by Ma'ayan Ventures), which is above the main network in Diagram A. Interestingly, Applisonix was listed as having completed its Initial Public Offering (IPO) at the Tel Aviv Stock Exchange (TASE) in the course of 2007 and thus represents one of only two companies in this dataset found to have already gone public. The other IPO company is Biondvax Pharmaceuticals Ltd., which is a joint project between the Office of the Chief Scientist of Israel and the Weizmann Institute. The fact that both these companies are syndicated investments by well-known VC firms supports the literature findings that the portfolio companies of highly regarded VC's are more likely to go public, and at a faster

rate, than the portfolio companies of lesser known VC's. The fact that these mini-networks contain international venture capital funds such as StageOne Ventures supports work by Castilla et al. (2000) that venture capital firms that are not otherwise connected to the main network of other firms may be more tightly integrated with firms not depicted within the network map (e.g. foreign firms or firms in other industries). The fact that Applisonix went public may be reflective of the strength of having international fund backing within the Israeli market.

Within the main network map it appears that The Weizmann Institute, Office of the Chief Scientist of Israel and The Hebrew University are jointly responsible for a large amount of the network linkages. Diagram B shows the same network as diagram A, but with the vertices sized according to the importance of their network linkages to other influential actors. In Diagram B the most influential network actor was Hadassah Medical School, an off-shoot of the Hebrew University. Once the centrality of all network actors was calculated it became apparent that The Hebrew University and Weizmann Institute, along with their associated bodies, were together the most centrally linked actors in the entire network. As a result it is fair to say that The Hebrew University in particular, and the Weizmann institute to a lesser degree, present network *hubs* of activity. This finding is congruent with the finding of Castilla et al. (2000) on the importance of Stanford University to the high-tech scene of Silicon Valley and suggests that the Israeli biotech industry is heavily dependent on universities and research institutions. More generally it is also congruent with Castilla et al.'s (2000) findings that networks in Silicon Valley encompass a wide range of firm sizes and actors.

One notable difference between the Israeli high-tech industries and those of Silicon Valley that emerges from the research of Castilla et al.(2000) is the almost total reliance of Silicon Valley on private enterprise rather than government support. In their research of Silicon Valley Castilla et al.(2000) identify one sole governmental support program in the 1950's as having contributed to the regions development. They conclude that the

dynamism underlying Silicon Valley firms is largely a result of the networks of supporting (private) business institutions and venture capital funds. Although more research would need to be conducted on the role of government in Israel before any conclusions can be reached, it appears that Israeli firms rely to a much greater extent on the support of government than do similar companies in Silicon Valley.

Also of interest was that Bioline Rx was listed as the single most central actor within this network. Bioline Rx is an established company included in this network since it is the parent company of (the start-up firm) Bioline Innovations Jerusalem, which appears to provide a short-cut between extreme ends of the network. The bridging effect of Bioline Innovations Jerusalem is no doubt responsible for the high centrality measure of Bioline Rx. This suggests that by acting to bridge structural holes in a network, actors can improve their own measures of centrality within the network. This is consistent with network literature, which says that actors can increase their access to resources by bridging structural holes since this allows them to gain resources from more diverse sources than they would be able to without this bridging action (Burt, 1992; Krackhardt, 1995). From the publicly available information used in this research it is not clear whether this bridging action was an intentional strategic decision by Bioline Innovations Jerusalem. This highlights one of the issues the literature has already identified, namely the difficulty in identifying actors spanning structural holes (Hoang and Antoncic, 2003). With the exception of Bioline Innovations Jerusalem it appears that no start-up firms have managed to span distantly related or unrelated units within the Israeli biotech industry, which suggests that there may be other factors which limit firms' abilities to do so. At the same time the paucity of bridging actors within the network suggests that resources may be localised within different sectors of the network, so actors who do manage to span such structural holes should be able to gain a significantly larger amount of resources than actors who remain localized within the network.

The high centrality measure for the Office of the Chief Scientist of Israel is indicative of

the importance of this office to the Israeli high-tech industry. The office provided funding to numerous start-ups developed through business incubators e.g. Allergyflight, Ora Bio, Naturamed and Rimonyx Pharmaceuticals. It is notable that all the firms that received funding from this office did so whilst in a business incubator, with the possible exception of Izun Pharma, which is listed as being developed through a research centre. These findings suggest that the Office of the Chief Scientist of Israel does not provide direct funding to firms if they are not within some form of institutional setting, which makes sense since it seems illogical for a governmental institution to provide individual business financing and support when institutions designated specifically for that task already exist within the market.

