European Planning Studies

ISSN: 0965-4313 (Print) 1469-5944 (Online) Journal homepage: http://www.tandfonline.com/loi/ceps20

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To cite this article: Amnon Frenkel, Emil Israel & Shlomo Maital (2015) The Evolution of Innovation Networks and Spin-off Entrepreneurship: The Case of RAD, European Planning Studies, 23:8, 1646-1670, DOI: 10.1080/09654313.2014.998171

To link to this article: http://dx.doi.org/10.1080/09654313.2014.998171

European Planning Studies, 2015
Vol. 23, No. 8, 1646–1670, http://dx.doi.org/10.1080/09654313.2014.998171

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The Evolution of Innovation Networks and Spin-off Entrepreneurship: The Case of RAD

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(Received January 2014; accepted December 2014)

ABSTRACT *We conducted an in-depth analysis of an Israeli startup, RAD Bynet, founded in 1981, that has intentionally, through the vision of its founder, given rise to 129 other startups employing some 15,000 workers, and created a unique "cloud". Through a survey of the existing firms, we sought to explore the nature of this ecosystem and to quantify the relationships that exist between the mother company and the enterprises that emerge from it. Our main findings were: (a) social and technological proximity encourages the tendency of the companies to maintain business relationships that probably contribute to knowledge exchange, while technological diversity drives innovation and startup formation; and (b) firms will choose to cooperate on the basis of a shared past and personal proximity relations, as well as technological proximity at a certain level; "viral clouds" of startups like the one we studied can thus intentionally be designed and developed.*

Introduction

Economic geographers have posited that "the more diversified a regional economy, the more knowledge spillovers will occur because firms get new and better ideas through other local firms that are active in many different industries" (Boschma & Iammarino, 2009, p. 289; see also Frenken *et al.*, 2007; Asheim *et al.*, 2011). Technological breakthroughs require combinations of technologies which often differ widely (for instance, innovations related to nanotechnology). The question then arises, what are the innovation policy implications that accrue from "industry mix" and "regional relatedness and diversity"?

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In the current paper we discuss these implications through a unique Israeli case study—the case of the RAD Bynet group. RAD is an Israeli startup founded in 1981, specializing in network hardware and components. The uniqueness of RAD and its founders stems from the fact that since its establishment a large number of startup firms have emerged from the original core of RAD (Breznitz, 2009). The company fostered startups within its own group, and many "alumni/ae" of RAD left to form their own startups, with technologies quite different at times from those of the "mother ship". A vast ecosystem of some 100 firms exists and can be used as a case study for examining entrepreneurial spin-offs enterprises. As such the case of RAD can serve as a microeconomics laboratory to investigate the policy implications of innovation driven by the "mother ship" process.

The reasons that lead to spin-off firms have been extensively studied in the literature. The first mention is geographical clustering of firms in the region which leads to spin-off of new ventures from existing firms which tend to stay in the region because of the benefits arising from their previous connections (Fritsch, 2005). In the case of RAD, as indicated by the empirical findings of this study, a substantial part of the spun-off (firms) locate in the same geographic area. However, the case of RAD is unique in the sense that a single company has led to the creation of more than 100 firms. Thus it is most appropriate to classify the RAD cases as alumni-based spin-off firms, even though in general this term is used in cases where the firm is founded by anyone who has studied or worked at a university (Roberts, 1991). Another example is the university spin-off firm or R&D spin-off firm where new firms are born from research labs in higher education institutions (Shane, 2004), for example, the most prominent case of Route 128 in Boston (Saxenian, 1985). M.I.T research laboratories performed in this case as incubators that stimulated hundreds of firms, especially in electronics-based industries (Dorfman, 1983). Similarly, in Germany in the case of German Max Planck Society, a research institution devoted to basic science, Fritsch and Krabel (2012) found that German scientists working in areas that have a commercially oriented business sector tend to move and set up their own company.

Clarysse *et al*. (2011) distinguish between university spin-offs firms and corporate spin-offs firms. While the first are based on technological opportunities arising from scientific innovations, the second are based on the opportunities arising from technological developments in other industrial firms. The latter are based on what was coined by Sapienza *et al*. (2004) "technology or knowledge relatedness". They claim that at least partial overlap of knowledge between the mother ship firm and the spin-off firm contributes to growth of the latter. Our study also examined the impact of technological proximity on the existence of a business relationship between the companies in the RAD cloud. In the case of RAD we found a partial technological overlap between the parent company and half of the spin-off firms in the cloud.

Specifically, we seek to understand first the nature of such an ecosystem, or "cloud" of startups, and to quantify the relationships that exist between the mother company and the enterprises that emerge from it. Several studies that focused on knowledge networks pointed to the importance that the exchange of technological knowledge has for firms' innovation activities (Giuliani & Bell, 2005; Boschma & ter Wal, 2007; Morrison, 2008; Sammarra & Biggiero, 2008; Broekel & Boschma, 2012). Following the lead of these studies in the current paper, the interactions among the various companies that belong to the RAD ecosystem are studied and quantified. The paper examines the determinants that contribute to interaction and collaboration among the RAD companies, and with the mother ship RAD, that lead to knowledge exchange. The assumption is that an ecosystem like that of RAD has benefited from different types of proximities—technological, social, personal, regional—that raise the motivation to interact and cooperate with each other for mutual gain.

Recent studies (Boschma & Frenken, 2010; Balland, 2012; Broekel & Boschma, 2012) investigate the role that these proximity dimensions play in building a technical knowledge network. These studies determine which proximity dimensions contribute to innovative performance among firms from different sectors. Nevertheless, the researchers point to the crucial need for further dynamic analyses that will examine knowledge network formation over time. In particular, they stress the need to understand how the dynamics of networks are affected by the various proximity dimensions and how these proximities change over time due to the evolution of networks.

We believe that an ecosystem like the one represented by the RAD cloud of enterprises creates the basic conditions that encourage the existence of a variety of proximities. Therefore it can serve as laboratory for the examination of the effect of such proximity indices on the willingness to cooperate and to establish mutual business interaction among the actors.

The Role of Proximities for Regional Economic Growth

Broekel and Boschma (2012) frame the research question as "both/and" rather than "either/or". They define a "proximity paradox", that is, "proximity may be a crucial driver for agents to connect and exchange knowledge, but too much proximity between agents on any of the dimensions might harm their innovative performance at the same time" (p. 409). In other words, there may be an optimal degree of proximity, sufficient to generate specialization but not so narrow as to stifle innovation, which by definition requires some degree of diverse thinking.

