Securing Their Future?

Markets for Technology and Survival in the Information Security Industry

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Abstract:

We study how markets for technology affect entry and survival in the information security industry. Markets for technology facilitate the entry of firms that lack proprietary technology. However, they also increase the relative advantage of downstream capabilities. Since we do not observe the entire population of potential entrants, we test these ideas by studying survival. The results show that a greater supply of technology increases the exit of firms, consistent with a lowering of entry barriers. However, firms with greater marketing capability and size are less likely to exit, the greater is the supply of technology, but greater technical capability is less potent. This is consistent with the hypothesis that markets for technology enhance the relative value of marketing and scale.

Keywords: Entrepreneurship, Technology licensing, firm performance

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1. Introduction:

The existing literature on entrepreneurship and industry evolution implicitly assumes that entrants to an industry develop their own technology and capabilities. Until recently, markets for technology were relatively rare and the assumption that entrants developed their own technology was therefore a reasonable one. However, markets for technology have grown in importance and potential entrants may not have to develop proprietary technology but instead can in-license (Arora, Fosfuri and Gambardella, 2001, Gans, Hsu and Stern, 2002). Similarly, firms with innovative technology may license to others to earn revenues to supplement or even supplant their own production.

In this paper, we explicitly consider how markets for technology condition the entry and subsequent performance of entrepreneurs, and how it changes the relative value of different types of firm competencies. When entrants do not have to generate their own technology but can instead license technology from others, this enables more firms to potentially enter the industry. Lower entry barriers mean more competition in the product market and greater likelihood of exit. The focus of the paper is to understand how markets for technology, and more precisely, the supply of technology conditions the relative importance of different types of firm capabilities, such as marketing capabilities, technical capabilities and scale.

We test these ideas in the context of the information security market. We develop a novel dataset of entrants in the Information Security Market (ISM), whose growth was has been boosted by the growth of the Internet. We exploit variation in the extent to which key technology is codified and patented across different ISM segments, which drives the extent to which technology holders are willing to out-license, to examine the impact of markets for technology on entry and exit.

This paper is organized as follows. Section 2 reviews the literature and develops a simple theoretical model of industry entry and exit. Section 3 provides a brief background on information security technologies. Section 4 provides a description of the data, and section 5 provides the empirical results, and explores the robustness of our findings to alternative explanations and confounding factors. In section 6 we conclude with a summary of our key findings of this work.

2. Previous literature and theory development

We make two major contributions to the literature on entrepreneurship and strategy. We provide a systematic test of how the market for technology affects exit from the product market. Second, we provide the first investigation of how the effect on survival of technical capability, marketing capability and scale are conditioned by the market for technology.

As our brief literature review highlights, the literature has focused on understanding what kinds of entrants are likely to enter early. Much of the research in entrepreneurship research has focused on factors associated with the improved survival of entrants. Diversifying entrants tend to enter industries whose resource requirements are similar to their own. For instance, in the television industry, many of the early entrants were radio producers (Klepper and Simons, 2000). Similarly in the automobile industry, entrepreneurs with experience in manufacturing carriages and bicycles not only entered early relative to other entrants but also survived longer (Klepper, 2002). Many studies of large manufacturing firms conclude that a greater fit between the resource requirements of the new industry and that of the potential entrant increases the likelihood of entry (Chatterjee and Wernerfelt, 1991; Chang, 1997; Merino and Rodriguez, 1997; Silverman, 1999). The fit could be based on technology or marketing. For instance, in the television industry, 14 out the 16 top radio producers in 1940 diversified into the television industry (Klepper and Simmons 2000). Similarly, in the automobile industry about 47% of the entrants diversified from related industries that included bicycle, carriage or engine manufacturing (Carroll et al, 1996).

Lead users, with extensive knowledge of consumer preferences, are another source of entry, even into manufacturing centric industries such as typesetting (Tripsas, 1997). Many industries also witness entry by entrepreneurs with very specific technical knowledge. In the medical devices industry, for instance, clinical doctors often identify opportunities that lead to new types of devices (Chatterji, 2007).

Our focus is on exit, rather than on the sources of entry per se. We do distinguish whether an entrant is a startup or an existing firm diversifying into ISM. In our sample, all existing firms that diversify into ISM are firms in information technology or communications (ICT); there are no firms from user sectors such as banking or retail that enter the ISM. However, there are startups with founders from the user sectors. Although diversifiers are disproportionately likely to be among the successful entrants, startups, including firms spun out of existing producers (spinoffs), typically constitute the majority of entrants (Dunne, Roberts, and Samuelson, 1988).[2] A key factor that critically determines whether incumbent diversifiers are more or less likely to succeed in a new industry is the type of assets required to commercialize the new competence destroying technology. Hill and Rothermael (2005) for instance, show that incumbents are less likely to succeed when the new technology can be commercialized through generic complementary assets, whereas they are more likely to succeed if the new technology can be commercialized through specialized complementary assets. In our empirical analysis we not only distinguish between incumbents and startups but also different types startups including whether

[2] Unlike other industries studied by scholars, there are far fewer spinoffs in ISM compared to other industry settings, perhaps reflecting the relative youth of ISM.

they are spinoffs from existing ISM firms, whether their founders are from other IT firms, user firms, or others.

Another key finding in the literature, discussed more fully below, is that the size at entry significantly conditions exit: all else held constant, the greater the size at entry, the lower the hazard of exit. Pre-entry experience may also be critical for subsequent performance (Helfat and Lieberman, 2002). For instance, Thompson (2005), using data on the ship building industry, found that pre-entry experience of entrants has a strong and long- lasting positive effect on firm survival that went beyond scale economies and learning. Klepper (2002) and Carroll et al, (1996) found similar patterns for automobiles, Mitchell (1989) for medical imaging, and Klepper and Simons, (2000a) for televisions.

However there is less consensus on which types of pre-experience is required, perhaps because this seems to vary by the nature of the industry. For instance, in televisions, knowledge of radio technology (such as vacuum tubes) was a distinct source of advantage (Klepper and Simons, 2000a). In the medical imaging industry, the advantage to diversifying entrants was due to their superiority in sales and distribution (Mitchell, 1989).

Consistent with the resource based view of the firm, these studies implicitly assume these capabilities (such as manufacturing expertise or knowledge of FDA procedures) must be accumulated in the firms they cannot be purchased or "rented" from the market; in fact, in some cases they may just evolve as a response to idiosyncratic situations that may be unique to a firm (Ahuja and Katila, 2004). For certain types of expertise this assumption seems natural. But as new markets develop, competencies that were earlier rare and difficult to replicate are available to all, albeit at a price. Thus, it seems natural that markets for technology should reduce the competitive advantage *in the product market* from proprietary technology, and enhance the importance of other sources of advantage, such as scale and marketing.

In our empirical analysis, we exploit differences in patent intensity across different segments of the ISM, which also affects the extent to which technology is licensed. Encryption technologies are patent intensive relative to other ISM technologies and are extensively licensed (Giarratana, 2004). We argue that an increase in the supply of technology to entrants reduces entry barriers and, hence also, increases the hazard of exit. There is some evidence in the literature to support this idea. Arora, Fosfuri and Gambardella (2000) show that markets for technology encourage investment by chemical firms in developing countries, implying that technology suppliers lower entry barriers. Lieberman (1989) finds that licensing was less common in concentrated chemical products, and the limited licensing that did take place was by outsiders (non producers and foreign firms). Moreover, he finds that when licensing was restricted, there was less entry. In a related study of twenty four chemical product markets, Lieberman (1987) reports that patenting by outsiders was associated with a faster decline of product price, once again suggesting that patenting by outsiders encouraged entry in the product market.