In this network map it appears that all the large Israeli universities were linked through joint contributions to firms, with the exception of Haifa University. Haifa University and its associated technology transfer arm were only linked to The Hebrew University and Weizmann Institute and their respective associated bodies through the most distant and indirect of connections. However, The Hebrew University and the Weizmann Institute were closely linked through a number of firms which they jointly contributed to e.g. Vaxil Biotherapeutics and Semorex Technologies. Similarly, Ben Gurion University was directly involved with the Hebrew University through joint contribution to the firm Linkagene. It seems that for some reason Haifa University appears to be lagging in regard to biotechnology since it was only involved with the firm Mycure, and then only from joint contribution with Migal Research Institute, which was otherwise unconnected to the network. Similarly, Kaplan Medical centre was also only linked to the network through contribution to one firm, Neuroderm, and its relationship with the other research institutes was distant and indirect. It is noteworthy that The Hebrew University, Weizmann Institute and Ben Gurion University enjoy a close relationship with the Office of the Chief Scientist of Israel, while Haifa University and the Kaplan Medical Centre seem only distantly connected to this office. To generalise, it appears that the closer Universities and other public institutions are associated with the Office of the Chief Scientist of Israel, the greater the number of firms they are involved with. As such it

seems that this office is of great importance to universities and research centres seeking to become entrenched as key players within the Israeli biotech sphere due to the financial support that it provides. In order for research centres such as Kaplan Medical Centre and Haifa University to increase their portfolio of biotech ventures they would be well-advised to form closer linkages with the office of the Chief Scientist of Israel.

Not surprising was the high degree of centrality of TEVA pharmaceuticals which is a major player, perhaps the leading player, in Israeli pharmaceuticals. What was surprising was that this high centrality was achieved through only three ventures, two of which were heavily syndicated with several other venture capital firms. It seems that the close association of TEVA to numerous other venture capitalists has resulted in its high degree of network centrality, which makes sense conceptually since it indicates that Teva has good access to network resources through its contacts. For other venture capitalists who have less syndicated portfolio companies the case of Teva suggests that they will be able to increase their access to network resources by making a conscious effort to syndicate more of their investments, and with a greater number of strategic network actors. Of the VC's not directly connected with a research institute, Pitango Venture Capital was found to be the most central actor. This actor was only involved with three separate ventures, although one of them was Bioline Rx. This suggests that the close association with the most centralized actor in the network (Bioline Rx) has resulted in Pitango also achieving a great degree of centrality.

Another interesting find was that VC fund Giza, widely considered to be one of the largest and most influential within the Israeli markets, was only connected to two other actors (Braintact and BiolineRx). However, both of these start-ups were connected to numerous other venture capital funds. So, on the surface it appears that the only action Giza has taken within the Biotech field is through a heavily syndicated investment in two firms. However, the issue at this stage could be one of the level of detail that has been used within this study. Since the primary focus has been on the entrepreneur-venture capital fund relationship, the relationships between the venture capital funds has only

been included secondarily to the data map when explicit information was found (e.g. VC fund Ofakim Hi-Tech Ventures is a fully owned subsidiary of another VC fund, Capital-Point, and is modeled as such in the map). Since Giza is one of the largest VC funds in Israel it is likely that a large amount of its investments are conducted at a higher level than individual biotech start-up firms; it may be investing in the VC funds that ultimately will invest in biotech start-ups. Another consideration is that it may shy away from seed-stage financing directly, in favour of investing in more established firms. Either way, Giza was found to have little direct influence within the biotech start-up market.

Also of note is that certain biotech firms appear to result in at least as many network linkages as some of the research institutes (e.g. Braintact was linked to six other actors in the network, as was the Weizmann Institute). This suggests that certain heavily syndicated firms may be responsible for generating network linkages to a similar extent as that created by the large institutional actors such as Universities and the Office of the Chief Scientist of Israel. In other words, being part of a crucial start-up may be important to venture capital firms in that it vastly increases their number of network contacts, and hence increases their abilities to access crucial information and resources in the future. No similar such findings have been identified in the literature, suggesting that this is an original contribution of this research paper.