There have been several key studies of the role of diversity in innovation. Ejermo (2003) has developed a measure of technological diversity and relatedness, based on patents, to measure the diversity or specialization of Swedish regions. He finds that "results strongly support that the likelihood of innovation is raised in regions with high technological diversity" (p. 1). With high intellectual integrity, however, Ejermo later challenges his own findings and notes that "the number of patent applications in Swedish regions is highly and positively dependent on regional technological specialization" (2005, p. 167).

The literature on regional growth, policy and planning has numerous studies showing the importance of both specialization and diversity. Boschma and Iammarino (2009) indicate the existence of an optimal degree of "cognitive proximity" (defined below), such that the links between the knowledge base of a region and the extra regional knowledge that spills in are neither too small (which makes them useless) nor too large (which makes them superfluous for innovation). Le Blanc (2004) examines the role of agglomeration externalities for information technology industries in the US. He finds that the regional co-location of distinct industries, such as telecoms, software, internet and media encourages employment growth. Boschma *et al*. (2013) study 50 Spanish regions, 1988–2007, and find that "territories diversify into industries that are related to the existing set of industries" (p. 31), in which old industries spawn new ones that are technologically adjacent to them.

The role of proximities in the encouragement of knowledge sharing and innovation has been studied in recent years. The most investigated index of proximity is geographical proximity, based on the assumption that the exchange of tacit knowledge is greatly facilitated by face-to-face contacts and as such is sensitive to geographical distance (i.e. Audretsch & Feldman, 1996; Ponds *et al*., 2007; Torre, 2008). However, in the past few years researchers have claimed that geographical proximity is only one of a number of proximity dimensions that might affect the ability and willingness of actors to cooperate and to interact (Boschma, 2005; Broekel & Binder, 2007; Boschma & Frenken, 2010). In our study, we make extensive use of three types of proximity: geographical, technological and social. Before discussing the empirical findings concerning RAD ecosystem we present the essence of the proximity indices that appear in the relevant literature

Geographic Proximity

A large body of literature shows that geographical proximity increases the likelihood that two agents will commit directly to sharing knowledge reciprocally (i.e. Broekel & Binder, 2007; Healy & Morgan, 2012). Although geographical proximity may provide certain advantages for tasks that involve knowledge exchange, there is evidence showing that over-proximity also may erode the company's innovative performance (Broekel *et al*., 2010). Giuliani (2007) claimed that in fact geographical proximity is not sufficient, and is even not necessary, for knowledge and information to be transferred between different agents. However, while studies suggest that geographical proximity is losing some of its importance, the inclusion of all types of proximity in one analysis shows that geographical proximity still affects and impacts positively the formation of information networks and links (Balland, 2012; Hardeman *et al*., 2012; Balland *et al*., 2013a, 2013b).

Cognitive Proximity

Cognitive proximity refers to the degree of overlap that exists in the information and knowledge base of two given agents (Cohen & Levinthal, 1990). Interacting companies learn from each other; they generate knowledge and exchange it with each other (Argote *et al*., 2000; Nooteboom, 2000). According to Nooteboom (2000), there are close relations between cognitive distance (which is desired so that innovation will appear) and cognitive proximity (which is desired so that a given agent will be able to interpret and absorb the information). The relationship between the cognitive distance and the appearance of innovation between two given agents is expected to assume an inverted U-shaped curve (Cohendet & Llerena, 1997). Namely, neither a state of excessive cognitive proximity nor one of excessive cognitive distance holds much chance that two agents who participate in technological-business activity will produce innovations. Therefore, it can be expected that great cognitive proximity may be potentially harmful to the company's performance (Nooteboom *et al*., 2007; Boschma *et al*., 2009; Boschma & Frenken, 2010).

Social Proximity

Social proximity refers to the depth of the social relationship between agents, in terms of friendship, family kinship and shared life experience (Boschma, 2005). The perspective of social proximity should be studied as a dynamic process, which refers to human relations in which a process of knowledge assimilation takes place in a broad social context (Kossinets & Watts, 2006). The concept of trust is central to social proximity; the trust level is expected to grow when social proximity increases. Trust tends to increase the exchange of information and encourages it (Maskell & Malmberg, 1999). Relationships based on trust are the most important component in the establishment of social relations.

Social proximity that is based on knowledge networks that are consolidated on the basis of interpersonal relationship could be formed, for example, among colleagues who were employed by the same organization and remained friendly even after they left that organization (Buenstorf & Fornahl, 2009), or even in the case where the organization itself ceased to exist (Broekel & Boschma, 2012). Social relationships arising from a common historical background play crucial role in the acquisition of information, and persuading capital holders to join the venture, whether as employees or investors (Sorenson, 2003). It is based on the fact that people prefer to develop and maintain social relationships with those with similar backgrounds and interests (Lazarsfeld & Merton, 1954). Therefore, social networks play an important role in the process of entrepreneurship. Existence of reciprocal social relationships with potential investors may improve the chances of obtaining capital entrepreneurs. As such, entrepreneurs in a region with plenty of firms tend to belong to the social communication networks that expose them to promising investment opportunities and a good assessment of the current market conditions (Sorenson, 2003).

Studies have shown that great social proximity may be a prerequisite, balancing rooted human relations (social cliques) and strategic-business relationships that are a product of the former (Rowley *et al*., 2000; Fleming *et al*., 2007). However, too strong a social proximity can also be harmful. A high degree of social proximity could block the entry of new agents into the network, and affect the network's rigidity (Uzzi, 1997). Financial studies have shown that investors who invested in projects related with social networks may earn positive abnormal returns because of their access to information about attractive investment opportunities that the social networks creates (Coval & Moskowitz, 2001; Garmaise & Moskowitz, 2004). Therefore, entrepreneurship resulting from the entrepreneurial ecosystem (as in the case of RAD in this study) often gains high priority in identifying new opportunities and the ability to mobilize financial and human capital to realize their vision. This is due to the social relationships among the players within the ecosystem compared to outsiders (Sorenson, 2003).

In summary, it appears that the types of proximity discussed here can influence the information networks that exist between different agents. Although in the past studies dealt mainly with the meaning of geographical proximity (Jaffe, 1989; Audretsch & Feldman, 1996), in recent years an increasing amount of research has been devoted to the different meanings of the other types of proximity as related to corporate behaviour (Cantner & Meder, 2007; Fleming *et al*., 2007; Ter Wal & Boschma, 2009; Hoekman *et al*., 2010; Balland, 2012; Cassi & Plunket, 2012).

