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The Birth of a New Industry: Entry by Start-ups and the Drivers of Firm Growth. The Case of Encryption Software

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The Birth of a New Industry: Entry by Start-ups and the Drivers of Firm Growth. The Case of Encryption Software

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Abstract

The paper analyses the birth of the Encryption Software Industry (ESI), a new niche in the software industry. Using a Chandlerian perspective, this work reports the main facts about firm entry and growth, with a particular focus on start-up strategies and actions.

Since scale economies do not play a major role in ESI, the paper investigates the different sources of firm competitive advantages.

This work shows that innovation and product differentiation, along with investments in co-specialised assets, are variables strongly correlated to young firm probability to survive and grow. In so doing, we have collected highly detailed information on product introduction, US patents granted, worldwide alliances and biographical data of firm founders.

Keywords: Entry, entrepreneurship, innovation, software
JEL: M13, L86, O32

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1 Introduction[2]

How do new industries emerge? What are the main drivers of firm entry and growth? Where do the actual market leaders come from?

These "Big-Bang" questions are usually unanswered in the literature, mainly because it is daring to collect reliable data of earlier industry stages. Even if Alfred Chandler's works have proved that these issues are fundamental, far too few are the studies that investigate the birth of industries. Moreover, the richness of information that can be collected in the first stages of an industry goes well beyond conventional wisdom of management and industrial studies.

Opening the black-box of the initial industry history is the main goal of this paper, which describes with massive empirical evidence all the main features and actors of a new market from its very beginnings. This will allow us to draw original insights on competition forces and strategic directions of a specific industry in which innovation, entrepreneurship and firm growth strategies are strictly interrelated. Moreover, what distinguishes this study from a classical Chandlerian industry study is the focus on a highly skill-based industry. In this sense, exploitation of scale economies does not play a major role and firms have to find different sources of competitive advantages.

Particularly, this paper studies the birth and development of the Encryption Software Industry (ESI), a market niche in the software industry. In ESI new start-ups were able to dominate the market, exploiting first business opportunities and previous technological breakthroughs of large incumbents. As a consequence, we will see that the history of this industry can mainly be described by small start-ups dynamics.

In so doing, we follow a common trend in the standard literature on small businesses (Churchill and Lewis, 1983; Kazanjian, 1988; Mitra and Pingali, 1999) and separate our analysis in two main sections. First we study the entry process and then we follow the leading start-ups along their path of growth. In fact, several contributions on this topic (Olson, 1987; Hanks and Chandler, 1994; Zacharakis et al. 1999) have long stressed that the capabilities that allow firms to survive in the first place are completely different from those yielding firm growth. This makes essential the paper division in two parts in order to provide the most appropriate and valuable comprehension on what drives firm entry and what drives firm growth.

After a brief data description, the paper illustrates the patterns of firm entry with a deep analysis of the industry environment, the products and the entrepreneurs (Section 3). Section 4 highlights the drivers of firm post-entry growth, according to the rate of product differentiation, investments in co-specialised assets and geographic expansion. Section 5 concludes and summarises the main findings.

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2. Description of data sources

In this section, we provide an ex-ante, detailed description of the data we used, since we triangulate in the paper a wide range of data from different sources.

- Firm entry was assigned when a new ESI product was released on the market. Products introduction data were taken from Infotrac's General Business File ASAP database, downloading all the press articles that report a "Product announcement", a "New software release" and a "Software Evaluation" in the security software sector. From this source we could extract the name of the company, the exact date of product introduction and the precise SIC code of the product.
- Information about alliances was drawn from Infotrac's Insite Promt database that, from a large set of trade journals, magazines and other specialized press, reports several categories of firm agreements like strategic alliances, licences, and product contracts. For the period 1993-1999 we downloaded all the events classified under the SIC Code 73726 (Encryption Software Sector). With these data, we created a value-added database (we refer to it as the EVENT database) reclassifying data and introducing some new information like the passive or active firm role (acquirer or acquired, licensee or licenser, ...) and the presence of a technological content in the agreement. We re-grouped the events in five broad categories: i) technological alliances; ii) distribution and marketing alliances; iii) technological licences; iv) product order contracts and v) mergers and acquisitions.
- Patent data are downloaded from the US Patent Office web site. We considered all the patents granted in the US class 380 (Cryptography) that include "equipment and processes which a) conceal or obscure intelligible information by transforming such information so as to make the information intelligible to a casual or unauthorized recipient, or b) extract intelligible information from such a concealed representation, including breaking of unknown codes and messages"[3]. For each patent we extracted all the information reported in the on-line front page of the patent (issue date, assignee, citations and inventors).
- Firm's financial data were taken from Hoover's, which collects data for the Security Software & Services industry.
- Data on the structure of firm groups (including subsidiaries) were taken from Business and Company Resource Center database, Gale Group's Infotrac.
- Information on firm profiles and histories, on biographical data of firms founders and managers were taken from Hoover's, Mergent-on-Line and Infotrac's ASAP[4] database.

We also conduct five interviews with managers of leading start-ups, precisely at Checkpoint, Baltimore, Aladdin and Network Associates.

3 Entry process in ESI

This section will show how the birth of ESI is mainly explained by start-up dynamics. Therefore, describing entry in ESI, we follow the approach of Gartner (Gartner, 1985), who proposed a useful framework to study new venture creation. The author highlighted three main fields of analysis: the environment, the new product (or process), and the entrepreneurs. At this point of analysis, firm organisational

[3] Us Patent Office classification manual, www.uspto.gov.
[4] For more details see the several notes in the text that cite the journal articles.

characteristics could safely remain in the background; since they could often be seen as a combination of the first three features (see Baron and Hannan, 2002). Consequently, the opening paragraph focuses on the environment.

3.1 The environment

Several researchers (Audretsch, 1991; Klepper, 1996; Shane, 2001) have confirmed the importance of technological regimes in influencing the dynamics of entry. Especially in the field of entrepreneurship studies, we agree with Bhide (p. 31) that "start-ups can more easily turn a profit in some fields then in others" (Bhide, 2000). First of all, the software industry is generally characterised by low entry barriers. Moreover, the industry underwent a process of market segmentation and firm specialisation that spurred the birth of several market niches and new firms (Torrisi, 1998). Given these features, the software industry appeared as a turbulent industry with a high rate of entry, exit, product innovation and imitation, where the low entry and exit barriers spurred firm birth and death more dynamically compared to other industries. In this sense, the software industry could represent the ideal environment to study and understand the birth of new market niches.

The early stages of ESI date back to the mid-1970s and the beginning of the 1980s, when the US Government financed military projects linked strictly to the security of data transmission. Large ICT firms awarded these types of contracts and worked actively on software security architectures. At this stage, university departments, especially from Stanford and MIT, and government agencies also played a major role. Some firms, such as Philips, NEC and Pioneer, were also involved in the design of the bulk of first cable TV sets, which included the encryption and the decryption of cable signals through TV decoders. This is also evident from data in Table 3.1 where the most cited[5] organisations that were granted a US patent in the 380 USPTO class in the period 1977-1992 were listed. We will discuss below the importance of patents in this USPTO class.

[Table 3.1 about here.]

Lately, after more than 15 years, the huge development of Personal Computer market and Internet, especially Internet financial transactions, introduced new consumers and market needs that have spurred the proliferation of innovative products in the industry[6]. Data provided by the International Data Corporation[7] evaluated the world market of ESI 2.17 billion dollars in 1997 and 3.2 billion dollars in 1998, with an estimate of 4.4 billion dollars for the 1999.

Graph 3.1 shows the Hazard and Survivor functions calculated on the sample firms that entered the ESI market from 1989[8]. The Hazard rate represents the percentage of exit among firms at risk of exit, while the Survivor rate is the percentage of survived firms (see Kiefer, 1988). The negative duration dependence of ESI data is a common finding in young industries with a massive flow of entry.

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[5] Backward citations from 1993-1999 sample patents.

[6] "Rising E-commerce will drive Growth for Security Software Companies", Business Week, 7/4/2000, p. 6.

[7] "Worldwide Internet Security Software Market to close in on 4.4 billion dollars in 1999", EDP Weekly's IT Monitor, 40(32), 1999, p. 18.

[8] We define an exit when a firm does not release any new product or new version of existing product after 2 years from the introduction of last product.

[Figure 3.1 about here.]

Graph 3.1 does not show any sound first mover advantage effect or any shakeout process in ESI . This is a quite sound proof that economies of scale in this industry do not play any significant role, given the low fixed costs needed to start an ESI venture. For example, the initial amount invested to set up CheckPoint Software, the fourth largest firm in ESI at 1998, was 300,000$[9].