The two most central of the Biotech start-ups were Vaxil Biotherapeutics and Braintact respectively. The high level of centrality of Vaxil Biotherapeutics is not surprising, given that it is a joint project between the Weizmann Institute and Hadassah Medical School, which together (as already mentioned) appear to have formed a hub of network activity. This firm also has input from Sheba Medical Centre, although since this is not connected to any other network actors it is unlikely to have much effect on the centrality measure of the firm. Somewhat more interesting is the case of Braintact, which is a joint project between Meytav (which is closely associated with the Haifa University), Yeda research (from the Weizmann institute) and Teva pharmaceuticals. As already mentioned, Haifa

University appears to be somewhat removed from the hub of activity associated with the dominant universities and research centres (I.e. Hebrew University and Weizmann Institute). Nevertheless, the high level of centrality of Braintact suggests that the act of gaining contribution from two otherwise distantly related sources (Haifa University and the Hebrew University *hub*) has allowed this firm to access resources from both institutes and their associated bodies, leading to a greater amount of resources than would be available if the firm was only closely associated with one of the research centres. For biotech start-ups the implication of this finding is that they can maximise their access to resources by getting a joint contribution from research institutes that do not otherwise closely cooperate.

It was of some interest that the Tel Aviv Economic Development Authority and the Jerusalem Development Authority were both only involved directly with a single firm and its associated venture capital provider and incubator. It appears that these two offices are not very involved with the biotech industry.

Another area of interest is that five start-ups were found to be fully-owned subsidiaries of larger firms: Kahr Medical and Protab, both of which are fully owned by Hadasit Bio-Holdings, which is the technology transfer arm of the Hebrew University. Nano Bio Pharma is a subsidiary of Fulcrum SP, while Punisyn Pharmaceuticals is a division of Rimonest. Lastly Semorex Technologies is the R&D subsidiary of U.S. company Semorex Inc. Whilst the existence of fully owned R&D subsidiaries is not unusual within high-tech industries it was somewhat unexpected to find the two firms fully owned by Hadasit Bio-Holdings, considering that it is affiliated with a university and not private industry. One possible explanation is that these firms, both founded in 2005, may still be under development before being introduced to further investors.

It also appears that some start-up firms had lead to the introduction of otherwise unrelated actors to the network of actors in the Israeli biotech environment. For example, E-Pill

Pharma was connected to Boston Scientific Corporation, Alice Labs and MB Venture Capital 1, none of which were otherwise represented within this sample. E-Pill Pharma was also connected to Pitango Venture Capital, which is a large and established Israeli VC fund. Seen this way, the backing of Pitango Venture Capital may have acted as sufficient guarantee of success to entice the other actors into the industry. The otherwise unrelated actors may have also been more active in fields other than biotech which were not considered within this research, thereby introducing inter-industry linkages to the network.

Also interesting was that the two VCs with the highest degree of centrality were Hadasit BioHoldings, the technology transfer arm of the Hebrew University, and YEDA Research and Development Company, the corresponding technology transfer arm of the Weizmann Institute. This suggests that the close proximity of these actors to the Hebrew University and Weizmann Institute respectively, which together form a network hub, has increased their respective centralities. This suggests that Hadasit BioHoldings and Yeda have access to more information and resources as a result of their strong linkage with research institutes. More generally, this supports literature that suggests actors should build close association with key players in the network as a means of securing network resources.

Although not every firm listed the entrepreneurs responsible for their creation and some companies indicated that their creation was the result of a team of entrepreneurs (e.g. Nano Bio Pharma), many firms did list their entrepreneurs as well as a short biography of them. In many cases the websites mentioned that the firm was a commercialisation of research conducted by the entrepreneur. In total 51 entrepreneurs were cited by name. What is most remarkable about this set of individuals is that no fewer than 20 were professors at a research institution at the time of creation of the firm, and an additional 21 held doctorates or were otherwise designated as a medical doctor. These findings indicate that 41 of the potential 51 entrepreneurs (or 80%) were either currently working at a research facility or had done so to a sufficient standard in the past to have been

awarded a doctorate. More than any other findings of this research, this fact speaks volumes about the nature of biotech innovation within Israel. It seems that such innovation is predominantly carried out by highly qualified researchers within research centres and universities, and then commercialised through external companies. In many cases the entrepreneurs were cited as staying on with their start-up company during pre-clinical trials and to conduct R&D work, but most firms were found to have a professional management team recruited specifically to ensure the commercial success of the technology. The biographies of these teams were frequently given on the firms' websites and suggest that the majority of individuals within them had extensive experience within the biotech industry.