Data

RAD Bynet Ecosystems

The RAD Group was founded 1981 by the Zisapel brothers. In 1985 (RAD's revenues reached $5.5 m.), just 4 years after its birth, RAD offered initial funding and support to an entrepreneur to launch LANNET, which developed a pioneering Ethernet switch.

This was done in order to avoid two conflicting pitfalls: Losing focus by producing an excessively wide product range, and losing innovation, by having talented engineers depart the firm when their innovative ideas are rejected as “not in our product line”. The success of LANNET (acquired in 1995, then again acquired by Lucent in 1998) showed that the model of LANNET could be extended to a large number of startup firms, with RAD at the centre.

In general, the ecosystem generated by RAD includes at most some 129 firms. Some of these firms (35 firms) no longer exist, typical of high failure rates among technological startups. This is due either through bankruptcy (28 firms) or through their acquisition by larger firms when ceasing to operate (7 Firms). However, the failure rate of RAD ecosystem companies (27%) is significantly lower than the overall failure rate of technological startups.

The Firms’ Survey

Data collection was conducted using an online survey. Of 129 companies associated with the RAD ecosystem, it was possible to review 119 firms.[1] With the survey, it was possible to identify, inter alia, various relations taking place between companies in the cloud, the relationship of RAD with them, and its role in establishing the various companies. In addition, the survey supplies the data that assist in measuring the technological-cognitive proximity that exists between the companies and an array of social relationships that take place between their managers in formal and informal settings. The primary research tool in the survey was a questionnaire, transmitted via e-mail to firm managers. The managerial rank chosen to be interviewed were General Managers (CEOs) and technology managers (CTOs) in the firms. The priority of the email survey is reflected in its many advantages (low cost, ability to administer a relatively large questionnaire, easy and immediate distribution, as well as the possibility offered to the subjects to answer the questions any time and place they desire). Most of the questionnaire consists of closed questions and scales.

The survey was conducted over several months at the beginning of 2013. In the first phase, questionnaires were sent to the 119 companies included in the survey. A round of calls was made to executives who had not yet returned the questionnaire even after the third reminder, in an effort to convince them to fill out the questionnaire and send it back. The final and direct phone call stage was found to be most effective, leading to a significant increase in the rate of response.

In total, filled questionnaires were received from 57 companies in RAD’s ecosystem. This scope of samples indicates a good rate of response (47%). This is a relatively high rate, considering that company managers are in positions that leave little free time to respond voluntarily to research needs.

The sample representativeness compared to the total population in the RAD ecosystem in terms of its characteristics is depicted in Table 1. The sample of 57 respondents reasonably represents the total population of firms in the RAD ecosystem (based on the Israel Venture Capital (IVC) data set) in terms of year of establishment, location, size and industrial sectors.

Close to half of the firms in the RAD ecosystem were founded during the 1990s with a smaller rate in the sample (the opposite occur in the 2000s), both mainly in the second half of this decade. In general, there is a good representation of the general population in the sample according to the founding years. Geographically, the majority of firms in the RAD

Table 1. Characteristics of the full RAD cloud firms versus the sample population[a]

Variable	Categories (%)	Total population	Sample
Year of establishment	1975–1989	9.9	10.5
	1990–1994	16.1	7.0
	1995–1999	32.1	28.1
	2000–2004	21.4	21.1
	2005–2012	20.5	33.3
	N	112	57
Location within the Metropolis	Core (Tel Aviv)	45.9	50.9
	Inner ring	17.4	10.5
	Middle ring	21.1	26.3
	Outer ring	6.4	8.8
	Outside the metropolis	9.2	3.5
	N	109	57
Size groups (workers)	1–49	54.2	63.2
	50–99	12.5	10.5
	100–499	24.9	19.3
	500–999	4.2	3.5
	1000–3000	4.2	3.5
	N	96	57
Industrial sector	Communication	51.3	54.4
	Biotechnology–medicine	16.8	24.6
	Internet	5.0	3.5
	Software	11.8	8.8
	Hardware	3.4	3.5
	Venture capital	7.6	1.8
	Remote sensing	0.8	0.0
	Unknown	3.4	3.5
	N	119	57

[a]The total number of firms varies depending on the availability of data in the IVC database.

ecosystem and the sample are located in the Tel Aviv metropolitan core and inner ring (63.3% and 61.4%, respectively). As we move farther away from this core, there is a distinct drop in the concentration of firms.

More than half of the firms in the RAD ecosystem and the sample are small firms in terms of number of workers (less than 50 employees). In both total population and sample, less than 10% are large firms with more than 500 employees. This property is common among technology-intensive companies. In the US the Bureau of Labor Statistics (2013) reports firms with fewer than 500 employees accounted for 25% of the jobs in high-tech industries. And of course, Israeli firms tend to be an order of magnitude smaller, on average, than American ones.

More than half of the firms in the RAD ecosystem and the sample belong to communications technologies (51.3% and 54.4%, respectively). Another major group in the “cloud” but with higher rate in the sample belongs to biotechnology and medical industries (16.8% and 24.6%, respectively). The rest are distributed among the other branches with a similar extent.

It is significant that the RAD model for spawning new startups has become, in a sense, viral. According to Ellis and Drori (2012), the RAD Group has been the most “fertile ground" for creating Israeli entrepreneurs, having produced 56 "serial entrepreneurs" who established more than one start-up each.

As mentioned above, similarly to the overall study population, a significant proportion of the sampled companies were established during the 1990s (35%) and during the 2000s (53%). Thus, it is not surprising that 44% of the managers who answered the questionnaire were from companies in their consolidation stage (i.e. the company has a distinct market share, and/or product after development), while 28% are at the germination stage (i.e. initial R&D, technology development, or prototype). Forty-eight per cent of the firms from which the questionnaire was received are located in the same area in Tel Aviv (Kiryat Atidim), where the parent company, RAD, is located. Another 14% of the companies included in the sample are in towns close to Tel Aviv, in the inner ring of the Tel Aviv metropolitan region.

Method

The Relation of the Cloud Members to RAD

The purpose of the first part of the data analysis as presented above was to examine the ongoing relationship of the companies in the cloud with RAD, the cloud founder. The intention was to gauge the extent of their relationships and the factors affecting the continued existence of such a relationship. To achieve this, several variables were developed, defining the relationships of the companies in the cloud, and specifically their relationships with RAD. The dependent variable, RAD_{CONC}, is a dichotomous one, such that company senior managers were asked in our survey "Do you or other senior managers in your company have any contact (organizational/business or personal) with RAD?" The distribution of the responses to this question showed that 59.6% answered positively.