Since we cannot observe the population of potential entrants, we cannot directly test if markets for technology reduce the competitive advantage from technology in product markets, but we can test its implications. More precisely, we test the implications of an increase in the potential supply of technology to a sub-sector (henceforth called segment) of the ISM. If an increase in the number of suppliers in the market for technology reduces entry barriers, then this will increase entry and increase competition in the product market. This should results in a greater chance of exit. Even in an equilibrium setting with forward looking firms, it is easy to show that as long as there is some uncertainty about the individual firm's cost, a reduction in the sunk cost of entry must, in a free entry equilibrium, imply a higher probability of exit.[3] We state this as our first hypothesis.

Hypothesis 1: All else held constant, an exogenous increase in the supply of technology will increase average hazard of exit in the product market

Firms generally compete by differentiating themselves according quality of the product or service, price of their offerings, the types of customers they cater to and so on. Some of these are purely strategic choices, while others depend on the type of assets and capabilities the firm has. These capabilities include technology, production expertise and facilities, brand name and reputation, human assets, established marketing channels, that are typically rare, valuable, imperfectly mobile (Barney, 1991; Markides and Williamson, 1996, Dierickx and Kool, 1989). For instance, Klepper and Simmons (2000a) suggest that technical ability was important in the success of radio firms. Moreover recent research also provides evidence of patents associated with higher survival rates (Helmers and Rogers, 2008, Cockburn and MacGarvie, 2007). Mitchell (1989) finds that marketing ability was important in medical devices while Chatterji (2006) similarly finds that ability to manage FDA trials the key differentiator among medical device spinoffs.

[3] Formally, suppose the unit cost of production, c, is equal to $c_0 + \varepsilon$, where ε is a mean zero random variable, whose realization the firm observes only after entering, and which has a distribution function F(). After the firm enters, it will produce if its unit cost c is the less than the price, P, and will exit otherwise. Further, suppose E is the sunk cost of entry. Then in equilibrium, E = $\int_0^{P(N)} \{(P(N) - c)\} dF$, where N is the equilibrium number of firms in the industry. The probability of exit for any entrant is simply 1-F(P(N)), so that the total number of entrants is N divided by the probability of exit. It is easy to see that as E falls, N increases. If the price, P, decreases with the number of firms in the product market, then as E falls, P falls as well. This implies that the probability of exit must increase.

There is a large literature on the role of firm size in conditioning firm survival and growth. First, the economics literature has stressed potential economies of scale and scope, which directly imply higher profitability and survival. A different view of scale is that scale is the reflection of important unmeasured capabilities of the firm that have allowed the firm to grow or allowed the entrant to raise the resources and capital required to enter on a larger scale. In this view, scale is therefore a symptomatic measure rather than an underlying cause. In fact, many empirical researchers take the view that one reason that firm size is positively correlated with survival is because firm size captures the effects of learning and accumulation of relevant competitive assets post entry (Geroski, 1995), a fact that is also true of small firms (e.g., Dunne et al 1989). Cohen and Klepper (1996) and Klepper (1996) instead argue that scale is causally related to survival. A firm with a larger scale of operations will optimally invest more in cost reducing efforts (such as R&D), because it can amortize the investment over a larger output. Clearly, these views are not mutually exclusive and indeed may be synergistic.

Our objective here is not so much to examine the effect of the different types of capabilities on survival of entrants, as to see how the effect is modified or conditioned by the market for technology. The literature has neither addressed this question in terms of developing clear theory nor in terms of prior empirical results. This is the focus of our paper.

The resource based theory of the firm implies that when technology can be accessed through markets, it cannot be a source of strategic advantage. This does not imply that technology is not valuable – to the contrary, creating a market for technology can only enhance the value of technology. However, with a well functioning market for technology, a technology holding firm that is not a very efficient producer will not have to use the technology itself to derive value. It can instead license to other firms. Simply put, fully efficient markets for technology separate the question of how valuable the technology is from the question of how efficient the technology holder is. Of course, a market for technology is never fully efficient in practice, but becomes more so as the number of potential and actual suppliers increases. This leads to the hypothesis that technology assets reduce the probability of firm exit, an effect which becomes weaker as the supply in the market for technology increases.

Hypothesis 2a: All else held constant, technological capability decreases the probability of firm exit.

Hypothesis 2b: The absolute effect of technological capability on exit diminishes as the supply of technology increases.

In economics there is a theoretical literature on firm size and exit, albeit from declining markets. Ghemawat and Nalebuff (1985, 1990) analyze the case where producers have the same costs and demand declines over time. They show that firms exit in decreasing order of firm size. Whinston (1988), however, shows that with firms of different sizes, multiple equilibria are possible, and the largest firms may not be the first to exit. Lieberman’s studies of exit from mature chemical markets supports the Ghemawat and Nalebuff theory, but also underscores the importance of distinguishing between firm size and the size of plants.

In the foregoing studies, strategic interactions among a small number of firms played a pivotal role in generating the results. Moreover, the literature focused on declining markets, rather than on markets where entry barriers have been lowered and competition intensified. However, the intuition behind the result as well as the reason for the theoretical ambiguity can be easily stated. If an increase in the number of licensors reduces entry barriers and, hence, price-cost margins this would naturally hurts firms with larger scale more than firms with small scale.

Thus, we have that an increase in the number of licensors reduces profits more for firms with a larger scale. However, as long as price-cost margins are positive, profits are greater for firms with greater scale. Moreover, larger firms may well have lower productions costs (either due to economies of scale or due to greater cost reducing investments). Therefore, how markets for technology condition the impact of scale of operations on the probability of exit depends on the distribution of firm size and is theoretically ambiguous. As already noted, the empirical literature tends to find that smaller firms have a higher probability of exit, although we are not aware of studies which analyze how changes in entry conditions differentially affect exit by large and small firms. This yields the following hypothesis.

Hypothesis 3a: All else held constant, larger firms are less likely to exit than smaller firms.

Hypothesis 3b: An exogenous increase in the supply of technology has an ambiguous effect on the relative hazard of exit of large versus small firms.

Finally, most empirical studies suggest that marketing capabilities are an important asset for firms and aid firm survival. We are not aware of studies of how markets for technology condition the effect of marketing capabilities on survival. However, intuition suggests that when technology is available from the market, this should raise the relative importance of marketing capabilities. To see the intuition more clearly, consider a situation where both technology and marketing capability must be internally generated. Firms that are weak in marketing may be able to offset that disadvantage partially by being strong in technology. Thus the effect of marketing ability per se in promoting the survival of the firm will be more muted than when technology becomes a tradable asset.[4] Formally, our final hypothesis is below.

[4] Gambardella and Giarratana (2008) analyze how markets for technology affect the choice between licensing or developing a product. They show theoretically that greater fragmentation of the downstream market encourages licensing, as does the generality of the technology, and find supporting empirical evidence. Their theory is

Hypothesis 4a: All else held constant, greater marketing ability lowers exit.