The rising civilian demand increased the spectrum and the complexity of different products and services offered. Due to these changing conditions, young small ventures were better suited to exploit these opportunities. Table 3.2 shows the world market leaders in ESI at 1998, ten years after the first product was introduced on the market. It is worth noticing that all these firms were start-ups in ESI. As in other industries (Henderson, 1993), ESI represents a classical example where start-ups are the organization forms that better adapt to young turbulent environments. As previously noted, this evidence leads us to focus mainly on the role of start-ups in ESI, leaving the study of incumbent strategies to further works.

[Table 3.2 about here.]

The industry offers now a wide selection of products going from the basic products of encryption, such as Firewall and Anti-virus programs to advanced security services like Public Key Infrastructures, Security Certification and Virtual Private Network. Table 3.3 shows the most important product niches of ESI, according to SIC code division. Generally, these products are software packages strengthening boundaries between networks and protecting computers against viruses and unauthorised users. They also integrate at the same time network access control, authentication, security, and policy management. The product functions aim not only to assure the secrecy and protection of data and data transmission against possible privacy attacks from outside, but also to provide verification and testing of possible intrusions and sabotages from inside.

[Table 3.3 about here.]

The design of the general security protection of an information system is now a complex project and it incorporates problem solutions from different technological fields such as mathematics, software, hardware and network design. According to the CEO of a provider of security software solutions: “Security policies are hard to design, hard to update, hard to enforce, and hard to make practical"[10].

Besides the low initial sunk costs, ESI was also characterised by initial low entry barriers from the technological point of view; the breakthrough innovations were protected by patents granted about twenty years before the rise of the industry. New firms could easily and with no costs base their product architectures upon those patents without paying any royalties. In Table 3.4 we include the number of patents cited by all patents granted in the period 1993-1999 and their number of citations; it is not difficult to observe the importance of the patents granted from 1976 to 1984

9 “Israel's safety net", Electronic Business, 1999, 25(5), p. 72

10 J. Wilbanks, CEO of SecureWork, in “Managing Managed Security", Information Security, Jan. 2001, p.12

compared to the others (see C/P ratio)[11]. Furthermore, the two most cited patents were granted by to public institutions like MIT and the Stanford University.

[Table 3.4 about here.]

The survival rate of firms that entered the market was low, especially in the first periods; the survival post-entry average rate is 19 % after a year and 10% setting the 2000 as the final year. This evidence is striking compared for example to data in manufacturing industries (Dunne et al., 1988), where the survival rate equals to 50.4% after 5 years and 13% after 15 years.

The high exit rate could be explained by two important factors: first by low exit barriers and secondly by the uncertainty about the quality of the product. In fact, only after a proved resistance against several attacks, the product could be considered effective. This implies that an initial, even casual, bad performance of a new product could be fatal to the producer, even if the product was substantially a good one (Smith, 1999).

Some concluding remarks: the process that spurred the birth of the ESI was characterised by demand pull conditions, but the particular technological core of the products and the presence of high skilled customers generated selective selection phenomena, especially in the earlier years, where only few new ventures were able to survive. To have a better idea of the factors that lie behind the survival capability of firms, we need now to describe the main features of ESI products.

3.2 The products: algorithms and software packages

Chrisman et al. (1998) pointed the ability of firm survival the effective measure of fitness in the context of entry by new firm formation. Along this view, the common, and perhaps the only, aim of a new venture in the first stages of its life is working as a self-sustaining economic activity (Kazanjian, 1988; Hanks and Chandler, 1994; Wagner, 1994). Given the high rate of sudden firm mortality after entry in ESI, we consider essential studying the preliminary selection factors among firms. In so doing, a “meticulous” comprehension of what is an ESI product is required.

Among all the different technologies required in a standard ESI product, the key feature is the crypto-algorithm that specifies the mathematical transformations that are performed on data. A crypto algorithm is a procedure that takes the plain text data and transforms it into cipher text. The process could be reversed with a secret key. The right balance between communication speed requirements and security protection is what assures the quality of the product. In fact, the time consumed by encrypting and decrypting processes depends on the length of mathematical algorithm and on the power of computing machines (Smith, 1999).

The crypto algorithm is the principal object of a firm's patent. This is mainly due to the recent trend of US Patent Office to loosening restrictions that had been placed upon patent applications directed to software inventions. Contrary to the previous discipline, mathematical algorithms could now be examined with respect to their novelty, non-obviousness and utility (Gosnell, 1999; Bessen and Hunt, 2003). Mathematical and software engineering capabilities represent indeed the core competences needed in the production of ESI products. The USPTO 380 class, “Cryptography”, is the strategic technological field for ESI. It could be the case that

[11] It is worth noting that on average the patents cited in the period 1976-1992 are 19.03% of the total patents granted in those years in the 380 class.

some firms were granted patents related to these technological competencies in classes different from the 380. Nevertheless, the class 380 accounts for the bulk of inventions in cryptography; it is worth noting that all start-ups that dominate the sector (see Table 3.2) have not been granted any patents outside this class by 2000.
At the very beginning, small firms entered specialised in a well-defined product area like, for example, Checkpoint and Axent in Firewall; Network Associates, Symantec and Trendmicro in Anti-virus software; Certicom, Entrust and Cyberguard in Virtual Private Network architecture; Baltimore in digital signature protocols. From interviews with start-up executives we conducted, it emerged clearly the importance for start-ups to build up reputation on a specific product. A manager of a firm leader in ESI affirmed: “At the beginning, the great idea was to transform a complex technological invention in a user friendly product off-the-shelf. It should be easy to install and use Our firm based its success creating the Firewall as now we know it”. The origin of ESI was basically a story of good innovations: a firm survived if it introduced a sound technological product. Consequently, the major causes of a firm's survival (or mortality) was the quality of the product, that is a combination of mathematical algorithm, case sensitive intrusions knowledge and software adaptability. For this reason, the success means simply the ability to propose a product with a sound mathematical core that adapts to different software platforms and preserves the speed of data transmission. In Frame A we include three examples of successful start-ups product introduction.

Frame A: Start-ups and innovative products in ESI

? Checkpoint created an innovative process to built firewalls, security products that could go directly off the shelf to a customer and that enforce the boundaries between different networks and protect firms against un-authorised users. Check Point's programmers introduced a new language, Inspect, specifically for directing the rapid inspection of communication packets and a compiler to translate policy rules written in Inspect into assembly language. The program opens data packets, checks the content and quickly inspects each data packet. The innovation is that the program sends along the data in parcels after they are checked, rather than waiting to reassemble them before the entire transmission. This methodology increased dramatically the speed of data transmission, with the same level of security[12].

? Geoffrey Rhoads, a physicist and founder of Digimarc, created the core Digimarc technology when he was working on a camera for cleaning up digital spaces images photographed through ground-based telescopes. Rhoads reversed the imaging filtering process and added a micro ownership mark to the photos. The technology could imperceptibly include digital data in visual content (like movies and photos) and valuable documents such as financial data-sheets and passports. In addition, Rhoads introduced a method that allows the identification of a copy of an original

[12] “Safe at 100 megabits per second. Check Point Software Technologies creates Internet firewall which supports high speed transactions", Forbes, Dec 30, 1996, p. 138. See also US Patent 5,835,726, filed in June 17th 1996, by G.Shwed et al., “System for securing the flow of and selectively modifying packets in a computer network".

signal from the original signal. This can be achieved by modulating the source code with a small "noise" code that could be cancelled in case of a copied product[13].

? Certicom's Elliptic Curve Cryptography is a technology especially useful in what is known as "small-footprint environments" such as smart cards or wireless communications devices, where space is the scarcest resource. If the standard string of computer bits necessary to encode or decode an encrypted message needs about 1,024 bits, Certicom's system accomplishes in 160. The difference is rooted in mathematics[14]. In fact while the standard cryptographic systems are based on integer calculus, the elliptic curve cryptosystem uses equations that can be calculated more easily and faster[15] .

These three examples help understand two important points: first, the importance of the quality of innovation and of the technical capabilities of the entrepreneur. Second, the important role of the patent protection in this industry, since all these three mathematical algorithms are strongly protected by patents. In fact, innovation and imitation have always represented essential strategic variables in the high-tech industries and intellectual propriety rights play a key part in protecting firm competitive advantages (Arora et al., 2001). Nonetheless, patents are usually not seen as good instruments (Cohen et al., 2000) to protect software innovations from imitation, and firms had often utilised other privacy techniques such as tacitness and secrecy. However, we would like to stress again that ESI represents a special case where patents do protect against possible imitation, thanks to the importance of mathematical algorithms.