The independent variables included first the variable SNYRTY, which is a dichotomous variable that indicates whether the managers or their colleagues in the company management held a senior position in RAD in the past. Using this variable also allows us to determine the extent to which this has a direct effect on the continued relationships with RAD. In addition, another variable was used, COMRS, as a dichotomous variable indicating whether RAD played a role in founding company *i*, beyond the fact that its CEO fulfilled a senior role in the past at RAD.

Another variable is YEAR, which measures the number of years that passed since the establishment of RAD and the establishment of company *i* in the cloud. Using this continuous variable, it is possible to examine whether there is a loosening of the ties with RAD on the timeline. That is, whether the companies are becoming more independent as time goes on.

Two other variables represented the degree of technological and geographic proximity of the cloud members with the RAD Company. RADIST is a continuous variable that measures in kilometres the geographical distance between the locations of company *i* in the cloud and the location of RAD. It allows us to examine the effect that the geographical proximity of the companies in the cloud to RAD has on the existence and strength of the ties between them. TECHNO is the variable through which the degree of the cloud members' reliance on technologies similar to those of RAD can be examined. Actually, the variable specifies a state in which technologies identical to those of RAD are being used. The assumption is that, if such technologies are employed, then it can be assumed that some of the revenues of these companies result from the use of these technologies. To create this dichotomous variable, we used the survey data that indicated the prevalence of the code words of the technology used in the development of their products, where 1 indicates a situation in which company *i* mentioned code words that appeared in part or in their entirety also in RAD.

Two other variables were used for descriptive statistical analysis only, indicating the nature of the existing relationship between the companies in the cloud and the founding company RAD. The first, INTENS, is a binary variable, indicating the intensity of the relationship of the senior executive of company *i* with RAD, where 1 indicates that an intensive relationship was reported, which takes place at several sites and has an orderly and steady character, such as professional and business meetings on a regular basis, meetings in conferences, and even meetings as a result of social and family ties; and 0 indicates otherwise. The second variable, BUSIN, is a binary variable that indicates the intensity of company *i*'s business relationship with RAD (as the original company), where 1 is defined as a relationship of moderate or high intensity, and 0 is the non-existence of a relationship or a relationship of low level intensity.

Inter-firm Contacts among Companies Comprising the RAD Ecosystem

In the second part of our article, our objective is to examine the nature of the relationships that characterize the ecosystem created by RAD. The research questions that were examined are related to the existing ties, their nature, and their level of intensity, as well as to identifying the contributions of different proximity measures to the empowerment of these relationships. The assumption proven in many studies is that the existence of synergistic processes between technological companies contributes to the promotion of mutual and dynamic innovation processes (Lundvall, 1992; Nelson, 1993; Braczyk *et al.*, 1998). The sharing processes that take place between firms in a given area, leading to knowledge exchange, have an effect on regional growth as claimed by Von Tunzelmann and Wang (2003).

In order to examine the structure of the relationships in RAD's cloud, several variables were developed through which it was possible to identify the presence and intensity of the relationship between the companies in the cloud. CONC_COMP1 was defined as a dependent variable that measures the intensity of the business relations existing between company *i* and companies other than those in the cloud from which that company's founder originated. The possible answers to the question in the survey were: (1) No contact (2). Low intensity contacts (random meetings in conferences, occasional meetings or other contacts that are not regular professional contacts). (3) Varying contacts with high intensity (such as regular professional meetings). From these answers, we built the dichotomous variable that divided the companies into two categories: 1 = those with highly intensive business contacts and 0 = those without business contacts or low intensity contacts. The distribution of the responses revealed that 38.6% of the companies in the "cloud" maintain highly intensive business contacts with other companies in the cloud, and 61.4% do not maintain business contacts or have contacts at a low level of intensity only.

We had no actual knowledge about the companies with which companies in the cloud maintain a business relationship that leads to cooperation and probably to knowledge exchange. The information reported in the field survey refers only to the existence of such relationships with companies in the cloud and their level of intensity. Therefore, we could not examine the intensity of an undirected network, consisting of a relationships matrix between any company *i* and company *j* in the cloud, similar to Broekel and Boschma (2012). Therefore, we had to settle for a more general measure indicating the existence of business relations among the companies in the cloud. In this way, the variable CONC_COMP1 yields 1, when business relations with high intensity that exist at several sites and have an orderly and steady character were reported, and 0 otherwise. Of all the sampled companies, 38.6% reported high intensity relationships between them and other companies in the cloud.

As mentioned, one of the study objectives was to examine to what extent different proximity measures contribute to the intensification of these relationships in RAD's cloud. That is, the purpose was to assess the extent to which different proximity measures affect the chances that companies will maintain relationships between them. To achieve this, we used three different proximity measures.

Geographic proximity. The cloud of RAD BINAT was essentially formed when most of the companies that came out of RAD established themselves geographically at the centre of the country and some in the close vicinity of RAD.

In order to assess the influence of geographical proximity on the cooperation that exists within the cloud, the geographic proximity measure, DIS, was calculated according to the aerial distance (in kilometres) between two given companies in the cloud. According to Ejermo and Karlsson (2006), it is customary to measure geographical proximity according to travel time, not aerial distance. However, the structure of the company cloud connected to RAD apparently does not justify the use of travel time, since the distance range is short in many of the observations (similar to the use made by Broekel and Boschma (2012)). The distance is therefore measured as the log of the aerial distance (in kilometres) between each pair of companies in the cloud, in order to counteract its influence on the estimation findings of abnormal observations. Since it was impossible to examine the relationship on the basis of an undirected network, the measure of geographical proximity, DIS, was calculated as the average of the distances of company *i* from any other company *j* in the cloud.

Cognitive proximity. Cognitive proximity represents the technological similarity that exists between the knowledge bases of the different companies in the RAD group. Because the companies included in the study belong mostly to the same technological–economic sector, it was not possible to distinguish between them by the sectorial databases that classify each company, according to a five digit numeric classification. Therefore, it was decided to characterize this proximity by the code words that describe the products and technologies that the company uses. To achieve this, the company executives were asked in the survey to specify up to 10 main products that their company manufactures or develops, and for each product indicated, to list five code words that describe the technology that the company uses in its development. Thereby, we received a set of code words that describe the products and technologies used by each company. A total of 179 pairs of code words that represent the products and technologies of the sampled companies with co-occurrence were received and entered in our database.