Hypothesis 4b: An increase in the supply of technology will enhance the effect of marketing ability in lowering exit.

3. The Information Security Market: A brief introduction

Before the Internet, computer attacks, with the exception of viruses, were largely restricted to large computer networks typically owned by the government. The large scale adoption of the internet in the mid 1990's meant that a growing amount of commercially valuable data had to be protected against attackers, accidental loss, and prying eyes. The growth of digital products (including songs and videos) required means of controlling the access and use of those products. Further, online commerce required secure communications, control over access, and authentication of participants. More recently, users have to be protected against spam and "phishing" attacks, which induce unwary users to part with confidential information. Thus, the ISM consists of several submarkets that emerged at different points in time.

Four major types of technologies are involved in securing information and computer networks: (i) Encryption, to disguise data and preserve confidentiality of transactions (ii) Packet inspection and filtering, based on pattern matching (for firewalls, anti-virus and intrusion detection) (iii) Image matching, to identify end users to systems based on their physical attributes such as fingerprints retina and (iv) "Single sign on" technology to enable users to be authenticated to multiple systems just using own common password.

complementary to our hypothesis. If indeed a market for technology enhances the value of marketing capabilities, one likely outcome is a greater differentiation among firms in how their products and services are perceived by customers. Put differently, an increase in supply of technology can itself lead to a greater fragmentation in downstream markets. We do not seek to resolve the potential "chicken and egg" story here but instead note that our analysis complements Gambardella and Giarratana (2008).

- *Encryption*: Encryption relies heavily upon the science of cryptography.[5] Before the internet, encryption was used to protect communication, such as communication between ATM terminals and central banking servers. Internet and e-commerce, and the increased sophistication of attacks, increased the need for stronger encryption.[6] The need for encryption solutions on small devices such as smart cards, cell phones and PDAs (where limited amount of data, including encryption strings, can be stored) required more efficient methods of encryption. At present RSA, and elliptical curve algorithms invented by Certicom are the two most widely used encryption methods to protect data.

- *Pattern Matching and filtering:* Pattern matching technology builds on routing technologies that direct internet communications. The most important filtering technology is the stateful inspection technology, which, is a method to keep track of previous communication between two networked computers. This technology was invented by, Checkpoint Technologies, a startup established in Israel, in 1996.

- *Image matching:* Image matching or biometric technologies are used to verify or recognize the identity of a person based on a physical characteristic like fingerprints or retina patterns. There are three basic methods (1) a mechanism to scan and capture an image; (2) compression, processing and comparison of the image to a database of stored images; and (3) interface with applications systems[7]. Large hardware producers like Hughes, IBM, Burroughs and Harris Corporation, and defense contractors were among the early participants in this technology, as

[5] Encryption uses encryption keys generated by multiplying two large random prime numbers. Decryption, on the other hand, involves factoring this large number to figure to discover the prime number that was originally used to encrypt the data.
[6] In 1976, a public key technology called the Diffie-Hellman algorithm was invented at Stanford in 1976. RSA, another key algorithm for public key cryptography was invented at MIT in 1977. Encryption of email was the first use of this technology.
[7] Source http://www.afmc.wpafb.af.mil/organizations/HQ-AFMC/LG/LSO/LOA/bio.htm. Retrieved 02/04/07.

biometric technologies were used principally by government agencies and financial firms prior to 1997.

- *Single sign-on:* Kerberos invented at MIT, is widely used in universities to authenticate students and staff to multiple systems with just one password is a leading example of a single sign-on technology. Since one of the selling points of e-commerce was the ability conduct transactions between two unknown parties, verifying identify instantaneously became another critical function of this technology.

Table 1 ISM technology and product map

	Encryption	Image-matching	Pattern matching	Single Sign-On
Firewall			X	
Antivirus			X	
Authentication	X	X		X
Spam			X	
Network (VPN)	X			
Encryption	X			
Hardware		X		
Consulting				

ISM products typically combine one or more of ISM technologies (see table 1)[8] as a product to cater to the needs of users. For instance, a Virtual Private Network (VPN) product uses encryption to enable organizations and desktop users to securely communicate using the internet. Authentication products use encryption (sometimes combined with pattern or image matching) to regulate user access to the network.

These differences in technology supply are related to the underlying nature of technology. Encryption technology, at its core, consists of mathematical algorithms that can be succinctly represented, and easy to protect via patents (Gambardella and Giarratana, 2008). By contrast, pattern matching technologies, such as anti-virus, reflect experience and heuristics

[8] In our empirical analysis, we sometimes group product market segments into those based on encryption technologies, and those based on other technologies. However, our results are not affected by separately controlling for each market segment.

rather than precise mathematical theories. The innovations in pattern matching technologies are less easily codified and can be invented around more easily than encryption algorithms.

The greater codifiability and superior patentability of encryption technologies implies that such technologies can be licensed more efficiently (Arora and Gambardella, 1994). An innovator who discovers a more efficient algorithm for encrypting data can appropriate the value of the innovation quite easily by licensing it to other firms, who can then implement the algorithm in software and hardware products.

There are a handful of firms that specialize as suppliers of encryption technology, of which RSA and Certicom are the most successful, mainly to network security and authentication product firms.[9] Other technologies such as image matching, pattern matching and single sign on are also licensed to others by firms that also sell products by incorporating the technology. For instance, Symantec sells an antivirus product but they also license pattern-matching technology. Similarly, Checkpoint not only sells firewall, but it also licenses pattern matching technology to other firewall producers. Our empirical analysis focuses on the downstream markets (i.e., product markets), and analyses how exit in this market is related to variations in technology supply in the market for technology, and how this is moderated by different types of firm capabilities.

Sources of firm formation and patterns of entry into ISM:

ISM has grown considerably over the past 15 years. The industry thus far has not experienced a shakeout, as also confirmed by Giarratana (2004). Entry (figure 1) shows two peaks – first around 1989 and the second one around 1995. The first peak was largely an after-effect of "Moris" worm, which sparked research in antivirus and network security technology.

[9] RSA after its merger with Security Dynamics in the late 1990s, entered the product market.

The second peak is around the advent of the internet, which increased entry, particularly by startups.

Entrants into the ISM were of diverse origins (table 2). About 83% of the entrants into the ISM were startups -- a statistic that is broadly similar to that of the U.S automobile industry. About 58% of the startups (48% of all entrants) had at least one founding member from a related industry such as computer hardware, software or telecommunications industry, a proportion once again, very similar to the U.S automobile industry (where related startups were 47% of total entrants).