In fact, the core of security products is the mathematical procedure that lies behind the encryption of data. For example, Entrust Technologies, one of the leading innovators in the field, is responsible for over 90 patents and pending patent applications[16].

Given the importance of patents in protecting algorithms, it could be useful to provide more specific information on what is the content of a typical patent in 380 USPTO class. Ronald Rivest, a former researcher at MIT, invented one of the most famous and widespread crypto algorithms at the RSA Data Security. This invention is protected by the USPTO patent 5,724,428, entitled "Block Encryption Algorithm with Data-dependent Rotations". This patent document includes: four flow charts reporting step-by-step the encryption-decryption routines and the detailed description of all the mathematical procedures that perform the encryption. Moreover, there are also some final considerations about how the length, in terms of bits, of the secret key (the usual password) affects the level of security and the speed of the cipher process.

Thus, patents protect mainly two separated things: 1) the structure of the sequences of steps and routines of the encryption process 2) the mathematical procedures that lie behind them. Software code is not mentioned in the patent document and so it is

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13 "Trolling the net. Digimarc's watermarking technology", *Electronic Business*, Sept. 1998, 24(9), p. 60. US Patent 5,710,834, filed in May 8th 1995, by G.Rhoads, "Method and apparatus responsive to a code signal conveyed through a graphic image".

14 A classical form of an elliptic curve is $y^2 + xy = x^3 + ax^2 + b$.

15 "Cheaper encryption tool gaining momentum. Certicom Corp.'s elliptic curve cryptosystem", *American Banker*, Apr. 2, 1997, p. 12. US Patent number 6,141,420, filed January 29th 1997, by S.Vanstone et al., "Elliptic curve encryption system".

16 "Network Magazine Names Entrust/PKI(TM) Software 2001 Product of the Year", *Market News Publishing*, June 8, 2001, p. 10.

not protected. The mathematical algorithm represents therefore a form of general-purpose technology (Bresnahan and Trajtenberg, 1995), which could be run and used on different software packages and applications (i.e. e-mail clients, compressing programs and Internet browser).

Mostly thanks to this effective patent protection, ESI market could be classified into two sub-markets: i) a market for the standard products of ESI (Firewall, Anti-virus . . .); and ii) a market for technology, where firms could acquire the right to use the proprietary mathematical algorithm patented. Figure 3.2 shows a graphical representation of the two sub-markets. As we can see, the mathematical algorithm could be used in several in-house research projects or for the production of third-party products.

[Figure 3.2 about here.]

In terms of market size, Hoovers data show that in 2000 for the top 15 start-ups in ESI (see Table 3.2) 56.6% of revenues comes from sales of product software, 28,3% from services and 14,9% from licensing the technological algorithm.

From our EVENT database, between 1993 and 1999, we collected 119 “Technological License Agreements” and 143 “Product Order Contracts”. Technological License Agreements include only contracts where the object of transaction is the mathematical algorithm; while Product Order Contracts represent the classical supply of off-the-shelf software products among firms (we excluded the business to customer contracts)[17]. These two events could be considered good proxies for the two types of markets. The most important buyers and sellers, for number of technological licenses and product contracts awarded, are ranked in Table 3.5. We would like to stress that Product Order Contracts and Technological Licenses Agreements are usually not the two faces of the same contract. On average, in the 92% of cases, for each firm, the product order contract is not included in the technology licensing agreement.

[Table 3.5 about here.]

Concerning the licenses, the most important seller of technology, among 53 different sellers, is RSA Data Security with 23 licensing contracts signed (19.3 % of total licenses concluded). Among 105 different firms, the most important buyer of the technology is IBM (8.3% of total contracts). These data show that leading start-ups are dominating both the market for products and the market for algorithms.

In most cases, a technology buyer utilizes the crypto algorithm in two ways: or to develop new proprietary in-house innovation from the technology acquired or to directly include the algorithm in an already existing product. In Frame B, we present two standard examples of Technological Licenses Agreements to explain the nature of this agreement and to highlight the specificity of this “market for algorithms" in ESI.

[17] This distinction is fundamental to avoid confusion; in fact a software product is often sold in term of number of licences.

Frame B: Technology licensing contracts and their applications

? In-house development: in 1995 VLSI Technology licensed RSA Data Security's RC4 Symmetric Stream Cipher encryption algorithm and embedded it on its own processor and memory cores. VLSI aimed to combine its processor with RSA technology in order to sell an innovative product to AT&T Bell Laboratories for the production of a new data encryption system[18].

? Third-part products: in 1997 VeriFone obtained the rights to use the "Elliptic Curve Algorithms" for smart cards by licensing the patent from Certicom. VeriFone will use the technology for its Personal ATM and VeriSmart System devices for downloading money into smart cards[19].

In conclusion, two factors were common among the most successful firms: the first is that they entered by specialising in a particular niche. Secondly, successful start-ups entered with a distinguished innovative product. Interestingly, the empirical evidence seems to confirm a strong interdependency between the technological and the product sub-markets. The Pearson correlation coefficient between product orders and technological licenses awarded by firm and by year equals 0.68, with a significance level of 5%. This high correlation supports the thesis that, especially in the first years of industry evolution, innovation played a major role. A good mathematical algorithm that gives firm success in the market for technologies seems to be a necessary condition for gaining a competitive advantage in the market for products. Moreover, the fact that the same large ICT firms are the major buyers in the two sub-markets confirms the importance of the role played both by high skilled consumers and by the quality of product innovation. The interaction between market focus and product innovation has been already spotted in the literature (Vinnell and Hamilton, 1999) as one of the key factors of survival in the early stages of a new business. Firm entry with an innovative and sound idea in a particular product area could create a strong reputation effect and sustain a competitive advantage in the preliminary phases of competition (Kazanjian and Rao, 1999). This means that specialized entry it is not a sufficient condition to guarantee firm survival, especially in high-tech sectors. It is the quality of product technologies combined with the business market focus that increase start-up reputation and profitability. The empirical evidence seems to confirm this point. Among the 200 out-gone firms in ESI from 1989 to 2000 only 3.5 % were granted a patent at USPTO. Results do not change introducing the age variable: comparing similar entry cohorts, among the 87 exit firms that survived at least 4 years, only 5.7% were grated a patent[20]. On the other side, 73% of survived firms by 2000 with more than 4 years of presence on the market were at least assignees of a patent.

3.3 The entrepreneurs

In the first periods of a new firm life, the firm and its entrepreneur were often indistinguishable (Meyer and Roberts, 1986; Terpstra and Olson, 1993). According to Gartner (Gartner, 1985), the points of strength and weakness of a new venture are at the beginning those of its founder. It is consequently quite obvious that the probability

[18] "VLSI to embed RSA encryption under license", *Electronic News*, Jan. 16, 1995, 4(1), p. 60.
[19] "VeriFone to license new encryption engine", *PC Week*, Jun. 30, 14(28), 1997, p. 53.
[20] Note that this industry at 2000 could count only on 11 years of life.

of firm success depends strongly on founder's competencies and abilities (Holmes and Schmitz, 1990). The high heterogeneity among start-ups is mainly due to different entrepreneur approaches in exploiting same business opportunities. Very intriguingly Baron and Hannan (Baron and Hannan, 2000) found from a 200 start-up survey in Silicon Valley that “founders embraced very different mental models of the ideal organizational form” (p. 9).
Cast under this light, firm founder characteristics are critical to assess what capabilities they brought inside their company, what incentives they had, what business idea they fitted in the organization and how they shaped the firm in the initial stages. Blanchflower and Oswald (1998) recognize in the presence of a valuable type of information or capability the key element in the nature of an entrepreneur. This means owning first information regarding the creation and evaluation of a business opportunity, and then information linked with the capability to exploit the business opportunity (Shane and Venkataraman, 2000). In other words, in order to exploit an opportunity, an entrepreneur should possess information about specific aspects of production and about user needs (von Hippel, 1988). While the latter refers to the ability to tailor business ideas towards possible specific customers (find or build a market), the former is properly linked to the typology of the entrepreneur. At this regard, there are three main entrepreneurial typologies: the innovator, who creates new products; the arbitrageur, who exploits market inefficiencies and the coordinator, who introduces an alternative use of resources (Bhide, 2000; Shane and Venkataraman, 2000).

[Table 3.6 about here.]