The first step for identifying the degree of cognitive proximity that exists between the two companies focused on identifying the extent of the similarity that exists between pairs of words. According to Breschi *et al*. (2003) and Broekel and Boschma (2012), similarity between two words that represent technologies in our study is estimated on the basis of their co-occurrence at the particular company. Therefore, if a word representing technology A often appears in different companies that also presented a code word that represents technology B, it is likely that these two code words are interrelated. In addition to this direct relationship, they assumed the existence of an indirect link between words that represent two technologies. An indirect link occurs when code word A is presented frequently by the same companies that display the code word C, as is true for code words B and C, because then A and B also represent proportionately similar technologies, each being similar to C. In order to calculate the extent of direct and indirect proximity between technologies, we used the Cosine measure, as presented by Ejermo (2003) in the following equation:

$$r_{ab} = \frac{\sum_{c=1}^{t} w_{ac} w_{bc}}{\sqrt{\sum_{c=1}^{t} w_{ac}^2 \sum_{k=1}^{t} w_{bc}^2}}, \tag{1}$$

where t is the number of words, and b, c, a, are the code words that represent the technologies or products examined. W_{ac} represents in the equation the number of times that the code words a and c were presented jointly by the companies.

When companies indicated multiple code words (represent different technologies and products), we have no information about the relative importance. For example, no information is given on the share of that technology or product in the company's total revenue, or, for instance, the number of employees that use this technology or produce the product that the code words represent. Therefore, we estimated proximity in two ways. First, we examined what the most similar pair of words is on the companies' word vector. That is, first we compared the word vector presented by two companies (i, j) as representing their products and technologies (t_i and t_j). Then, we identified for each code word a (a ε t_i) in company i the maximal r_{ab}^{i} in the code words of company j. Similarly, the code words of company j were identified. The r_{ab}^{i} were summarized and divided by the sum of the number of words which were presented by the two companies, i and j. This prevented bias in the proximity measure, which was calculated in this manner for the benefit of companies that presented more code words. The estimation is represented by Equation (2):

$$S_{ij} = \frac{\sum_{a=1}^{t_i} \max\limits_{b=1,\ldots,t_j}(r_{ab}) + \sum_{b=1}^{t_j} \max\limits_{a=1,\ldots,t_i}(r_{ab})}{t_i + t_j}. \tag{2}$$

Since the Cosine index values, r_{ab}, range from 0 to 1, the cognitive proximity measure ranges also between 0 and 1, where 1 represents perfect technological proximity. In extreme cases, all of the technologies of company i are compared to one technology of company j. The underlying logic is related to the absence of information about the relative importance of a certain technology to the company, and for this reason, we assume that proximity, even to a particular technology, produces some proximity between the companies, since they have a common knowledge base that allows effective communication. Again, since we were unable to assess the relationships on the basis of an undirected network, the measure of cognitive proximity of each company COG_i in the cloud was calculated as the average of the proximity distances between company *i* and any other company *j* in the cloud.

In addition, we used the square value of the proximity measures to test nonlinear relationships. Since the two measures can be affected by multi-collinearity, we subtracted the average value of the variable before calculating the square value:

$$\mathrm{COG}_i^2 = (\mathrm{COG}_i - \overline{\mathrm{COG}_i})^2 \tag{3}$$

making this measure similar to standard deviation. Therefore, the value of COG_i^2 is higher for both high and low values of the proximity measure.

Social proximity. As mentioned above, social proximity can be considered a good predictor of the existence of a relationship between two companies. In order to trace the existence of social connections arising from membership in the cloud of RAD, we examined whether the corporate managers who were interviewed in our study had a personal connection to the company from which the founders of their company arrived. The hypothesis tested is that such personal relationships may contribute to collaborations and intensive cooperation and to their nature. In order to examine the relationship that exists between companies, we defined the personal contact variable PERSON, as a binary variable that indicates the intensity of the personal relationship with one of the companies from which the founders arrived. In this variable 1 specifies that a rich personal relationship representing several types of personal ties was reported.

In addition, we used an indirect variable, PRC_EMPLY, a continuous variable that measures the percentage of employees who came from the same company as the founders. According to Broekel and Boschma (2012), shared history may produce communal proximity, which will affect the willingness to collaborate, so that this variable can express the intensity of possible relationships as a percentage of those employees is higher.

Control variables. In addition to these, we also included other variables, which serve as control variables that may affect the likelihood of cloud members maintaining relationships. First, we defined the logarithmic value of the absolute size of company *i* in the cloud (SIZE) by the number of its employees. This continuous variable may control the variance factor of the companies' conduct, which is affected by their size (see Beise & Stahl, 1999; Graf, 2011).

Two functional control variables were defined in order to examine the effect that functional relations have on the companies in the cloud. COM_CONCT is a dichotomous variable, where 1 indicates that at least one member company from which the founders or executives of a company arrived played a role in the establishment of company *i* in the cloud, and 0 otherwise. The second variable, RAD_CONC, is a dichotomous variable, where 1 indicates that company *i* or one of its leaders communicates with RAD, and 0 otherwise (Allen, 1984).

All the above variables are presented in Table 2, which includes a description of their characteristics. Table A1 presents the correlations between the variables. Most of the correlations between the variables are weak, hence the variables can be included in the regression model. However, some of the variables that measure the existence, intensity,

Table 2. Variables related to RAD

Variables	Type	Shares of zero values	Mean
Senior position in RAD (SNYRTY)	Dichotomous	70.2	0.30
Business roll of RAD company in establishment of company surveyed (COMRS)	Dichotomous	82.5	0.18
# of years since Rad establishment (YEAR)	Continuous	0	18.80
Geographic distance from RAD (RADIST)	Continuous	36.8	7.15
Technological similarity with RAD (TECHNO)	Dichotomous	59.6	0.40
Strength of the relationship (INTENS)	Dichotomous	47.4	0.82
Intense of business connection with RAD as Origin Company (BUSIN)	Dichotomous	86.0	0.14
Strong Intense of personal connection with companies from which the founders came from (PERSON)	Dichotomous	75.4	0.25
Percentage of employees from the company from which the founders came from (PRC_EMPLY)	Continuous	33.3	14.50
Cognitive proximity (COG)	Continuous	7.0	0.13
Cognitive proximity effect (COG^2)	Continuous	7.0	0.01
Geographic distance (DIS)	Continuous	0.0	2.16
No. of employees (SIZE)	Continuous	0.0	115.80
Business roll in establishment of the origin company/ies (COM_CONC)	Dichotomous	49.1	0.52
Senior in the company have relations with RAD (RD_CONC)	Dichotomous	40.4	0.59

and nature of the relationships have a high correlation, and therefore these variables were analysed in separate models.