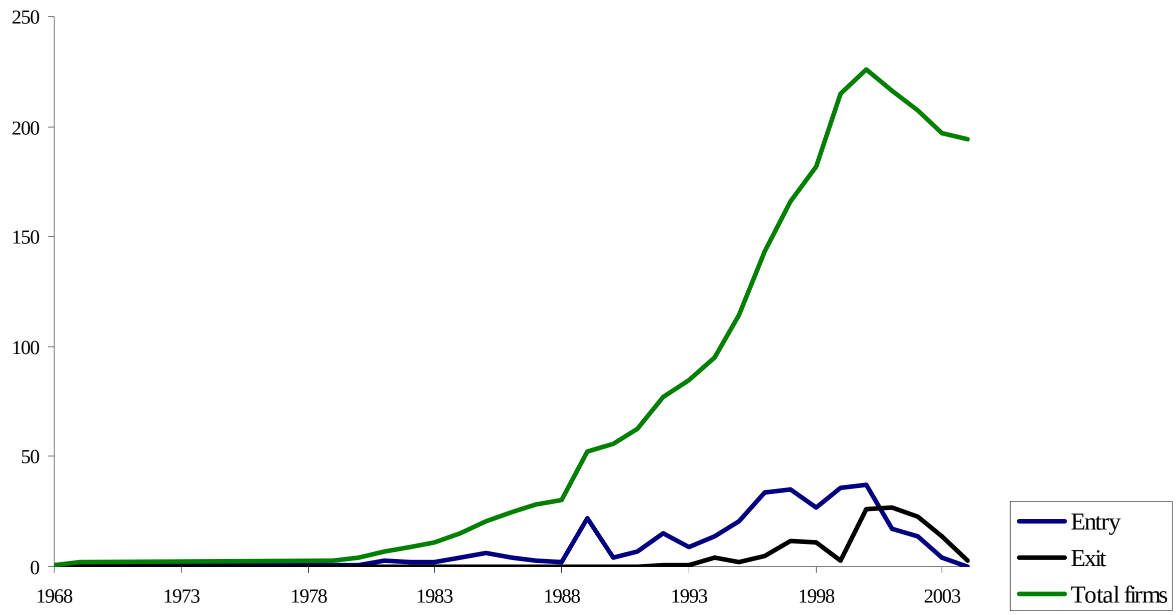

Figure 1 - Entry and exit into ISM

The ISM also witnessed entry by university based startups particularly in encryption, a pattern that was true of the laser industry (Sleeper, 1998) as well as of medical devices (Chatterji, 2006). However, the proportion of such entrants was significantly lower (8% in ISM vs. 26% in laser and 29% in medical devices).

Overall, despite the pervasive nature of IT and non-manufacturing nature of ISM, the sources of entry in the ISM are surprisingly similar to other manufacturing industries studied in the literature, with two exceptions: first, the importance of hackers, and second the virtual absence of spin-offs. Hackers personify what von Hippel (2005) has dubbed the democratization of innovation, perhaps a throwback to the tinkerers and inventors of the 19th century.[10] While in most manufacturing based industries, spin-offs constitute a big percentage of all startups, only 6% of all entrants in the ISM, perhaps reflecting its relative youth.

Table 2- Sources of entry in ISM

Entrant type	ISM	Automobiles	TV industry	Medical devices	Laser
Diversifiers	17%	17%[a]; 35%[b]	30%[e]	-	-
ICT startups	45%	47%[a]			
user startups	21%	32%[a]	-	34%[c,y]	44%[d]
Spin-offs	5%	20%			18%
University	8%	-	-	29%[c,z]	26%[d]
Hackers	10%	-	-	-	-

Notes: The total proportion adds up to more than 100% because many firms have multiple founders. In our empirical analysis we club hackers and University professors with user startups.
[a] Carroll et al, 1996; [b] Klepper, 2002; [c] Chatterji, 2006; [d] Sleeper, 1996; [e] Klepper and Simons, 2000
[z] Compared with clinical doctors in medical devices industry.
[y] Entrants from defense, financial services, insurance and aerospace compared with "outsider"+ serial entrepreneurs in medical devices industry.

Table 3 – Entry, exit, patenting, and licensing by submarket type

	Pre 1995	1996-2004	Total	Security patents per entrant at time of entry	Licensing deals per producer
Encryption based[b]	42	174	216	12.85 (8.75)	0.69 (0.01)
Other[c]	16	111	127	2.69 (11.35)	0.26 (0.02)

Table 3 (cont.) – Entry, exit patenting, and licensing by submarket type

	Specialized technology suppliers	Avg. Share of Non-prod. Security Patents In Stock of Total Information Security Patents	% entrants with in-licensed technology[a]	Proportion of firms that exited on or be ore 2004
Encryption based[b]	17	73.18 (12.81)	65	0.27 (0.03)

[10] For, instance von Hippel, 2005 in his study found that nearly 50% of webmasters implemented custom extensions to the security module of Apache web server.

Other[c]	0	26.16 (7.81)	13	0.22 (0.04)

Notes:
[a] Percentage of entrants with in-licensed technology based on a subset of entrants for which information could be gathered.
[b]Encryption based: encryption products, network security, and authentication
[c]Other: firewalls, antivirus, spam control, hardware, and consulting

Technology and product markets:

As explained earlier, ISM comprises of several product markets. Firewall, antivirus, authentication, encryption, hardware, network security, spam control and consulting. Encryption is by far the most patented intensive ISM technology (Giarratana 2004). Roughly two thirds of all security patents related to encryption technology. Encryption based market segments are also more licensing intensive. Table 3 shows the number of patents per entrant and the number of licenses per entrant in ISM. There were almost three times as many licensing transactions per firm in encryption based markets relative to other markets. Finally, for a subset of entrants, we were able to trace the source of technology. The last column in table 3 shows that whereas 65% of the entry in encryption was based on licensed technology, the corresponding figure is only 13% for the other markets. Encryption based markets also had above 5 times more non-producer patents than non encryption markets.

4. Data:

Our sample consists of 343 security firms, followed from the time of entry until 2004 or their exit, whichever is earlier. From the Corptech directory, we obtained names of all firms that entered ISM between 1989 and 2004. We then manually augmented this dataset with information on the submarket of entry using Internet archives (www.archive.org), an internet web site that maintains historical archives of many web sites.

Firms in our sample exited due to two reasons: non viability of the business (death) or acquisition by another firm (merger) (identified using Lexis-Nexus mergers and acquisitions database). These were coded separately in the dataset. As we will explain later, in the empirical analysis, we treat unsuccessful acquisitions (based on reported transaction values) and distress acquisitions as exits, while we treat successful acquisitions equivalent to survival.

We also recorded the sources of entry by tracking information about the founders (for up to 4 founders) of security firms from a variety of publicly available data sources on the internet such as ZoomInfo (www.zoominfo.com), LinkedIn (www.linkedIn.com), Google Archives (www.archives.google.com) Internet Archive (www.archive.org) and EDGAR database.

Type of entrant: We distinguish between existing firms (non-startups, henceforth) entering ISM from startups. We classified startups into one or more of the following categories based on the immediate prior experience of founders: *spin-offs* (firms founded by employees of an ISM firm), *ICT startups* (startups founded by employees of computer hardware, software, IT consultancies, or telecommunication firms – ICT firms), *user* startups (founders from defense, finance, aerospace and automobile industries), and *other* startups, with founders from universities or hackers.

For all sample firms, we also collected the number of information security patents from the US.PTO database. Security related patents are those that belong to the US patent technological classes 705 subclass 50-79, 380 and 726. In the empirical analysis, we use the number of information security patents, weighted by the number of forward citations.