In Table 3.6 the founder's origins of the 15 largest start-ups were listed. The more evident regularity is that more of 50% of top start-up founders were employees of a large ICT firms (53%). The remaining 35% were former government or university researchers and last, 12% were former founders or employees of other software start-ups. Successful firm founders have gained some advantages while working for large ICT firms or government-academic institutions. In fact, these two organisations represented the producers of the basic technology of the sector (see Table 3.1) and the main users of these products (see Table 3.2).
As a matter of fact, we could suppose that these entrepreneurs could have been subject to some learning processes about the basic technologies (how to innovate) and user's needs (how to exploit). According to this view, Klepper and Sleeper (Klepper and Sleeper, 2000) introduced the term of “heredity" that spin-offs received from the parent firm especially when there is some knowledge embedded in human capital. For example in the automobile industry, Klepper (Klepper, 2001) highlights how spin-offs from incumbents firms have a high probability of surviving and growth.
It is interesting that among the 18 entrepreneurs coming from ICT incumbents and universities, 72% are assigned at least one patent at USPTO (Table 3.6). In this sense, their fundamental entrepreneurial competence was the ability to exploit mathematical skills linked to the ability of software compiling and design. Moreover, it is worth noting that among these founders-inventors, 61% were also assigned a patent before starting their company, when employed in a R&D laboratory of a large ICT firm or university.
Firm founders in ESI are typically innovators, because it is an innovation that has pushed them to set up a new venture.
In Frame C we collect some useful cases to support this hypothesis.

Frame C: Firm founder origins

? B. O'Higgins, the founder of Entrust, has overall responsibility for the technology vision and direction for the company. He was previously with Nortel where he established the Secure Networks group in 1993 and with BNR-Bell Northern Research, which he joined in 1979. At BNR, he was involved with a variety of technology development programs, including public key security systems, technology for new telephone products, in-building wireless communications systems and high performance computing architectures for call processing applications[21].

? A.Vanstone, the founder of Certicom, was a professor of Mathematics, and he has published more than 150 research papers and several books on topics such as cryptography, coding theory, finite geometry, and combinatorial designs[22].

? Prior to launching Trend Micro, S. Chang worked as an engineer in the R&D laboratories of Hewlett-Packard. He received his B.S. in Applied Mathematics and his M.S. in Computer Science. He founded Trend Micro in 1988 with the mission of developing anti-virus software for personal computers, with a company's focus to address total network security[23].

To conclude this section, the link between innovation and new firm formation was the major issue presented, where innovation was the key to open new market niches, avoiding potential entry barriers. Then, entrepreneur characteristics were fundamental to understand start-up performance especially during its first years, because ESI was a classical case study where inventors become entrepreneurs. We then stressed the importance of patents as a tool to defend firm knowledge assets, an aspect quite remarkable in the software industry. In ESI, patents helped to build a market for technology that was essential in shaping competitive outcomes. This is also highlighted by the presence of two separated markets for software products and mathematical algorithms.

4 The drivers of start-up growth

In the previous sections we have highlighted the main factors beyond firm entry, while here we draw attention on the firm growth process.
Firms survived from first competitive shocks faced new challenges. Empirical studies (Audretsch, 1991; Geroski, 1995; Klepper, 1996) have found how size and age positively affect the capacity of surviving of new entrants. In the case of ESI, Table 3.2 shows that top 15 start-ups have different entry times (see Table 3.2) and Graph 3.1 that first mover advantage effects are insignificant. Therefore, firm age does not seem a powerful discerning variable.

[21] "Network Magazine Names Entrust/PKI(TM) Software 2001 Product of the Year", *Market News Publishing*, Jun. 8, 2001, p. 34.
[22] "Certicom's Founder Receives Security Award for Mathematics from RSA", *Market News Publishing*, June 11, 2001, p. 100 .
[23] "Behind-the-scenes attack on the virus plague. Steve Chang, Founder of Trend Micro", The Financial Times, Jun. 7, 2000, p. 8.

On the other hand, clearly size, growth and survival are strictly correlated. The research challenge of this section relies in disentangling the drivers of start-up growth in an industry where scale economies and sunk costs are negligible.
The more the time a firm is able to remain on the market, the more is the number of requirements, information and feedbacks that it should elaborate. In fact, some scholars (Pavitt, 1988; Dodge et al., 1994) have noted that young firm evolution is linked with the firm capacity to deal with an increasing level of complexity. Especially in ESI, from an initial phase mainly based on technological advantages, the competition moved towards a multifaceted dimension. Most of the ESI start-ups experienced that being technologically at the frontier was not a lasting sufficient condition to growth. Following the entrepreneurship literature (see for example Vinnell and Hamilton, 1999), we highlight below two main issues that are conventional in explaining young firm growth. These factors are i) product differentiation and ii) international expansion linked with investments in co-specialised assets. In analysing them, we remind that the interactions between these factors and firm size are correlated and not linear (for example, the more a firm offers a broad range of products, the more it accesses to new international markets, the larger will be its size).

4.1 Product differentiation

Product differentiation is one of the main channels that strengthen firm competitive advantages. Firms selling a broad range of products are in a better position to gain high margins, to increase their costumer base, to process and screen more information about market trends. Two main orders of motivations sustain the firm broadening of product variety: demand side factors and firm strategic factors (Lancaster, 1990).
Tailoring products on customer preferences with product differentiation favours the reduction of sales uncertainty and the achievement of higher market shares. Along this view, empirical works have confirmed a positive relationship between market share and product line breadth (Kekre and Srinivasan, 1990). For example, in a study on the computer workstation industry, Sorenson (Soreson, 2000) has recently found that product variety strongly affects the probability of a firm's survival.
The second type of factors refers to the strategic utilization of product differentiation against potential competitors. Firms could offer a broad product variety as a strategic barrier to pre-empt new specialized markets entrants, especially when scale economies are modest. Lacanster (Lancaster, 1990) studied product variety as a tool to saturate the product space in order to deter entry. This is an essential point to understand how product differentiation could affect firm performances in software industry. We will see that when scale economies do not play a major role as in ESI, the range of product portfolio becomes one of the most critical variables to obtain and defend a competitive advantage.
Looking at product data on a time scale dimension, Table 4.1 shows the number of different versions of products in each niche in two sub-periods. There is evidence of an increasing product proliferation, linked with the rise of the software packages tailored to network design and security.

[Table 4.1 about here.]

Graph 4.1 shows that ESI evolution is characterised by two trends: as the ratio between products and firms increases (less firms, more products) the average firm diversification increases, and otherwise. It seems that waves of specialized entrants, that increase the level of average firm product specialisation, are followed by periods of market consolidation where specialised firms leave the market, and companies with a broader product variety survive.

[Graph 4.1about here.]

Moreover, it is worth noting that the average Herfindahl index calculated on the product portfolio of the survived firms at 2000 equals to 0.741, while the Herfidahl index for out-gone firms is 0.924 (the two values are statistical different, T-test = 8.793). Introducing firm age, the Herfindahl index for the 87 exit firms that survived at least 4 years is equal to 0.867, while for the survived firms by 2000 with more than 4 years of life is 0.694 (T-Test = 13.715).
The average Herfindahl is computed across different product niches according to Table 3.3. Using the total sample, Pearson correlation coefficient between firm duration on the market and firm level of product differentiation (Herdindahl index) equals -0.71, with a significance level of 5%.
Herfindahl index for the top 15 start-ups (see Tab. 3.2) equals to 0.265 for the period 1989-1995 and 0.174 for the period 1996-2000, highlighting an increasing product differentiation of the market leaders. Data seem to confirm that out-gone firms remained product specialised, while firms that survived adopted product differentiation.
If in ESI competing with a broad product selection is considerably correlated with firm survival capabilities, it will be extremely interesting to understand how a firm, born specialised in a particular niche, could have succeeded in expanding its product range. We would like to stress that every firm entered in ESI was specialised in a particular product niche and there is not a case of a firm that entered with a diversify product portfolio. In this context, alliances and mergers and acquisitions (M&As) are important sources of knowledge and resources, especially for young small firms (see Stuart et al., 1999; Baum et al., 2000). We analyse these two aspects in the next paragraphs.

Technological alliances
The in-house development of new products is based on the exploitation of economies of scope from the firm knowledge resources (Teece, 1986). As a matter of fact, young firms often do not own all the technical competencies needed to develop new products. Recently firms have exploited technological alliances as useful tools to quickly learn new technological competencies and exploiting research synergies. Empirical works on technological alliances reached the conclusions that collaborative ventures are useful to determine the product innovativeness especially for small firms (Kotabe and Swan, 1995). Stuart et al. (Stuart et al., 1999) found that alliances generate positive effects on young companies beyond other firm characteristics, especially with large incumbent partners. Sakakibara (Sakakibara, 1997) showed that alliances are more productive if partners have complementary technological skills. Empirical works have already established that the mechanisms sustaining firm growth in networks are highly correlated with the internal growth ones (Riccaboni and Pammolli, 2002). The importance of technological alliances should be correlated with the high technological core of ESI product, as discussed in great length in previous sections. In this sense they represent a valuable proxy of firm R&D strategies in the context of product development (see for example Anand and

Khanna, 2000). From the EVENT database, during the period 1993-1999 we collect 256 collaborative ventures in ESI with the aim of conducting R&D projects. The number of different firms involved is 273[24] . In Table 4.2 the firms are ranked according to their number of R&D ventures.