The Model

To test the research hypotheses, two basic models were estimated. One is the model that examines the influence of various factors on the extent of the continuous relationship that companies in the ecosystem maintain with the founding company, RAD. The other examined the influence of various factors on the existence of relations between the companies that belong to RAD's ecosystem. The dependent variable is then regressed with a standard logit model on the independent variables. The logit model was selected because both dependent variables are binary variables, 1/0. In the first model, 1 suggests an association between company *i* and RAD, while 0 suggests the absence of any connection. In the second model, 1 indicates the existence of high intensity business relationships between company *i* and other companies in the cloud, which take place at several sites in an orderly and regular manner.

Results

The Relationships of the Companies with RAD

The results of running the logit model on the variables related to RAD Company are presented in Table 3. The predictive level obtained by the model indicates that the model

Table 3. Logit regression on RAD connection to its ecosystem

Depended variables		Estimate	Standard error
Intercept		0.471	32.132
SNYRTY	Senior position in RAD	22.001	34.730**
COMRS	Business roll of RAD company in establishment of company surveyed	19.550	4.490**
DIST	Geographic distance from RAD	−0.083	0.177*
YEAR	# of years since the establishment of RAD	−0.044	6.613
TECHNO	Technological similarity	0.972	4.094
Chi-squared test of fit improvement = 33.651 on 5 d.o.f., *P*-value = 0.000			
−2 Log-likelihood = 42.187			
Cox & Snell $R^2 = 0.452$			
Nagelkerke $R^2 = 0.609$			

*Significant at the 0.10 level.
**Significant at the 0.01 level.

accounts well for the connections that were found. The results confirm the hypothesis that the presence in a company of executives who previously held a senior position in RAD affects the continued existence of relationships between that company and the parent RAD Company. The variable SNYRTY was found to be positively and statistically significantly related to the dependent variable, indicating the continued existence of a connection between the offspring company and RAD. Companies in whose establishment RAD played a business role tend to preserve ties with RAD, as indicated by the positive and statistically significant relation between the variable COMRS and the dependent variable. The third variable that was found to be statistically related to an offspring company maintaining ties with RAD is RADIST, the geographical distance, of the company *i* from RAD, although the statistical significance is moderate. The findings indicate that geographical proximity has a positive influence on maintaining relations.

However, the model results do *not* indicate that technological proximity has an effect on the continued tendency of a company to maintain relations with RAD. From this, one might conclude that the continued relationship with RAD is based more on the social proximity that stems from a shared history, and is *not* due to the existence of common ground based on knowledge related to the use of similar technologies. This finding is of great importance for the development of social networks that lead to the establishment of hi-tech firms by entrepreneurs with a shared history. Another finding of interest is the non-existence of a statistical relationship between the number of years since the founding of RAD and the year when the company was established, in the cloud. That is, the time variable has no effect in any direction on the probability of maintaining ties with the founding company in the cloud, a finding that reinforces the above conclusion.

In order to understand the intensity and nature of the relationships as influenced by a shared past, we applied a chi square model to the additional variables due to the ordinal nature of the scales. The results are shown in Table 4.

The findings clearly indicate that a common past probably leads to greater current intensity in the relationship. Over 80% of the companies whose managers filled senior positions

Table 4. Type of relationships

Intense of the senior connection with RAD (INTENS)	Does one of the managers in the company was in a senior position in RAD, in the past? (SNYRTY) No	Yes	Total	
No connection	60.0%	17.6%	47.4%	$\chi^2 = 9.149$; df = 2; sig = 0.010
Weak connection	15.0%	41.2%	22.8%	
Strong connection	25.0%	41.2%	29.8%	
Total	100.0%	100.0%	100.0%	
N	40	17	57	
Intense of business connection with RAD				
Non- or weak business connections	92.5%	70.6%	86.0%	$\chi^2 = 4.747$; df = 1; sig = 0.029
Moderate and strong business connections	7.5%	29.4%	14.0%	
Total	100.0%	100.0%	100.0%	
N	40	17	57	

at RAD in the past report the continued existence of a relationship in the present, sometimes many years later. About 50% of these companies define this relationship as an intensive, regular and constant relationship (includes professional and business meetings on a regular basis, meetings in conferences, and even meetings held as a result of social and family relationships), as opposed to only 25% of the companies whose managers do not share such a common history.

Moreover, the shared history is also reflected in greater willingness to maintain relationships on a business basis with RAD, although the scale is not especially large. Only 14% of all companies reported a business relationship with RAD; however, this percentage is almost double among companies with a shared history, but only 7.5% among the companies whose managers did *not* have a shared history.

The Relationships of the Companies in the Ecosystem

The regression results with respect to the relationships within the cloud are shown in Table 5. The obtained explanatory level is high, indicating the model's ability to account for the relationship system in the ecosystem.

The results arising from the model shown in Table 5 indicate that most of our hypotheses concerning the factors affecting the existence of intense business relations of company *i* with other companies in the cloud were supported. First, it was found that social proximity is particularly relevant to the existence of business relationships between the companies. The variable PERSON was found to be positively and statistically significantly related, at a high level, to the tendency to maintain intense business relationships. On the other hand, shared history, which is measured by the percentage of employees in the company who came from the company of the founders, PRC_EMPLY, was not found to influence the tendency to maintain relationships. This result is interesting, because it was found that in 66% of the companies in our sample, workers are employed

Table 5. Logit regression on connections among companies in RAD ecosystem

Depended variables		Estimate	Standard error
Intercept		−5.591	156.441**
PERSON	Strong intense of personal connection with companies from which the founders came from	4.239	298.191***
PRC_EMPLY	Percentage of employees from the company from which the founders came from	0.140	4.385
DIS	Geographic distance	0.068	21.377
(DIS^2)			
COG	Cognitive proximity	9.824	776.478*
(COG^2)	Cognitive proximity effect		
SIZE	No. of employees	−0.030	0.271
COM_CONC	Business roll in establishment of the origin company/ies	1.916	229.262***
RD_CONC	Senior in the company have relations with RAD	2.139	40.717**
Chi-squared test of fit improvement = 34.202 on 7 d.o.f. *P*-value = 0.000			
−2 Log-likelihood = 40.839			
Cox & Snell $R^2 = 0.457$			
Nagelkerke $R^2 = 0.619$			

Notes: Numbers in parentheses are based on models not reported estimations. Since the other variables' coefficients did not change significantly they are not listed.
*Significant at the 0.10 level.
**Significant at the 0.05 level.
***Significant at the 0.01 level.

who arrived from the same company as the founders, and on average the percentage stands at 14.1%.