Supply in the market for technology: Our hypotheses are implicitly specified in terms of the supply of technology. We develop two alternative measures that proxy for the supply of ISM technologies. The first is the number of *non-producer information security patents,* (lagged by one year from the date when the focal firm was established). These represent information security technology that can be potentially embodied in products sold by ISM producers. We constructed this variable by removing the total number of security patents, held by ISM producers (producers that entered ISM any time during the sample period) from the total pool of security patents. We then assigned the remaining patents (held by non ISM firms, individuals, and universities) to ISM segments using a many-to-one US.PTO sub-class - ISM segment mapping developed using the following method: we first identified specialist firms – ISM firms that only produced one type of ISM product and had more than 15 security patents (up to 3 firms per ISM segment). We then determined the most common US.PTO patent sub-classes that the specialist firm's patents patented in -- we first, collected all the US.PTO subclasses that the specialist firm's patents related to using all the patents that were granted to the specialist firm had till 2004. From this set of US.PTO subclasses, we then removed subclasses in which the specialist firm had less than 5% of its total patents. We then used the remaining US.PTO subclasses to assign every remaining security patent to an ISM segment using the identified subclasses (see appendix for details). This variable thus varies not only between segments but also within a segment over time.

Our benchmark specification uses the number of non producer security patents. This measure captures the notion that non producers that hold technology have an incentive to license it because they do not intend to enter the industry, and licensing is thus a profitable strategy (e.g., Arora and Fosfuri, 2003). While it is plausible that sub-markets that have many patents are more prone to hold-up problems, which discourages entry (Cockburn and MacGarvie, 2007), since we use patents held by firms that did not enter the ISM, we argue that our measure perhaps captures the extent to which technologies can be freely licensed as opposed to measuring the existence of thickets. Moreover, many non-producers of ISM technologies comprise of universities and smaller firms that may lack complementary capabilities to commercialize the technology. Arora and Ceccagnoli (2006) show that small entities and entities that lack complementary marketing and manufacturing capabilities are more likely to use patents to earn licensing revenue. This is also consistent with, for instance, Lieberman's (1989) findings that patenting by foreign producers is associated with entry into chemical markets. A potential disadvantage is that patenting trends may also pick up unobserved differences in the economic conditions in the relevant market segments, and thus be potentially related to entry and exit. Accordingly, we lag this variable to minimize this problem. In addition, in the regressions, we use industry age and its square as controls.

Our second measure uses the numbers of specialized technology suppliers i.e., firms that specialize in licensing ISM technology to others. In the data set there are 17 pure technology suppliers that entered the ISM at different points in time, all of whom licensed encryption technology. One potential disadvantage with this measure is that the number of specialized technology suppliers may depend upon product market conditions. For instance, intense product market competition may favor the entry of specialized suppliers (e.g., Bresnahan and Gambardella, 1997). Accordingly, we also use market segment fixed effects to control for differences across markets. Moreover, we also estimate a specification where we use only the variation over time.

Table 4: Description of measures used

Variable	**Description**	**Unit of observation**	**Mean**	**Std. Dev**
Log(1+non-producer patents)	Log of 1+ # weighted security technology patents held by non-ISM producers.	Firm	4.95	2.03
Log (1+tech.suppliers)	Log of 1+ lagged specialized technology suppliers.	Segment and year	2.52	0.51
Log (1+security patents)	Log of 1+ # of weighted security patents held by a firm at entry.	Firm	0.37	0.91
Log (1+ IT trademarks)	Log of IT trademarks held by firm at entry.	Firm	0.94	1.01

Sales executives	# sales or marketing executives in the firm at the time of entry. This variable includes founders who perform sales or marketing function in the firm.	Firm	1.12	0.83
Log(Size)	Log of 1+ # employees at entry.	Firm	3.70	1.25
Encryption based segment	Dummy variable for markets that use encryption technology; covers NW security, authentication and encryption product segment	Segment	0.62	0.49
Industry age	Age of the industry measured from 1970		8.87	5.68
ISM tenure	Current year minus ISM entry year	Firm and year	6.88	4.94
Non-startup	=1 if the entrant is a diversifying firm	Firm	0.17	0.38
User startup	=1 if the entrant has a founding member from non ICT firm	Firm	0.11	0.31
ICT startup	Startup with a founder from an ICT firm	Firm	0.48	0.5

Marketing Capability: We develop two different measures that proxy the marketing capability ISM firms. For non startups (i.e., existing ICT firms diversifying into ISM), we collected the number of *IT trademarks* such firms had at the time of entry into the ISM, using a keyword search on the US PTO trademarks database (http://tess.uspto.gov).[11] Since startups typically did not have any trademarks at the time of entry, we measure the marketing capability of startups using the number of *sales executives* that the startup had listed in the CorpTech directory, at the time of entry. The CorpTech directory lists the names of top executives (among top 10 employees of the firm) that are reported by the firm to be performing sales or marketing functions in the firm. Since these two measures, *IT trademarks* and *sales executives*, are not commensurable, we interact each measure with a dummy for the type of firm (i.e., startup or non-startup) in the empirical analysis.

[11] We used the following search query on the trademark database. Trademark description includes ("computer") OR ("hardware") OR ("pixel") OR ("telecom") OR ("telecommunications") OR ("software") OR ("Wireless") OR ("computing") OR ("database") OR ("data base ") OR ("pixels") OR ("computer program") OR ("Network") OR ("LAN") OR ("Networking") OR (" computer protocol ") OR (" Internet ").

Scale: The scale of operations in ISM is only available for startups. For startups, we measure scale by as the number of employees at the time of entry into the ISM. For 35 startups we are unable to obtain data on size. We use this measure only in for analysis of the startup sample.

ISM tenure: It is well known that survival is time dependent – firms that survive for a certain number of years are likely to survive longer (Dunne *et al.*, 1988. 1989; Evans 1987; Audretsch and Mahmood, 1995, Mata and Portugal, 1994). In other words, hazard rates are not independent of how long the firm has survived. To control for this, we control for how long the firm has survived using ISM tenure, which is the number of years a firm has been in the industry. To allow for non-linearities, we also include the square term. For startups we measure tenure from the year the startup was established till the year of observation. For non-startups we measure tenure from the year the non-startup entered the ISM, till the year of observation.

Industry age: It is plausible that firm survival may vary over the age of the industry, as it grows and then matures (see for instance Agarwal and Gort, 2002). We control for this using Industry age, which is simply the number of years from 1970.

Encryption based segment dummy takes a value of 1 if the focal firm entered encryption products, network security, and authentication segments and 0, if the focal firm entered non encryption based markets comprise of firewalls, antivirus, spam control, hardware, and consulting segments.[12] We use this in to control for differences between encryption based technologies and other information securities.

Non-startup: Since it is plausible that failure rates are particularly higher for younger firms relative to older ones (e.g., Stinchcombe, 1965), we distinguish between startups and incumbent

[12] Note that we only measure the segment of entry.

firms diversifying into ISM, using a dummy variable that equals 1, if the focal firm was an incumbent firms that diversified into the ISM.[13]

In addition, we distinguish between different categories of startups in some specifications.

User startup equals 1 if the focal startup was started by a founder that worked for a non ICT based industry immediately to starting the ISM firm. [14]

ICT startup is a dummy variable that equals 1 if the focal firm was started by a founder that worked for an ICT firm immediately prior to founding the focal startup.

Spinoff takes a value of 1, if the focal startup was started by a founder that worked for another ISM firm immediately prior to founding the focal startup.

Entry Cohorts: As discussed, the demand for information security prior to the Internet was limited and the growth of the Internet provided a great boost to demand. The boom years were also a time of great entrepreneurial experimentation and it plausible that firms that entered during that period were different from those that preceded them. After the collapse of the Internet bubble, it is plausible that financing and survival for Internet focused companies became harder. Accordingly, we distinguish between *when* the firm entered, using three time periods: Prior to the Internet (1980-1995), Internet boom years (1996-2000), and post bubble (2001-2004).