[Table 4.2 about here.]

Table 4.2 shows that the more active firms are the leading start-ups and large ICT firms. This evidence highlights how the fastest growing start-ups used intensively technological alliances during the sample period.
It is worth noticing that only in 43 out of 256 technological alliances partners have the same core niche specialization. Moreover, taking the sample of 15 top start-ups, in 81% of cases an alliance with a technological complementary partner was antecedent to the firm product introduction in that specific new niche. This evidence is confirmed by the Graph 4.2, a network graph on technological alliances among the firms with the highest number of alliances, grouping them according to their initial niche specialisation.

[Figure 4.2 about here.]

Graph 4.2 shows that the 15 top firms in ESI that enter specialised in a particular niche set up technological linkages with small firm specialised in other niches of ESI and with large ICT firms. This seems to confirm that technological complementarities are important factors at work. The high propensity to conclude alliances among technologically complementary start-ups supports the hypothesis that technological alliances are means to quickly absorb non-core firm competencies, expanding firm product variety. And this is beyond the classical alliance benefits as a type of endorsement (see Stuart et al., 1999). Interviews with managers of some start-ups confirmed that research consortia and technological co-operations were indispensable to firm growth and product differentiation. For example, Checkpoint found in 1997 OPSEC a research consortium with the aim of providing users with an integrated Internet security solution. OPSEC is formed now by more than 350 partners, including firms like IBM, Microsoft, Cisco and Siemens[25].
However, being an important actor in a technological network should be connected with the firm ability to be a strong potential technological partner. Firms that have the high participation intensity in technology networks have also a sound technological base. Some statistics supports these conjectures: in the EVENT database, among all the firms that set up at least one technological alliance, only 27% owns a patent in the 380 USPTO class. But this 27% of firms accounts for more than 54% of technological alliances. External learning is also a function of the in-house effort in R&D (see for example Cohen and Levinthal, 1989).

Merger and acquisitions
During the period 1993-1999, 82 acquisitions have been completed in ESI. In EVENT database we classified the firms involved for their active (buyer) or passive (acquired)

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[24] Note that the partners of an alliance could be more than two.

[25] See www.opsec.com.

role. The acquirer firms are 52 in our sample[26]. The firms with the highest number of acquisitions are Network Associates (5 acquisitions), Axent Technology (4) and RSA Data Security (4). In Frame D we briefly analyse the acquisition strategy of these three firms.

Frame D: Mergers and acquisitions in ESI

? In the 1996 Network Associates, which was specialised in the network access design, acquired McAfee, an anti-virus and utility software firms. A year later, it acquired Pretty Good Privacy, one of the leading technological firms in the data protection area and in 1998 Trusted Information Systems, a Firewall maker.

? RSA Data Security, a data protection specialist, merged in 1996 with Security Dynamics, a firm operating in the authentication and digital signatures niche. In 1997 RSA acquired Intrusion Detection, a network software security maker, and in 1998 Dynasoft, a firm specialized in Unix-security networks.

? In 1997 Axent Technology took control of Raptor Systems, one of the most important owner of patents in Firewall technology; in 1998 it acquired Security Network Consulting, a general network design security expert, and in 1999 PassGo Technologies, a storage data protector.

The acquisition course of action of these three firms is clearly directed to acquire market shares in new product niches. This trend well represents the strategy in the whole industry. In 77% of acquisitions partners involved (acquired and buyer) had different product niche specialisation, and in 96% the acquired firm was less diversify then the buyer. Evidence seems to confirm that the criterion that led small firm acquisition strategies was to saturate all the market niches in ESI.

4.2 Downstream capabilities and geographic expansion

Investments in co-specialised assets, like service efforts and marketing capabilities are an important mean of appropriation of R&D returns. Building a sound network of downstream channels and distributors implies a better exploitation of firm technological resources (Teece, 1986). Also downstream control could lower the rate of possible imitation and act as a barrier to potential entrants. As Teece noted: “A competitive advantage can be gained or lost on the market of complementary assets" (Teece, 1986, p. 289).

We proxy investments in downstream assets with the number of commercial alliances set up by firms (as in Gambardella and Torrisi, 1998).

In EVENT database, we registered 296 commercial strategic alliances signed in encryption software sector between 1993 and 1999. These alliances have plain distribution and marketing aims. Table 4.3 lists the top firms for number of commercial alliances. It is possible to note that this sample is characterised by top ESI start-ups (Check Point, Axent . . .) and large ICT firms (IBM, H&P, . . .). It is evident that top start-ups are the major investors in downstream assets.

[Table 4.3 about here.]

[26] In most acquisitions the buyer was an ESI start-up, and only in 3 cases out of 82, the buyer was an incumbent from other sectors. These data show that the M&A dynamics were phenomena that occurred inside the groups of start-ups in ESI.

The building of these downstream capabilities is directly linked to a firm's capacity to open new geographic markets where it can establish its presence. The positive outcomes of this dual strategy are several, such as sales and profit expansion, entry and growth in new product niches, better screening of market opportunities and direct contact with a larger customer base.

The literature has pointed that internationalisation tends to be easier among firms with high intensity of R&D that offer technological complex products with a high level of product differentiation. This holds especially for firms in which its intangible asset value is large relative to its market value (Ethier; 1986; Markusen, 1995).

Moreover, recent studies (Kotha et al., 2001) have found a positive correlation between intangible assets of software firms and propensity to internationalise. Other scholars (Morck and Yeung, 1992) found evidence that especially for small, young and dynamic firms the presence of intangible assets is correlated with a high degree of internationalisation and high “abnormal" stock market returns. This is particularly true for niche products with general-purpose functionalities such as the ESI product.

Data show that the main geographic markets for encryption software products are North America and Europe; as a matter of fact, according to Hoovers, in 1999 the 66.7 % of the revenues in ESI came from the US market, followed by Europe (16.1%) and Asia (3.8%). Our alliance data show an important tendency to firm internationalisation. In this respect, we assign to each agreement the country where the alliance investment is direct. We then calculated for each firms, the Herfindahl index on the commercial alliances by year and by country. As figure 4.3 shows, when the number of commercial alliances is rising, the dispersion of alliances among different countries increases. Firms in ESI use commercial agreements also to open new geographical markets. This was extremely important for firms in emerging countries like Israel (Aladdin, CheckPoint) or Ireland (Baltimore) where the dimension of indigenous markets was small (Arora et al., 2001). Managers at Baltimore and Checkpoint agree in stressing the importance of firm internationalisation strategies: ”It was strategically profitable in the long run that we do not focus on our local customers from the beginnings”

[Figure 4.3 about here.]

In order to summarize this section, we have seen that product differentiation was central for start-ups in order to gain competitive advantages when scale economies are small. Moreover, investments in co-specialised assets, especially aimed to the firm geographic expansion, are necessary to sustain growth of young firms. At this regards, alliances appear as good tools to study small firm behaviour.

6 Conclusions

In this paper we analysed the birth of a new market niche in the software industry. We depicted the different phases of competition and the strategic responses of main actors, focusing on the process of entry by start-ups and post-entry firm strategies.

We have shown that a sound technological base, a broad product variety and structured co-specialised assets are variables strongly correlated to start-up probability to survive and grow.

In detail, we illustrated the strict link between innovation and new firm formation, where innovation was the key to open new market niches, avoiding entry barriers and discovering new potential customers. Following this point, entrepreneur characteristics were fundamental to understand start-up performance especially during its first years. ESI in fact was a classical case study where inventors become entrepreneurs exploiting their technological knowledge.
We then stressed the importance of patents as a tool to defend firm knowledge assets. This is quite unusual in the software industry, where firms do not extensively protect their innovation by means of patents. But in ESI, patents helped to build a market for technology that was essential in shaping competitive outcomes. This is also highlighted by the presence of two separated markets for software products and mathematical algorithms.
We saw that if technology was crucial in determining the positive result of firm entry, exploitation of economies of scope direct to product differentiation and investments in downstream assets linked with firm geographic expansion represented the key to understand firm growth when scale economies are small. At this regards, alliances appear as essential tools to achieve these results for small firms that usually rely on scarce resources.
Sound evidence confirmed the importance of small firms in opening new markets where large incumbents, for several reasons, have low incentives to invest. On the other side, we highlighted how large established firms acted as incubators of technological competencies embedded in the future entrepreneurs, and also as important actors both in the technological and commercial networks in ESI.
This paper leaves some points of discussion open. The relationship between firm initial capabilities and the patterns of firm growth is still in need to be deeper studied.
In ESI the coexistence of good initial capabilities and optimal growth strategies determinate the success of a start-up. But causes and consequences of a firm's success do still not have a clear-cut role. In future works it will be interesting to investigate if i) initial firm competencies embedded in entrepreneurs and ii) firm strategies direct towards product differentiation and geographical expansion are the two faces of the same mechanism, or, otherwise, whether firm strategies produce an effect beyond firm-founder initial capabilities.