The fact that such a large number of the entrepreneurs held doctorates raises several possible mechanisms through which these entrepreneurs may have acted: They may have formerly been researchers within a research establishment who decided to exit to commercialise a technology they had discovered. Alternatively, they may have been researchers-turned-entrepreneurs as they made a career decision to leave the research field to form their own companies. Lastly they may have generated the technology but remained within their research institution whilst professionally composed management teams developed the commercial potential of the technology. Regardless of the mechanism, the award of doctorate and the lengthy research commitments it requires suggests that the majority of biotech entrepreneurs have spent considerable time within a research institute. Following on from this, it seems likely that a rich web of contacts exists between the academic environment that most biotech entrepreneurs were formerly a part of, and the commercial environment that they now operate in. With strong networks between academia and commercial biotech it seems feasible that many individuals would cross between the academic and commercial spheres, possibly numerous times within their careers. This is similar to findings by Castilla et al. (2000, p. 229) that key individuals "move back and forth from industry to academic positions in research centres and affiliates programmes.

Limitations

One serious limitation to this study is the presentation of the resulting three dimensional network maps. It is difficult to find any truly representative view in two dimensions (i.e. a picture) of these images. Added to this is the difficulty of comprehending the spatial component of a three-dimensional object from two dimensions. Castilla et al. (2000) also highlight this as an area of difficulty in presenting their research.

Another area of limitation to this study is the availability of crucial information from publicly available sources. Several start-up companies have been found to not specify who has backed them (MATIMOP lists them as privately owned, and hence presumably privately funded) or if they were part of a technological incubator. In such cases the company has been listed but is shown as unlinked to any other actors in the network map. Although this does not add directly to understanding the network, it does provide an indication of the number of privately funded start-ups or firms that otherwise did not use the publicly available sources. Whether such firms used private business incubators or VC funds that otherwise chose not to disclose their investments is unclear without further research from additional sources.

Possibly the greatest limitation of this research is that it is a static study, although the literature has already suggested that a more appropriate way to model networks and draw inferences as to their dynamics is through a longitudinal study (O'Donnell et al., 2001).

Areas identified for future research

The most immediate need for this research is that it be extended to include a longitudinal time study of the Israeli biotech industry. The static view presented in this paper is suitable for drawing broad conclusions as to whom the important network actors within the field are, but without a time element it provides no indication of the dynamics driving the networks development. An understanding of such dynamics are of great importance to public policy and government assistance programmes and represents the most logical

continuation of this research. The Pajek software includes the ability to model a network over discrete time intervals and to add and subtract actors from the network during those time intervals, thereby allowing a longitudinal dataset to be modelled. I suggest that a longitudinal dataset from the same time period as this study (2000-2008) which shows the incorporation of new biotech firms as well as attrition or success (taken as IPO or M&A) of existing VC portfolio firms, as well as the number of biotech firms within each VC's portfolio during each time period, would add greatly to an understanding of the Israeli biotech industry. Such a study would identify the success rates of the different VC's as well as their rate of throughput of biotech firms, which would allow the most important institutions and venture capital firms to be identified. However, in order to gather data for such a study it would be necessary to have access to more reliable and detailed sources of information than were provided on the publicly available internet sites used in this research. I would recommend a subscription to the Israel Venture Capital (IVC) website as a suitable source of information for such a study.

Another option Pajek allows is the alteration of the size and shape of vertices. Since the literature has already suggested that in Israel it seems that the six largest companies are investment leaders (Israel Business Today, 2000), a useful addition to the model would be sizing the vertices according to the size of the venture capital fund. Certainly from the perspective of a more complete graphical output such an extension would add to the literature enormously and would not be particularly difficult to achieve. Data on fund size should also be available from the IVC website.

Another area of study that would add an interesting addition to the high-tech network literature is an in-depth look at the extent to which government within Israel is responsible for the regions development. As already noted, in Silicon Valley government appears to have played a secondary role to private enterprise. However, in Israel it appears that government programs have been crucial to drawing foreign funds into the market. A comparison between the roles of government in the two regions would add a dimension to the literature not identified during this paper, namely the role of government in entrepreneur-venture capital networks.