Unlike many other studies, which found that geographical proximity has an impact on the creation of cooperation between companies, our research did not find such evidence. Geographical proximity has no effect on the companies' tendency to maintain intensive business relationships within the RAD cloud. However, this result can be attributed to the relatively small distance between most of the companies in RAD's cloud. Apparently, the differences in the distance between the companies are insignificant in terms of their tendency to communicate with each other. This is probably a direct result of research which is based on spin-off firms from one mother ship and this may restrict the possibility of detecting the existence of the effect of geographic proximity.

On the other hand, to some extent, this finding supports the hypothesis that social proximity is of higher importance and has a significant effect. In fact, the geographical effect found in other studies was often due to the existence of social contacts that were not measured in these studies (Ponds *et al.*, 2007) and is strengthened in light of the findings of the current study.

As for cognitive proximity, a positive statistical association was found between technological proximity, as measured by the COG variable, and a company's tendency to maintain intensive business relations with the companies in the cloud. However, the relation is significant at a statistical level of 0.1 only, but still indicates the contribution that could be to technological proximity between the companies to their willingness to maintain contacts on this background, as found in other studies (Mowery *et al.*, 1998;

Cantner & Meder, 2007; Sorenson & Singh, 2007; Broekel & Boschma, 2012). The square COG measure was found to be not statistically significant so that, as Cantner and Meder (2007) and Broekel and Boschma (2012) found, it is impossible to verify an inverse U relationship between the tendency towards cooperation and technological proximity.

Supposedly, it could be deduced from these findings that social proximity considerably affects the tendency to maintain intensive business relationships, more so than technological or geographical proximity. The findings with respect to technological proximity were expected to indicate higher technological proximity (the average of technological proximity in the cloud stood at 0.13 on a scale of 0–1). This expectation is based on the fact that the source of the cloud is one founding company, which bred many other companies, some of which continued and bred other companies. For most companies, a significant cognitive proximity measure (over 0.7) was found with a few other companies (2–4 companies in the cloud). Only two companies showed such a high cognitive measure in relation to a significant number of companies (about 15 companies in the cloud). This is probably the result of a policy taken by the founder of the cloud, which led to high technological diversity in the cloud (Table A2 shows the most common code words).

Similar to the findings of Broekel and Boschma (2012), firm size was not found to affect the existence of intense business relations between the companies. On the other hand, role proximity was found to have a positive effect on the intensity of business ties. As stated, this proximity was measured by two variables. The variable COM_CONCT, which indicates that the existence of a role in the founding of the company, which became the company from which the founders of the company arrived, has a positive influence on the tendency to maintain intensive business relationships in the cloud. The second variable indicates the influence of RAD, the founding company of the cloud, on business relations in the cloud. It was found that when a company, or one of the directors, is in communication with RAD, the company has an increasing tendency to maintain business relationships with companies in the cloud, as measured by the variable RD_CONC. These two variables are statistically significant, <0.05, with RAD's impact being stronger than that of the other company from which the founders arrived.

Summary and Policy Implications

In this paper, we studied an unusual event associated with the germination of hi-tech companies, which grew out of the ideological concept of a high-tech entrepreneur who established the RAD BINAT company in 1981. Over the years, through a deliberate effort of the founder, companies were founded by entrepreneurs who had initially departed from the parent company, and during the following three decades, the companies that were thus born gave birth to other companies. This created a unique ecosystem, represented by RAD, which included at its peak expansion about 129 companies, some of which were closed over the years or were purchased by other companies and ceased to operate as independent entities. However, the unusually high rate of survival of firms, 73%, clearly indicates that in the RAD cloud the mentoring and informal advice are indeed helping the RAD cloud startups to endure and prevail.

A central research question was the extent of the relationship measured between the companies in the cloud and the company that founded the cloud, 30 years later. The findings showed that the tendency to maintain such a continuous relationship is stronger among the companies in whose establishment RAD played a business role or where one of the company managers had held a senior position in RAD. These findings probably indicate the contribution of trust relations that were established among companies, which affect their willingness to conduct ongoing business relationships.

In addition, the study findings provide compelling evidence about the effect of the different proximity measures on the tendency of the companies to maintain intensive business relations with other companies in this unique ecosystem. The study found that social and technological proximity encourages the tendency of the companies to maintain business relationships that probably contribute to knowledge exchange. This is because in this case what is involved is a group of independent companies for whom the main motive for collaboration is the business utility stemming from this collaboration. Thus, in these cases, in addition to personal and social contacts that contributed to collaboration, a common denominator was required, minimal technological proximity, in order to create the pragmatic basis for such technological connections.

An interesting finding was the relationship between geographical proximity and other proximity measures. Due to the tendency of most of the cloud companies to settle in close geographical proximity, no distance differences were created that affect the tendency of a business relationship to exist between the companies. This finding reinforces the hypothesis that geographical proximity in itself is not sufficient to create connections. Other conditions are necessary for the existence of cooperation, particularly proximity based on personal and trust relationships, which is even more important than technological proximity. From this, it can be concluded that firms will choose to cooperate when a basis for action is created on the background of a shared past and personal proximity relations, as well as technological proximity at a certain level. This finding is reinforced also in light of the positive and significant effect of functional proximity. Our findings indicating that companies in whose establishment other companies played a fundamental role, or who maintain a stable relationship with RAD Company, the founder of the cloud, tend to maintain business relationships with other companies in the ecosystem to a greater extent than do other companies.

However, the limitations of our study did not allow us to fully identify the mutual relationships, owing to the undirected network that was created in the ecosystem. Therefore the conclusions that can be reached given this limitation are more general and relate to the extent of the relations that exist within the ecosystem in general and not at the individual level between company i and company j. A refinement of the data requires further research that will allow an examination of the behaviour of the network itself. In addition, an analysis of the dynamics that characterizes these types of networks, in order to increase our knowledge about the development of such ecosystems and the factors that feed and preserve them over time is required. Also, continued research should examine the effects on the level of innovation of firms that belong to the cloud, an element that was not explored in this study. All these could have consequences for public policy that could encourage the emergence of similar systems.