References

Anand B.N., Khanna T., 2000. Do firms learn to create value? The case of alliances. Strategic Management Journal, 21(3), 295-315

Arora A., Gambardella A., Torrisi S., 2001. In the Footsteps of Silicon Valley? Indian and Irish Software in the International Division of Labour, SIEPR Policy paper No. 00-41

Audretsch, D., 1991. New-firm Survival and the Technological Regime. Review of Economics and Statistics, 73(3), 441-450.

Baron J.N., Hanna M.T., 2002. Organizational Blueprints for Success in High-Tech Start-ups. California Management Review, 44(3), 8-36

Baum, J.A.C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone: alliance network composition and start-ups' performance in Canadian biotechnology. Strategic Management Journal, 21, 267-294

Bessen J., Hunt R.H., 2003. An Empirical Look to Software Patents, Paper presented at the EPIP Conference, Munich, April 2003

Bhide, A., 2000), The Origin and Evolution of New Businesses, Oxford University Press.

Blanchower, D., Oswald, A., 1998. What makes an Entrepreneur? Journal of Labor Economics, 16(1), 26-60.

Bresnahan, T., Trajtenberg, M., 1995. General Purpose Technologies "Engines of Growth? Journal of Econometrics, 65(3), 83-108.

Chrisman, J., Bauerschmidt, A., Hofer, C., 1998. The Determinants of New Venture Performance: an Extended Model. Entrepreneurship: Theory and Practice, 23(1), 5-7.

Churchill, N., Lewis, V., 1983. The Five Stages of Small Business Growth. Harvard Business Review. May, 30-50.

Cohen, W., Levinthal, D., 1989. Innovation and Learning: the Two Faces of R&D. Economic Journal, 99(397), 569-596.

Cohen, W., Nelson, R., Walsh, J., 2000). Protecting their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not), NBER, WP 7552.

Dodge, H., Fullerton, S., Robbins, J., 1994. Stage of the Organizational Life Cycle and Competition as Mediators of Problem Perception for Small Businesses. Strategic Management Journal, 15(2), 121-134.

Dunne, T., Roberts, M., Samuelson, L., 1988. Patterns of Firms Entry and Exit in US Manufacturing Industries. Rand Journal of Economics, 19(2), 495-515.

Ethier, W., 1986. The Multinational Firm. Quarterly Journal of Economics, 101(4), 805-834.

Gambardella, A., Torrisi, S., 1998. Do Technological Convergence Implies Convergence in Markets? Evidence from the Electronics Industry. Research Policy, 27(5), 445-463

Gartner, W., 1985. A Conceptual Framework for Describing the Phenomenon of New Venture Creation. Academy of Management Review, 10(4), 696-706.

Geroski, P., 1995. What do We Know about Entry? International Journal of Industrial Organization, 13(4), 421-440.

Gosnell, G., 1999. Internet Related Intellectual Property Issues. Journal of Internet Law, 2(4), 23-34.

Hanks, S., Chandler, G., 1994. Patterns of Functional Specialization in Emerging High-tech Firms. Journal of Small Business Management, 32(2), 23-37.

Henderson R., 1993. Underinvestment and Incompetence as Responses to Radical Innovation – Evidence from the Photolithographic Alignment Equipment Industry. Rand Journal of Economics, 24 (2): 248-270

Hippel von, E., 1988. The Sources of Innovations, Oxford University Press, NY.

Hippel von, E., 1990. Task Partitioning: an Innovation Process Variable. Research Policy, 19(3), 407-418.

Holmes, T., Schmitz, J., 1990. A Theory of Entrepreneurship and its Application to the Study of Business Transfers. Journal of Political Economy, 98(2), 265-294.

Kazanjian, R., 1988. Relation of Dominant Problems to Stages of Growth in Technology-based New Ventures. Academy of Management Journal, 31(2), 257-279.

Kazanjian, R., Rao, H., 1999. The Creation of Capabilities in New Ventures: A Longitudinal Study. Organization Studies, 20(1), 125-137.

Kekre, S., Srinivasan, K., 1990. Broader Product Line: a Necessity to Achieve Success. Management Science, 36(10), 1216-1231.

Kiefer, N.M., 1988. Economic Duration Data and Hazard Functions. Journal of Economic Literature, 26 (2), 646-79

Klepper, S., 1996. Entry, Exit, Growth and Innovation over the Product Life Cycle. American Economic Review, 86(3), 562-584.

Klepper, S., Sleeper, S., 2000. Entry by Spin-off, Working Paper, Carnegie Mellon University.

Klepper S., 2001. Employee Start-ups in High-Tech Industries. Industrial and Corporate Change, 10 (3), pp. 639-74.

Kotabe, M., Swan, K., 1995. The Role of Strategic Alliances in High-technology New Product Development. Strategic Management Journal, 16(8), 621-636.

Kotha, S., Rindova, V., Rothaermel, F., 2001. Assets and Actions: Firm-specific Factors in the Internationalization of US Internet Firms. Journal of International Business Studies, 32(4), 769-792.

Lancaster, K., 1990. The Economics of Product Variety. Marketing Science, 9(3), 189-211.

Markusen, J., 1995. The Boundaries of Multinational Enterprises and the Theory of International Trade. Journal of Economic Perspectives, 9(2), 169-189.

Meyer, M., Roberts, E., 1986. New Product Strategy in Small Technological-based Firms: a Pilot Study. Management Science, 32(7), 806-821.

Mitra, R., Pingali, V., 1999. Analysis of Growth Stages in Small Firms: a Case Study of Automobile Ancillaries in India. Journal of Small Business Studies, 37(3), 62-71.

Morck, R., Yeung, B., 1992. Internationalization: an Event Study Test. Journal of International Economics, 33(1), 41-56.

Olson, P., 1987. Entrepreneurship and Management. Journal of Small Business Management, 25(3), 7-14.

Pavitt, K., 1988. International Patterns of Technological Accumulation, in N. Hood and J. Vahlne, eds, Strategies in Global Competition, Groom Helm, pp. 123-143.

Riccaboni M., Pammolli F., 2001. On firm growth in networks. Research Policy, 31(8) 1405–1416

Sakakibara, M., 1997. Heterogenity of Firm Capabilities and Cooperative Research and Development: an Empirical Examination of Motives. Strategic Management Journal, 18(4), 143-164.

Shane, S., 2001. Technological Regimes and New Firm Formation. Management Science, 47(9), 1173-1190.

Shane, S., Venkataraman, S., 2000. The Promise of Entrepreneurship as a Field of Research. Academy of Management Review, 25(1), 217-226.

Smith, R., 1999. Internet Cryptography, Addison-Wesley, Reading USA.

Soreson, O., 2000. Letting the Market work for You: an Evolutionary Perspective on Product Strategy. Strategic Management Journal, 21(5), 577-592.

Stuart T.E., Hoang H., Hybels R.C., 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. Administrative Science Quarterly. 44(2), 315-349

Teece, D., 1986. Profiting from Technological Innovation: Implications for Integration, Licensing and Public Policy. Research Policy, 15(1), 285-305.

Terpstra, D., Olson, P., 1993. Entrepreneurial Start-up and Growth: a Classification of Problems. Entrepreneurship: Theory and Practice, 17(3), 5-21.

Torrisi, S., 1998. Industrial Organisation and Innovation: an International Study of the Software Industry, Edward Elgar Publ, Cheltenham, UK

Vinnell, R., Hamilton, R., 1999. A Historical Perspective on Small Firm Development. Entrepreneurship: Theory and Practice, 23(4), 5-12.

Wagner, J., 1994. The Post-Entry Performance of New Small Firms in German Manufacturing Industries. Journal of Industrial Economics, 42(2), 141-154.

Zacharakis, A., Meyer, G., DeCastro, J., 1999. Differing Perceptions of New Venture Failure: a Matched Exploratory Study of Venture Capitalists and Entrepreneurs. Journal of Small Business Management, 37(3), 1-10.