Conclusion

This study sought to identify whether networks similar to the ones in Silicon Valley exist among Israeli entrepreneurs and their venture capitalists, and if so whether these networks provided a counterweight to the relatively high levels of risk to investing in Israel. To do this the study first considered the relevant bodies of literature, taken to be entrepreneurship, venture capital and network theory. The entrepreneurial literature showed how the nature of entrepreneurship has evolved and highlighted the difficulties in understanding entrepreneurship from within classical economic theory, thereby providing a justification for the development of a dedicated entrepreneurial literature. This literature suggests entrepreneurship is partly inherent to certain individuals under favourable circumstances and can partly be learnt, which suggests that attempts to foster entrepreneurship can be beneficial. Perhaps most crucially the research suggests that the presence of supporting institutions such as universities and research centres, as well as a more general culture of entrepreneurship and inter-industry personnel and information flows (particularly with academia) is crucial to the form of high-tech innovation considered in this paper.

With regard to the venture capital literature the review shows that VC funds typically maintain a portfolio of approximately nine companies and provide a range of benefits to these firms beyond the provision of capital, e.g. connecting them to business partners, searching for additional sources of capital and recruiting suitable management teams. The managers of the VC funds, and their prior experience, is a crucial factor influencing the type of investments that VC funds will invest in. These funds are often specialised by industry and follow a fairly standardised process of searching for investments. Of relevance to this paper was the finding that VC managers place a high emphasis on receiving referrals from trusted sources within a network of contacts. The background of VC fund managers is also identified as crucial in determining their investment focus: those with technical backgrounds are identified as most likely to invest in high-tech start-up ventures and add the most value to their portfolio high-tech firms.

The network literature highlights the limitations of network research at present: the lack of theory and methodological techniques means that beyond providing a very broad framework for analysis and a few quantitative tools such as centrality and network density, much network analysis remains subjective.

In understanding the effect of networks on VC and entrepreneur relationships in Israel a three-dimensional network mapping program (Pajek) similar to that used by Castilla et al. (2000) was used to generate a three dimensional network map of interconnections. Data was obtained from the MATIMOP database, a government site listing firms by sector. Only firms incorporated between 2000 and 2008 and listed as biomedical technology (biotech) were included within the dataset, and all information obtained was from publically available websites. The resulting image shows that there is a high level of interconnections between venture capital firms and biotech start-up firms within Israel, as well as numerous links they both have to institutional actors such as hospitals, research institutions, universities, governmental offices and business incubators. There are also separate mini-networks within the industry, as well as numerous firms that appear to be unconnected to the main institutions. Despite the presence of these actors unaffiliated with the majority of other network actors, it appears that in the main networks play a crucial role within the Israeli biotech industry. Also possible although not considered within this research is that the firms unaffiliated with the main networks are associated with firms from other (related) industries although additional research is needed to clarify this issue.

The Hebrew University and associated Hadassah Medical School, in conjunction with the Weizmann Institute, play a crucial hub role within this network in much the same way as Stanford University does for Silicon Valley. The network seems to have developed around these institutions, along with the Office of the Chief Scientist of Israel, which provided funding to a number of Institutions. It appears that the presence of this office

may have allayed the fears of investors by its involvement. It also seems that the involvement of several international VC firms may have reduced the fears of investing in the region for other VC's, thereby enticing them to the region. Additionally the strong presence of supporting institutions (in particular Universities and research institutes) suggests that start-ups within Israel have access to suitable business infrastructures to enable them to reach full potential. More generally it seems that networks in Israel occur amongst a wide range of firm sizes, which is congruent with the findings of Castilla et al. (2000) for Silicon Valley.

Also significant to this research was the strong role that government has played in fostering the Israeli venture capital and high-tech industries through the Office of the Chief Scientist of Israel. Castilla et al. (2000) do not identify government as a strong contributor to the development of Silicon Valley, yet data from Israel suggests that government has provided a crucial service within Israel's economy. The extent of government's involvement suggests that the Office of the Chief Scientist of Israel can be considered a network hub within the set of actors comprising the Israeli biotech industry

The central finding of this research was the role that highly-educated medical researchers from within academic and research institutions played in the role of biotech entrepreneurship. Around eighty percent of biotech entrepreneurs held a doctoral degree or were professors at research institutions. By virtue of their presence they indicate that strong networks exist between academia and industry. The focus of institutions on recruiting professional management teams, as well as the presence of technology-transfer companies affiliated to research institutions, suggests that the commercialization of innovations in biotechnology is well established and an encouraged practise for researchers within Israel's major universities. This cultural element of entrepreneurship is the same as that described by numerous authors for Silicon Valley. Given the similarities between the two regions, Israel's reputation as having a high-tech industry constructed in a similar way to that of Silicon Valley appears well justified, at least

insofar as the biotech industry is concerned.

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