5. Empirical results:

The ideal measure of the extent to which technology can be freely in-licensed, in the market for technology is the price of technologies to potential entrants. Since such data are not available, we use two proxy measures, namely the number of specialized technology suppliers and the number of non-producer security patents. Our benchmark specification uses the number

[13] All incumbent firms diversifying into ISM were ICT firms in our data.
[14] Our startup categories are not mutually exclusive and startups can belong to more than one startup category,

of non-producer patents. As explained earlier, this measure varies both across ISM segments as well variation over time.

We consider startups at risk of exit from the time the startup was established while we consider diversifying entrants at risk of exit from the time of entry into ISM. Observations that relate to firms that were still alive at 2004 were considered as censored observations. Moreover, firms that were acquired on friendly terms, we also considered as censored observations. Moreover we considered firms that were sold in distress as exits.[15]

As is standard in the literature, we use estimate hazard models that estimate the conditional probability of exiting the product market, as a function of the number of non-producer security patents. The use of survival as a measure of performance is very common (Klepper and Simons 2000; Carroll *et. al*.1996; Thompson 2005). However, it is possible that the decision to exit reflects considerations unrelated to performance. Further, these considerations may vary across firms. For instance, diversifiers may have deeper pockets, or may be willing to lose a little money in security markets to achieve other strategic objectives, such as providing a complete suite of products to customers. On the other hand, founders that identify personally with the business may tend to linger on long after it is clear that the business is not viable. (See Blanchflower and Oswald, 1998, for evidence of the non-pecuniary benefits to entrepreneurship) More importantly, there is no reason to believe that these departures vary in any systematic way with our measure of technology supply in the market for technology. Thus,

[15] Whether the sale was distress was determined using the language of the press release of the acquisition. if the press release stated that the merger was an "asset purchase", it was treated as a distress sale and classified as an exit e.g. Netopia acquisition of DoBox Inc http://www.bizjournals.com/sanfrancisco/stories/2002/04/01/daily4.html (last accessed july 27, 2008) , Contentwatch acquisition of NetNanny software see http://www.manac.com.au/releases/44/Net_Nanny.pdf (last accessed July 27th 2008). If "asset sale" was not used in the press release, this was considered not considered to be an exit. A total, of 79 firms in our sample were acquired, of which 11 of the acquisitions were classified as being distress. We get qualitatively similar results even if we treat all acquisitions as censored observations.

though exit decisions may depart from the expected profitability of the firm, this should not bias our estimates.

Table 5 -Cox proportional hazard regressions of exit, all entrants

	Spec 1		Spec. 2		Spec. 3	
Non-startup dummy	-1.83	***	-1.88	***	-1.84	***
	(0.29)		(0.26)		(0.18)	
Encryption based segment	0.28		0.25			
	(0.26)		(0.27)			
Log(1+non-prod. sec patents)	0.17	***	0.17	***	0.26	***
	(0.05)		(0.05)		(0.06)	
Log (1+ sec. patents)	-0.20	**	-0.17	*	-0.18	**
	(0.10)		(0.10)		(0.07)	
Non-startup*Log (1 + IT trademarks)	-0.20	***	-0.21		-0.22	***
	(0.07)		(0.08)		(0.07)	
Startup* Sales Execs	-0.42	***	-0.44		-0.37	***
	(0.17)		(0.15)		(0.13)	
Spinoff			-0.27		-0.13	
			(0.63)		(0.66)	
ICT startup			0.13	*	0.24	**
			(0.07)		(0.10)	
User startup			-0.21	***	-0.20	***
			(0.06)		(0.04)	
ISM tenure	-0.10	*	-0.09	*	-0.08	*
	(0.05)		(0.05)		(0.04)	
ISM tenure^2	-0.01	***	-0.01	***	-0.00	
	(0.00)		(0.00)		(0.00)	
Industry age	-4.91	***	-4.79	***	-4.52	***
	(1.00)		(0.85)		(0.64)	
Industry age^2	-0.09	***	-0.09	***	-0.08	***
	(0.02)		(0.01)		(0.01)	
N	326		326		326	
Entry cohort dummies (2)	Yes		Yes		Yes	
Sub market fixed effects (7)	No		No		Yes	
LL	-287.49		-286.91		-279.92	

Notes: ***Significant at 1%. ** Significant at 5%. * Significant at 10%. Startups have no trademarks at entry. Standard errors cluster corrected by ISM segment.

We focus our analysis on ISM producers and exclude 17 observations which relate to firms that are specialized technology suppliers. We use IT trademarks as a proxy for marketing assets for non-startups while we use number of sales executives at the time of entry to measure of marketing capability for startups. We use the citation weighted security patents to control for technical capability of firms.

In specification 1, we do not distinguish between the different types of startups, but simply between startups (de novo entrants) and incumbent firms diversifying into ISM. As well, we distinguish between encryption based market segments (encryption products, network security, and authentication) on the one hand and others (firewalls, antivirus, spam control, hardware, and consulting) on the other. In specification 2 we further distinguish between different types of startups (spinoffs, ICT startups, user startups and others). In specification 3 we put in individual market segment fixed effects, instead of merely a dummy for encryption based segments and non-encryption based segments.

Hypothesis 1 postulated that an exogenous increase in the number of technology suppliers lowers entry barriers, increases entry and product market competition. Ultimately, this increases the average likelihood of exits in the ISM. The results broadly support this hypothesis. The estimated effect of *log(1+ non producer security patents)* is statistically significant in all specifications and economically large. Specification 1, for instance, implies that that a 1 standard deviation increase in the supply of technology is associated with a about a 96% increase in the hazard of exit.

As is the case with many other industries, diversifiers (non-startups) are likely to survive longer than startups. In specification 1, diversifiers are almost 84% less likely to exit relative to startups. All sources of competitive advantage find support as well. Hypotheses 2a and 4a implied that technological and marketing capability respectively should improve performance. The estimation results broadly confirm this. The coefficient of *log(1+security patents),* which measures technical capability is significant and large – e.g., from specification 1, a firm with one standard deviation higher technical capability than average has a 17% lower hazard of exiting the ISM. Both our measures of marketing capability find support as well: In the case of startups, one standard deviation higher than average marketing ability (*sales executives*) at the time of entry is associated with about a 18% decrease in the hazard of exit; in the case of non startups, a 1 standard deviation higher marketing ability than average (*IT trademarks*) lowers the exit hazard by about 6%.

Specification 2 shows that the estimate of the effect of technology markets on the average hazard of exit is unchanged after we control for the type of startup, instead of merely distinguishing between startups and other entrants. Interestingly, user startups appear to perform better than ICT startups, and spinoffs do not appear to enjoy any particular advantage compared to other startups, contrary to the findings in the prior literature. The estimates of specification 3, where we additionally control for the individual market segment fixed effects, show that our results are not driven by unobserved differences across the different market segments.

Hypotheses 2, 3, and 4 deal with technical capability, scale and marketing capability respectively. As noted, we do not measure scale for non-startup firms. As well, we have different measures for marketing capability for startups and non-startups. Finally, as noted, exit decisions may systematically differ across startups and other entrants. This suggests using a more homogenous sample as well. Startups account for the bulk of our sample. Table 6 reports the results where we confine ourselves only to startups.