Table 3.1: Most cited assignees, granted patents 1977-1992

Firm	Sector	Citations	Patents	C/P Ratio
IBM	Computer	528	46	11.47
Motorota	Telecom	226	24	9.41
Scientific Atlanta	Telecom	202	18	11.22
Pitney Bowes	Computer	165	16	10.31
Qualcomm	Electronics	97	3	32.33
AT&T	Telecom	97	8	12.12
Pioneer	Electronics	95	9	10.55
Philips	Electronics	95	7	13.57
Aisin Seiki	Cars	83	6	13.83
Stanford University	University	80	2	40
M.I.T.	University	75	2	37.5
NEC	Electronics	72	6	12
General Instrument	Electronics	68	8	8.5
NCR	Computer	63	5	12.6
Hitachi	Electronics	62	4	15.5
VISA	Services	53	2	26.5
Total		2061	166	17.34
Other		2520	224	11.81

Source: US Patent Office

Table 3.2: World market leaders in ESI at 1998

Rank	Firm	Revenues ($ml)	World market share	Year of entry	Firms in the same entry cohort
1	Network Ass.	990	0.171	1993	18
2	Symantec	578.4	0.099	1990	8
3	RSA Data Security	171.3	0.029	1991	17
4	Check Point	141.9	0.024	1995	35
5	Rainbow Tech.	109.2	0.018	1998	56
6	Axent Tech	101	0.017	1994	29
7	Trend Micro	86.2	0.014	1991	17
8	Secure Computing	61.4	0.010	1994	29
9	Entrust Tech.	49	0.008	1997	57
10	Cylink	42.8	0.007	1995	35
11	SystemSoft	42.6	0.007	1998	56
12	VeriSign	38.9	0.006	1998	56
13	BindView	38.5	0.006	1995	35
14	Aladdin	36.1	0.006	1997	57
15	Safenet	23.2	0.005	1998	56
Total		2487.3	0.429		

Source: IDC Corporation, Infotrac

Table 3.3: Product niches in ESI

Description	Sic code
Authentication Digital Signature	7372663
Antivirus	7372612
Data storage protection	7372691
Firewalls	7372681
Utility software	7372614
Network Software Security	7372611
Virtual private network access	7372613

Source: Infotrac

Table 3.4: Citations and granted patents cited by ”1993-1999" patents (backward citations), 1976-1984

Year	Citations(C)	Patents(P)	C/P Ratio
1976	19	2	9.5
1977	194	7	27.71
1978	110	7	15.71
1979	50	5	10
1980	189	19	9.94
1981	167	14	11.92
1982	160	14	11.42
1983	165	12	13.75
1984	181	16	11.31
Average	137.22	10.66	13.47
Average 85-92	552.5	250.5	2.20

Source: US Patent Office

Table 3.5: Main buyers and sellers of products and technology in ESI, 1993-1999

Technology licenses				
Rank	*Main licensors*	*N°*	*Main licensees*	*N°*
1	RSA Data Security	23	IBM	12
2	Certicom	13	H&P	8
3	Network Ass.	10	Time Warner	4
4	Entrust	5	Microsoft	3
5	Check Point	4	Compaq	4
6	Macrovision	4	NEC	3
7	VeriSign	4	Network Ass.	3
8	Diversinet	2	Lucent	3
9	Cylink	2	Rainbow Tech.	3
10	Finjan	2	Secured Comm.	2
Product order and contracts				
Rank	*Main sellers*	*N°*	*Main buyers*	*N°*
1	VeriSign	10	Verizon	6
2	RSA Data Security	8	IBM	5
3	Secure Computing	5	H&P	4
4	Check Point	4	Visa	4
5	Network Ass.	4	NSA	2
6	Cylink	4	Infonet	2
7	Entrust	4	KPMG	2
8	Cisco Systems	4	Microsoft	2
9	Axent	4	Time Warner	2
10	Baltimore Tech	4	Sun Micr.	2

Source: EVENT database

Table 3.6: Founders of top 15 start-ups and their origins

Firm	**Founder**	**Patent assignee**	**Former founder's employer**
		Large Firms	
Certicom	P.Panjwani	v	Motorola
Cylink	L.Morris		Xerox
Entrust Tech.	B. O'Higgins	v	Nortel
Network Ass.	W. Larson	v	Apple and Sun Micr.
Network Ass.	J. McAfee	v	Lockheed Martin
Rainbow Tech.	W. Straub		GTE and Compaq
RSA Data Security	C. Stuckey		IBM
RSA Data Security	R. Rivest	v	MIT, Pitney Bowes
Safenet	A. Caputo	v	Computer Ass.
Secure Comp.	K. Beseke	v	Honeywell and Motorola
Trend Micro	S. Chang	v	H&P
		Small firms	
BindView Dev.	E. J. Pulaski		Network Research, systems integrator
SystemSoft	R. Angelo		Phoenix Technologies, a software producer
VeriSign	J. Bidzos		RSA Data Security
		University and Public Research Laboratories	
Certicom	S. Vanstone	v	University of Waterloo
Aladdin	Y. Margalyt	v	Hebrew University
CheckPoint Soft.	G. Shwed	v	Optrotech, Israel Defence Forces
CheckPoint Soft.	M. Nacht		Optrotech, Israel Defence Forces
Rainbow Tech.	A. Jennings	v	Mathematician
Safenet	A. Hastings	v	National Security Agency
Symatenc	G. Hendrix		Stanford University

Source: Hoover's and US Patent Office

Table 4.1: New products by market niche in ESI, 1989-95 and 1996-2000

	Years	
	1989-95	**1996-2000**
Description	**N of products**	**N of products**
Authentication-Digital Signature	26	39
Antivirus	21	11
Data storage protection	104	207
Firewalls	7	89
Utility software	15	22
Network Software Security	39	340
Virtual private network	0	242
Other	23	83
Total	235	1033
	Concentration Index	
Herfindhal	0.253	0.214
C2	0.608	0.529

Source: Infotrac

Table 4.2: Top firms for number of technological alliances in ESI, 1993-1999

Rank	**Firm**	**Alliances (a)**	**a/Sales ($ mil.)**
1	RSA Data Security	39	0.406
2	Microsoft	27	0.002
3	Check Point Soft.	19	0.273
4	Network Ass.	18	0.053
5	VeriSign	17	0.167
6	H&P	14	0.000
7	Time Warner	13	0.005
8	Internet Security	12	0.230
9	IBM	12	0.000
10	Entrust Tech.	11	0.235
	Sample average	5.877	0.099
	Sample stand.dev.	7.107	0.272