However in general, based on the IVC data set we note that 55% of the companies in the RAD cloud reported they had products in the market and received revenues, most of them even indicated growth in their revenues. This suggests that a large part of the firms in the cloud are productive. In addition, another 15% are at the R&D stage and engage in the development of technological innovation. In fact, only 30% of firms in the cloud are in the early stages of seeking capital or VC funds and are not yet productive.

Boschma *et al*. (2013) stress the importance of "policy intervention at the regional level", because "it is at this level where the main assets to diversify successfully are present" (p. 47). Within the RAD cloud, we have shown that networking, especially informal networking played a crucial role. While the networking and connectivity in the RAD cloud was largely based on acquaintanceship and common background, there are clearly ways that public policy can foster connectivity within regions.

If new industries are to emerge from old, as they must in a dynamic competitive global economy, new capabilities must build on existing old ones. This may require strategic government intervention; for example some of the RAD cloud companies benefited from R&D grants from Israel's Office of Chief Scientist, Ministry of Economy.

A major contributor to the RAD cloud was the existence of a strong venture capital industry able to finance meritorious startups. While RAD provided some funding, most of the funding was external. Israel's VC industry was fostered by a unique government policy that offered matching funds to external VC investors. Within 3 years, 10 more funds were established, with capitalization of over $20 million each, and the VC industry was launched, attracting many foreign-based VC funders who to this day predominate in Israel's VC industry. It is doubtful whether the RAD cloud could have grown so rapidly without strong venture backing.

Many of the RAD cloud companies were established in 1990–1995. This period coincided with a massive immigration of human capital from the former Soviet Union to Israel. This in turn resulted from a fortuitous (for Israel) change in American legislation, which redefined Russian immigrants as economic, rather than political, emigrés, thus being subject to strict immigration quotas. One wonders whether America regrets this policy change, which could have brought enormous human capital to the US. The lesson is clear; today there are countries which established a policy that encourages the migration of skilled workers to help economic growth (i.e. Germany. Canada, Australia).

Moreover, it is hard to overestimate the importance of world-class technological universities. Many of the RAD cloud founders graduated from Israeli research universities. They learned not only state-of-the-art technologies but also acquired a cultural value of launching their own businesses.

The RAD cloud is a practical reality-based innovation. But is there theory underlying it, that can provide policy foundations? We can follow Simmie (2012) that suggests three policy paths based on Denmark's wind power industry as a case study: Displacement (subordinate technologies arise to displace existing dominant technologies); Layering (new technologies are added to those already existing) and conversion (old technologies are changed). All three such effects exist within the RAD cloud.

Finally, an extensive survey of European innovation (the European Regional Innovation Survey, ERIS), revealed the crucial importance of network-building among firms and other actors in a regional innovation system (Koschatzky & Sternberg, 2000). The authors stress the importance of linking networks within regions, with national and international knowledge sources. In a sense, the RAD mother ship facilitated such links, when the global RAD company became the "eyes" of new startups, especially in identifying niche businesses and unmet needs in world markets.

Perhaps the main policy implication of our study relates to the creation of vibrant dynamic cities (for a study of Copenhagen, see Bayliss, 2007). Knowledge-based urban development is rapidly gaining momentum due its potential for inducing economic growth (Florida, 2002; Raspe & Van Oort, 2006; Yigitcanlar, 2010) Creative people are drawn to such cities. And they are created by strong public policy, building physical, communication and educational infrastructure, with cultural events, great public schools, universities and pleasant environments. Tel Aviv is such a city. It is doubtful that the RAD cloud could have happened without the ambience of Greater Tel Aviv and its attractive environment for creative people (Frenkel *et al*., 2013a,b). Ultimately, this was the main message of Jacobs (1993) two decades ago. It remains highly relevant to this day.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007–2013 under grant agreement number SSH-CT-2010-266959.

Notes

1. Some of the companies managers associated with RAD ecosystem could not be traced. Most of them relates to start-ups that ceased to exist in their initial stages of development.

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Appendix

Table A1. Correlation matrix

	SNYRTY	COMRS	YEAR	RADIST	TECHNO	INTENS	BUISN	PERSON	PRC_EMPLY	COG	COG^2	DIS	SIZE	COM_CONC
COMRS	0.304*													
YEAR	−0.041	−0.453**												
RADIST	−0.096	−0.314*	0.035											
TECHNO	−0.224	−0.003	−0.163	0.037										
INTENS	0.311*	0.308*	−0.262*	−0.363**	0.168									
BUISN	0.289*	0.876**	−0.357**	−0.325*	0.079	0.317*								
PERSON	0.298*	0.167	0.073	−0.105	0.023	0.050	0.167							
PRC_EMPLY	−0.144	−0.065	0.348**	0.060	−0.215	0.023	−0.037	−0.037						
COG	−0.068	0.061	−0.273*	0.010	0.546**	0.275*	0.220	0.120	−0.156					
COG^2	0.010	0.335*	−0.322*	−0.220	0.147	0.295*	0.246	0.034	−0.042	0.158				
DIS	−0.011	−0.275*	0.140	0.915**	−0.078	−0.393**	−0.289*	−0.094	0.096	−0.140	−0.295*			
SIZE	0.009	0.164	−0.427**	−0.149	0.095	0.240	0.218	−0.056	−0.208	0.297*	0.112	−0.151		
COM_CONC	0.027	0.453**	−0.086	−0.042	0.021	0.126	0.397**	0.127	0.211	−0.044	0.040	0.021	0.073	
RD_CONC	0.536**	0.379**	−0.202	−0.271*	0.020	0.788**	0.332*	0.122	0.133	0.131	0.155	−0.261	0.133	0.193

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Table A2. Most common code words

Word code	% of firms which mentioned a code word
Network	14
Security	11
Accelerator	11
Management	11
GPS	11
Wireless	11
GPRS	11
Cell	9
Application	9
DOS	9
Server	7
Mobile	7
Access	7
Medical	7
LAN	7
Ethernet	5
External	5
Switch	5
Base	5
Device	5
Vascular	5
Bonding	5
Class	5
Backhaul	5
Remote	5
Gateway	5
Voice	5
Web	5
Protection	5
Control	5
Gateway	5
Video	5
Cloud	5