To account for startups that do not report their initial size (35 in all), in specification 1, we use the *size not reported* dummy variable, which takes a value of 1 if the focal startup does not report its initial size, and interact this dummy variable with log(size) in the regression. In effect, the effect of size is measured only using firms for which size is available but we are able to use all observations. Our results are unchanged if we use only the observations for which size is available, as shown in later specifications.

First, the results support hypothesis 1 – the impact of technology supply is statistically significant and economically meaningful. An increase in the supply of ISM technology is associated with higher average exit hazards – a one standard deviation increase in the supply of technology increases the relative hazard from 2.1 to 2.8, or by about one third.

Second, the results the benefits of size supports hypothesis 3a. For instance, in specification 1 in table 6, a firm one standard deviation larger than average has a 10 percentage points lower hazard of exit: the relative hazard of exit drops from 0.51 to 0.41. Similarly, hypotheses 2a and 4a are also supported: Both technological (*security patents*) and marketing capabilities (*sales executives)* decrease the probability of exit for startups.

In specifications 2 through 4, we test hypotheses 2b, 3b, and 4b, by interacting the measure of technology supply with measures of technical capability, marketing capability, and size. In order to avoid three way interactions with size we drop observations that relate to startups that do not report their initial sizes. This leaves us with 235 observations in specifications 2 through 4.

The results support hypothesis 4b: the interaction between our measure of technology supply and marketing capability is negative, implying that the relative advantage due to marketing ability is amplified by a market for technology. For startups with no sales executives, a one standard deviation increase in the supply of technology increases the hazard of exit by about 30%. By contrast, for startups with one sales executive, a one standard deviation increase in the supply of technology has virtually no effect on the hazard of exiting the ISM. In sum, the intensification of product market competition due to lowering of entry barriers differentially benefits firms with marketing capabilities.

Table 6 -Cox proportional hazard of exit (Startups only)

	Spec. 1	**Spec 2**	**Spec. 3**	**Spec. 4**
Encryption based segment	0.14	0.02	-0.12	
	(0.16)	(0.11)	(0.10)	
Log(1+non prod. Patents)	0.15 ***	0.13 *	0.20 ***	0.22 ***
	(0.04)	(0.07)	(0.05)	(0.06)
Log (1+ sec. patents)	-0.23 *	-0.74 ***	-0.79 ***	-0.81 ***
	(0.13)	(0.15)	(0.12)	(0.09)
Log(1+non prod. Patents.)*(log(1+sec.patents))		0.11 ***	0.13 ***	0.18 ***
		(0.02)	(0.01)	(0.03)
Sales Execs	-0.33 ***	-0.16	-0.17	-0.19
	(0.18)	(0.10)	(0.11)	(0.12)
Log(1+non prod. Patents)*Sales Execs		-1.20 ***	-1.32 ***	-1.28 ***
		(0.60)	(0.38)	(0.45)
Size not reported dummy	-0.03			
	(0.25)			
Log(1+non prod. Patents)*log(size)		-0.04 ***	-0.06 ***	-0.08 ***
		(0.02)	(0.01)	(0.03)
(1-Size not reported)*log (size)	-0.18 ***			
	(0.02)			
Log(size) at entry		-0.15 ***	-0.13 ***	-0.22 ***
		(0.05)	(0.03)	(0.04)
Spinoff			-0.02	-0.03
			(0.08)	(0.23)
ICT startup			0.18 **	0.19 **
			(0.08)	(0.09)
User startup			-0.44 ***	-0.27 *
			(0.08)	(0.15)
ISM tenure	-0.11 ***	-0.11 ***	-0.10 ***	-0.09 ***
	(0.01)	(0.01)	(0.01)	(0.10)
ISM tenure^2	-0.01 ***	-0.00 ***	-0.00 ***	-0.00 ***
	(0.00)	(0.00)	(0.00)	(0.00)
Industry age	-4.62 ***	-4.76 ***	-4.76 ***	-4.22 ***
	(0.81)	(0.66)	(0.67)	(0.56)
Industry age^2	-0.08 ***	-0.09	-0.09 ***	-0.07 ***
	(0.01)	(0.01)	(0.01)	(0.01)
N	270	235	235	235
Entry cohort dummies(2)	Yes	Yes	Yes	Yes
Sub market dummies(7)	No	None	None	Yes
LL	-262.99	-204.69	-205.03	-197.01

Notes: ***Significant at 1%. ** Significant at 5%. * Significant at 10%. Startups have no trademarks at entry. 35 startups do not report entry size. [a] Firms for which size is not available are dropped from specifications 2,3 and 4.

We did not have strong theoretical priors on the interaction between markets for technology and firm size (hypothesis 3b). The results indicate that the intensification of product market competition appears to also benefit larger firms. From specification 2, for a startup of average size, a one standard deviation increase in the supply of technology increases the relative hazard by 0.52, whereas for startups that are one standard deviation larger than average, the relative hazard increases by only 0.32.

Consistent with hypothesis 2b, the interaction term of technology supply with technology capability is positive and is statistically significant. At the average level of technology supply, a one standard deviation increase in firm's technical capability decreases the relative hazard of exit by 0.29 whereas when technology supply is one standard deviation higher, a similar increase in the firm's technical capability decreases the hazard of exit by only 0.06. In other words, a firm's technical capability is a less potent advantage when technology is available from others.

5.3 Robustness checks and alternative explanations:

5.3.1. *Startup types and market effects* In specification 3 we additionally distinguish between the different types of startups namely related, unrelated, spinoffs and other startups. The impact of the independent variables of interest is largely unchanged. In specification 4, we additionally include all the ISM segment dummies, once again without much change in the results, implying that the heterogeneity between ISM segments does not affect our main results.

5.3.2: *Alternative measure of technology suppliers* We next test the robustness of our principal results using an alternative measure for technology supply the number of specialized technology suppliers. Since all the specialized technology suppliers in our sample license only encryption technology, there is no time variation in non-encryption markets, and thus the effect is identified within encryption based markets only, unlike the other measure of technology supply, which has time variation across all market segments.

As earlier we start by exploring the effect of technology supply on the likelihood of exits in specification 1 of table 7. Specification 1 shows that a one standard deviation increase in the number of specialized technology suppliers increases the average hazard of exit by about 2.5, broadly comparable to what we found earlier. Other results appear to be qualitatively similar our earlier results. Thus, the hypothesized effect of markets for technology in conditioning exits in the ISM is robust to alternative measures.

In specification 2, we explore the robustness of our results on how markets for technology condition the effect of different types of firm capabilities. The effect of technology suppliers is moderated by marketing capability (supporting hypothesis 4b). A one standard deviation increase in specialized licensors increases the relative hazard of exit by about 2.5 times and 1.35 times for a startup with no and one sales executives respectively. The interaction between technology suppliers and technical capability, although positive per hypothesis 2b, is not very precisely estimated. The interaction between technology suppliers and size is negative and significant. A one standard deviation increase in technology supply increases the relative hazard of exit by 17%, for a startup that is about 1 standard deviation larger, the hazard of exit increases by only 3%. In sum, our results about the effects of markets for technology are not sensitive to alternative measures of the supply of technology.