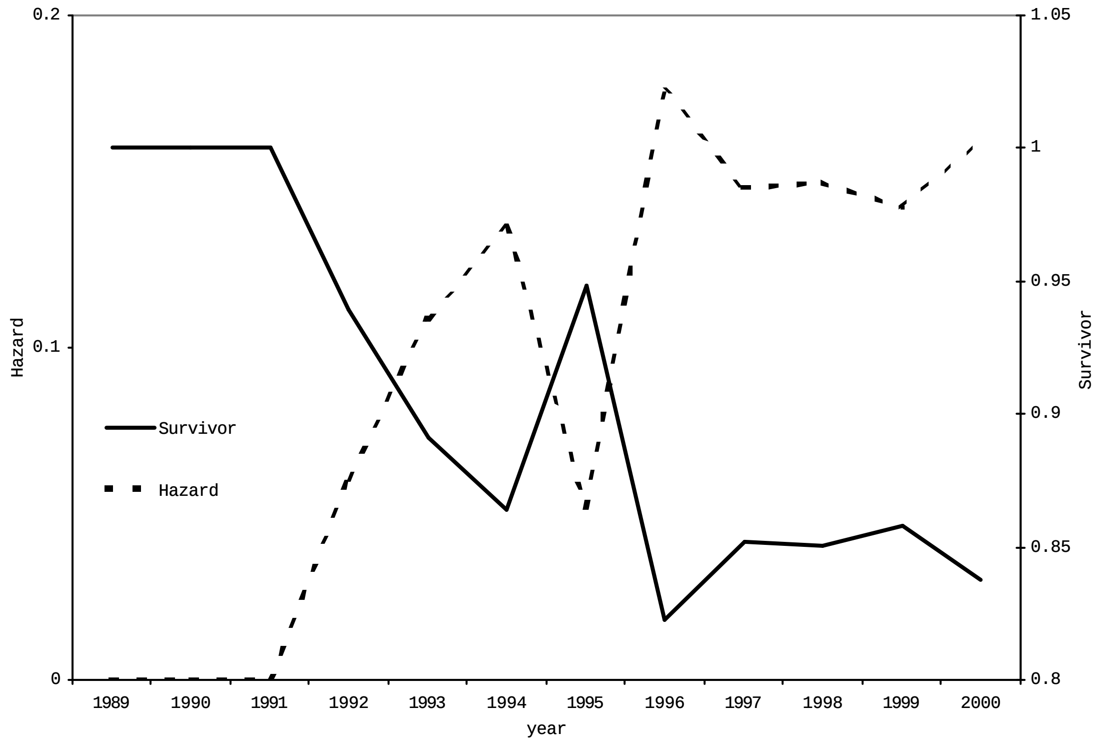
Source: EVENT database

Table 4.3: Top firms for number of commercial alliances in ESI, 1993-1999

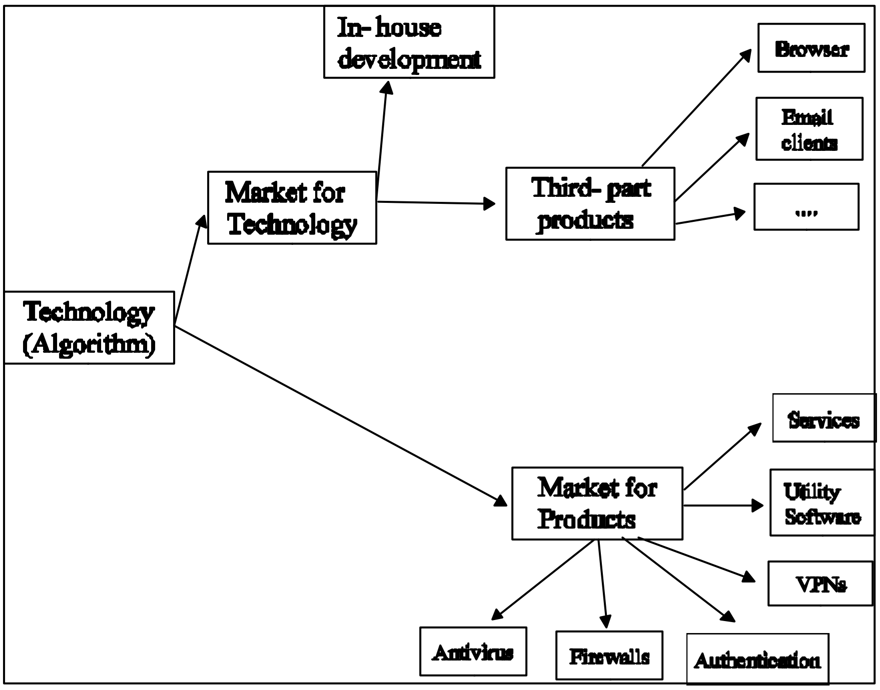
Rank	Firm	Alliances (a)	a/Sales ($ mil.)
1	Network Ass.	28	0.083
2	RSA Data Security	22	0.229
3	Axent Tech.	14	0.402
4	VeriSign	13	0.128
5	Computer Ass.	10	0.003
6	Check Point Soft.	10	0.144
7	IBM	10	0.000
8	Time Warner	9	0.003
9	Secure Computing Corp.	8	0.297
10	Microsoft	7	0.001
	Sample average	4.411	0.077
	Sample Stand.dev.	5.194	0.185

Source: Event database

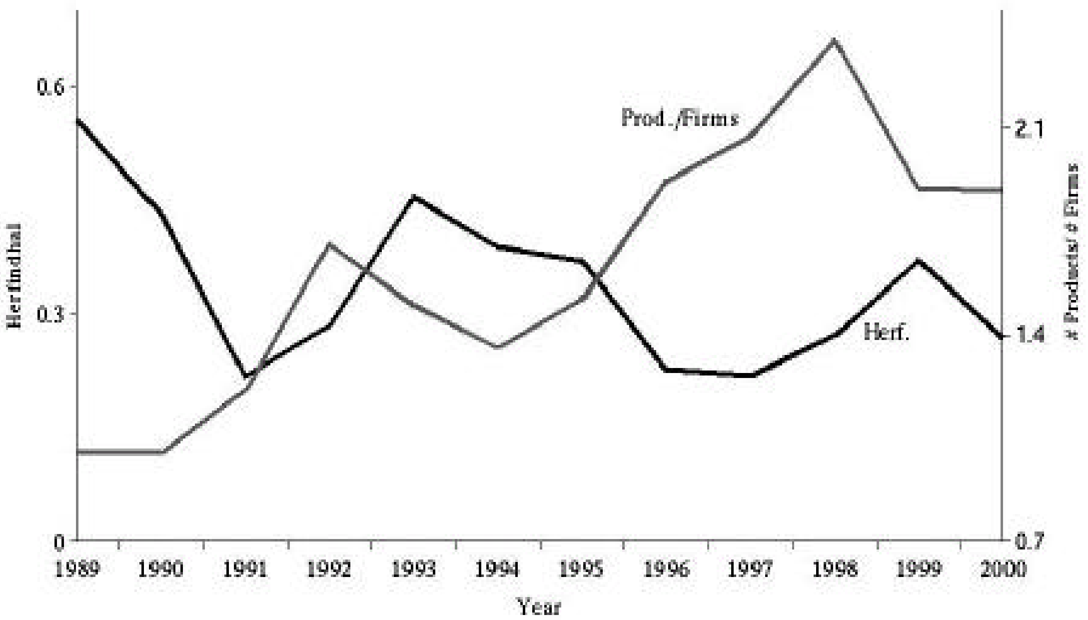
Graph 3.1: Hazard and Survivor Functions, 1989-2000



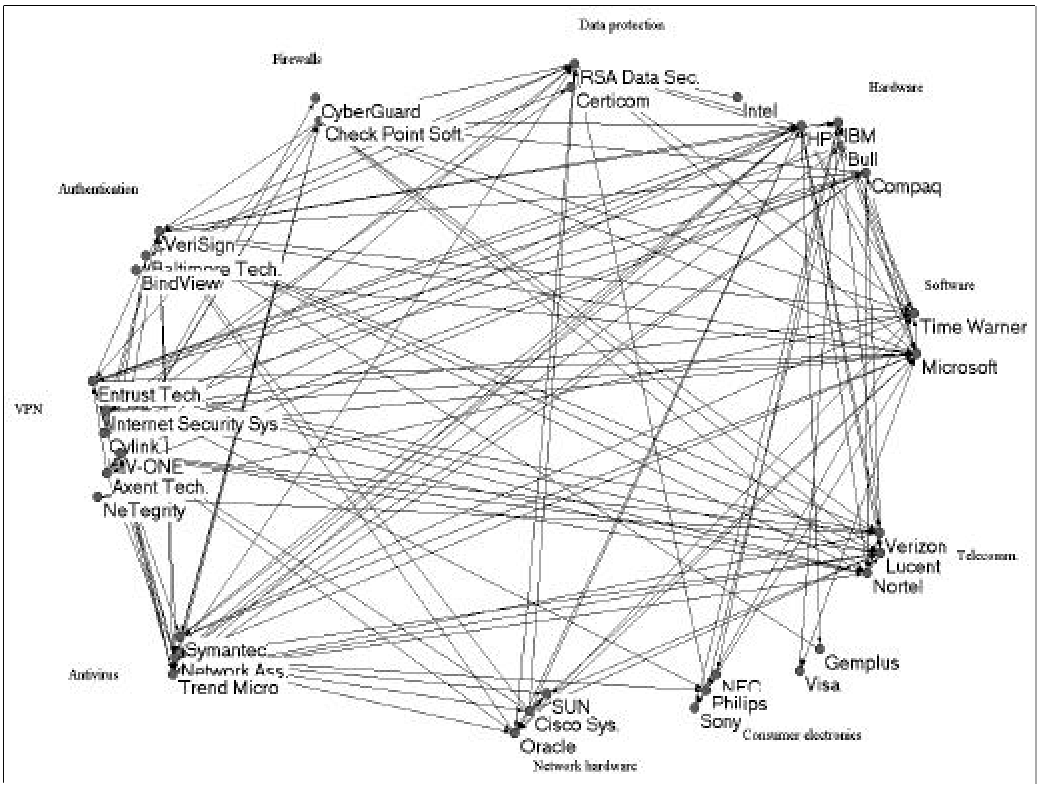
Graph 3.2: The market for products and for technologies in ESI



Graph 4.1: Number of products standardized by number of firms compared to average firm diversification index, 1989-2000



Graph 4.2: Network of technological alliances, top ESI start-ups and incumbents by sector specialization, 1993-1999



Graph 4.3: Firm number of commercial alliances compared to their geographic expansion (Herfindahl Index)