5.3.3: Results using encryption market only Another possible concern is that the estimates reflect unobserved differences between the various ISM segments. To address this concern, we redo the analysis using only firms *within* encryption based markets. The encryption market sample consists of 201 entrants, 166 of which are startups. We observe the entry size for only 160 startups in the encryption based segment.

Table 7 –Robustness checks: Cox proportional hazard of exit (Startups Only)

	Spec. 1	Spec 2	Spec. 3	Spec. 4
Non-start up dummy	-1.79 ***			
	(0.28)			
Encryption based segment	0.22	0.20		
	(0.31)	(0.28)		
Tech. supply measure[a]	0.70 ***	0.94 ***	0.16 ***	0.05 *
	(0.23)	(0.36)	(0.06)	(0.03)
Log (1+ sec. patents)	-0.19 **	-0.11	-0.09 ***	-0.78 **
	(0.09)	(0.08)	(0.07)	(0.38)
Tech. supply measure *(log(1+sec.patents))		0.03		0.19 ***
		(0.23)		(0.06)
Non-startups*log(1+trademarks)	-0.16 ***			
	(0.06)			
Sales Execs.	-0.35 ***	-0.25	-0.33 ***	-0.17
	(0.18)	(0.25)	(0.05)	(0.15)
Tech Supply Measure *Sales Execs		-0.45 ***		-1.18 ***
		(0.15)		(0.10)
Size not reported dummy[b]	-0.03		0.02	
	(0.25)		(0.49)	
Tech Supply Measure *log(size)		-0.12 *		-0.44 **
		(0.09)		(0.21)
(1-Size not reported)*log (size)	-0.18 ***		-0.13 *	
	(0.02)		(0.08)	
Log(size) at entry		-0.33 ***		-0.10 ***
		(0.09)		(0.02)
Spinoff			-0.02	-0.02
			(0.09)	(0.25)
ICT startup			0.26 **	0.20 **
			(0.03)	(0.10)
User startup			-0.28 ***	-0.26 *
			(0.05)	(0.15)
ISM tenure	-0.11 ***	-0.11 ***	-0.10 ***	-0.09 ***
	(0.01)	(0.01)	(0.01)	(0.10)
ISM tenure^2	-0.01 ***	-0.00 ***	-0.00 ***	-0.00 ***
	(0.00)	(0.00)	(0.00)	(0.00)
Industry age	-4.62 ***	-4.76 ***	-4.76 ***	-4.26 ***
	(0.81)	(0.66)	(0.67)	(0.56)
Industry age^2	-0.08 ***	-0.09	-0.09 ***	-0.08 ***
	(0.01)	(0.01)	(0.01)	(0.01)
N	326	235	201	160
Entry cohort dummies(2)	Yes	Yes	Yes	Yes
Sub market dummies(7)	No	None	None	None
LL	-285.46	-206.68	-129.57	-129.24

Notes: [a] Tech supply measure is Log (1 + specialized licensors) in specification 1 and 2, and Log(1+ non producer patent) in specification 3 and 4.
[b]42 firms do not report entry size. In the encryption market 26 firms do not report entry size. All specifications include 2 cohort dummy variables.

In specification 3 of table 7, we show the effect of markets for technology on the likelihood of exits using a subsample of firms (startups only) in the encryption market, and using our benchmark measure of technology supply. Technology supply increases the likelihood of exit among encryption firms: a one standard deviation increase in technology supply increases the hazard of exit by about 85%. Other results are qualitatively similar to the results shown above. In column 4 of table 7, we redo the estimation with by interacting our measure of technology supply with measures of firm capabilities, using only using startups in the encryption market. We lose some precision due to the fewer observations, but the results are qualitatively similar otherwise.

Overall, these checks testify to the robustness of our empirical estimates to alternative measures and to more homogenous (albeit smaller) samples. Simply put, our results are neither artifacts of unobserved heterogeneity across market segments, nor of the empirical proxies we use for the key theoretical variables.

6. Discussion and conclusion

Our results from the analysis of exit in ISM confirm the principal findings in the literature, while also adding to the literature by analyzing how markets for technology influences exits as well as the relative importance of different types of firm capabilities for survival. They reiterate the independent role of technology, marketing, and scale in facilitating performance. Moreover, despite accounting for differences in marketing and technological capability as well as initial size, differences in the type of entrant have large effects in both entry and exit. In particular, diversifiers outperform startups, including spinoffs and startups from related industries, indicating that incumbent firms diversifying into a new industry bring not just size, marketing assets, proprietary technology *and* experience, but also something else, which appears conditions entry strategy and to confer significant survival benefit, an avenue for further research.

As is often true of empirical analyses, our findings must be tempered by the reality of data imperfections. Not only do we fail to measure all the possible sources of advantage, but those that we do measure, we measure only imperfectly. Trademarks and the number of sales executives may not capture all important elements of marketing assets, such as the quality of the sales and marketing teams, existing relationships with customers, or the level of branding. Similarly, patents are but one manifestation of technical capability. Clever virus researchers for instance, rarely produce patentable technology. Instead, competitive advantage relies on the early discoveries of viruses and other types of malware and then the development of ways to detect and block them. In turn this may require the ability to constantly monitor the relevant Internet activity and a deep knowledge of the hacker community. Indeed, the differences across entrant types may be picking up these types of unmeasured differences in technical and marketing capability.

A second important caveat is also measurement related. Our key independent variable, the number of non producer patents, is an imperfect proxy for underlying conceptual category, namely the ability of potential entrants to get access to the technology required cheaply and easily. In addition, the measure is related to the nature of the underlying technology. We have tried to address these concerns in a variety of ways, including using an alternative measure for the supply of technology, using detailed market segment level controls, and even only using the variation over time (within a segment). Our results are robust to these alternatives, giving us confidence that measurement error is not likely biasing our result.

Subject to these caveats, we make two related contributions. To our knowledge, this is one of first papers to explicitly address examine how markets for technology conditions competition in an industry. In addition, we are also able to provide valuable empirical evidence on the performance of different types of entrants and on the role of different types of capabilities, marketing, technical and scale.

Our most important insight from our results is the role of markets for technology in conditioning competition. Our analysis also shows how the presence of technology markets alters the relative importance of different sources of competitive advantage for survival. Markets for technology lower entry barriers and enable firms that do not have proprietary technology to enter the industry. This stimulates competition in the related product markets and lowers the price cost margins of firms, leading to increased average exit rates. Further, markets for technology increase the relative importance of hard- to-replicate-assets such as marketing ability and scale, by hastening exits by firms that do not hold these assets.

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Data appendix:

A. Mapping of US.PTO subclasses to ISM segment

ISM Segment	**Most commonly cited US.PTO subclasses**
Encryption product	380/1, 380/39 through 380/43, 380/255, 380/259 through 380/261, 380/264,380/270, 380/277 through 380/286, 380/46, 380/47, 380/29, 380/30 and patent classes 709, 713
Authentication	380, 726/1 through 726/8, 726/17, 726/18, 726/19, 726/27, 726/28 through 726/30, 726/31 through 726/33%
Hardware	726/9, 726/20, 726/34, 726/34, 726/36%
Parental control	726/26
Network	380,726/22, 726/33
Firewall	726/11 through 726/16
Antivirus	726/24 and 726/25