

# Patents and the Survival of Internet-related IPOs

February 7, 2006

DRAFT ONLY

Iain M. Cockburn

Boston University and NBER

cockburn@bu.edu

Stefan Wagner\*

Munich School of Management, LMU Munich

swagner@bwl.uni-muenchen.de

## Abstract

We examine the effect of patenting on the survival prospects of 356 internet-related firms that made an initial public offering on the NASDAQ at the height of the stock market bubble of the late 1990s. By March 2005, almost 2/3 of these firms had delisted from the exchange. Changes in the legal environment in the US in the 1990s made it much easier to obtain patents on software, and ultimately, on business methods, though less than 1/2 of the firms in our sample obtained, or attempted to obtain, patents. For those that did, we hypothesize that patents conferred competitive advantages that translate into higher probability of survival, though they may also simply be a signal of firm quality. Controlling for other determinants of firm survival such as age, venture-capital backing, financial characteristics, and stock market conditions, patenting is positively associated with survival. Quite different processes appear to govern exit via acquisition compared to exit via delisting from the exchange due to business failure. Firms that applied for more patents were less likely to be acquired, though if they obtain unusually highly cited patents they may be a more attractive acquisition target. These findings do not hold true for "business method" patents, which do not appear to confer a survival advantage.

\*Financial support from the German Academic Exchange Service DAAD is gratefully acknowledged.

# 1 Introduction

Invention, entrepreneurship, and entry are very significant factors driving growth and competition. Patents are tightly linked to these fundamental economic processes, providing signals of quality to investors, some measure of protection from rapid imitation, and a basis for many types of commercial transactions in the market for knowledge (see Arora et al. (2001), Gans et al. (2002), or Scotchmer (2005)). This paper explores the role played by patents in shaping industry dynamics and firm survival during the remarkably rapid and unconstrained real time experiment provided by the dot-com boom of the late 1990s. During these “bubble years” new firms had unusually easy access to capital to fund their exploration of commercial opportunities opened up by the explosive growth of the internet. Entrepreneurs devised and implemented new business models and developed new products at an extraordinary pace, with new firms appearing apparently from nowhere to become household names in financial services, retailing, and many other sectors. Unfortunately, it equally quickly became clear that many of these new businesses were intrinsically unprofitable and the boom years of unrestricted entry, easy access to capital, and extraordinary valuations of untested new companies were quickly followed by an equally dramatic period of collapsing stock prices, exit and bankruptcies.

This remarkable episode took place against a backdrop of a worldwide surge in filing and granting of patents, and the extension of the patent system, particularly in the United States, into new subject matter areas such as software and business methods. Patentability of software per se was firmly established in the US by the mid-1990s, and decisions in the US courts in the late 1990s such as *AT&T v. Excel Communications* and *State Street v. Signature Financial Services* were widely interpreted as opening the door to a flood of patents on methods of doing business, particularly those implemented in computers and networks.

The new dot.com companies therefore had the option of seeking patent protection for many aspects of their products and business processes — as many inventors and entrepreneurs apparently did, with thousands of “business method” patent applications filed with the USPTO between 1999 and 2002. These patents generated enormous controversy, with many industry participants, legal scholars, and economists concerned about the potential adverse consequences of allowing large numbers of low-quality patents to issue. See Hall (2003), Merges (1999), Meurer (2003), Cockburn (2001), Hunt (2001) and many others. Many of these concerns parallel those expressed about the consequences of software patents for innovation and competition. Critics argued that the flood of business method patents would “choke” innovation by blocking new technological developments or making it prohibitively expensive for new firms to enter these markets, or allow patentees to control entire markets by obtaining patents with inappropriately broad claims, and/or trivial inventive steps over the existing technology. Apparently concerned about the opportunistic assertion of patents on business methods against incumbent firms, the US Congress took the unusual step of singling out business methods for special treatment, creating a limited “earlier inventor” defense against patent infringement (or prior user right) for “a method of doing or conducting business”.<sup>1</sup> However the impact of these patents on the profitability and growth of these the

---

<sup>1</sup>35 USC Sec. 273.

companies that obtained them, and on the pace of innovation in the industries in which they compete is far from clear.

Quantitative research on patents for software and business methods is limited. For example, Lerner (2002) found no clear evidence on the impact of patents on innovation in finance, while Bessen & Hunt (2004) suggest that increasing numbers of software patents are associated with a decrease in R&D by large software companies. There is, therefore, considerable uncertainty about the economic value and impact of these patents.<sup>2</sup>

Rather than attempt to directly assess the monetary value of these patents, or relate them to indicators of technological change, this paper examines the impact of patenting on the survival of a sample of internet-based and software firms that went public during the boom phase of the dot-com bubble, and then faced high probabilities of business failure during the bust period that followed. To the extent that patents obtained by these firms improved their competitive position, through mechanisms such as excluding competitors, supporting higher margins, raising rivals' costs, or signaling quality, they should have conferred a survival advantage. Estimates of the size and significance of such an effect may provide useful insight into the economic impact of these types of patents.

The remainder of the paper proceeds as follows. In Section 2 of the paper we briefly summarize previous findings on firm turn-over and review existing literature scrutinizing software and business method patents. Section 3 contains a short description of the dataset used for the analysis, which combines financial data and patent data for 356 firms that made an IPO on the NASDAQ at the height of the stock market bubble between 1998 and 2001. In Section 4, results are presented from estimating multivariate hazard models relating firm survival to patenting, financing, and economic performance. Finally, Section 5 concludes and offers some implications of our findings for future research and the current debate on patent policy.

## 2 Patents and the Turn-over of Internet Firms

In 1998 The United States Court of Appeals for the Federal Circuit removed the last obstacles to obtaining patents on pure business methods in the United States with its famous *State Street Bank and Trust Co. vs Signature Financial Group* decision involving US patent No. 5,193,056 in 1998 (Hunt 2001, Conley 2003).<sup>3</sup> As a consequence large numbers of applications for business method patents were filed in the USPTO. Many of the patents that subsequently issued protect inventions closely related to internet business models and software used in various e-business applications. The rapid increase in application and grant figures as well as some widely publicized patent infringement cases initiated a broad debate on the legal and

---

<sup>2</sup>Hunter (2003) and Allison & Tiller (2003) argue that business method patents compare well to patents in other technologies in terms of citation of prior art, etc.

<sup>3</sup>“As an alternative ground for invalidating the '056 patent under Section 101, the court relied on the judicially-created, so-called "business method" exception to statutory subject matter. We take this opportunity to lay this ill-conceived exception to rest.” *State Street Bank & Trust Co. v. Signature Financial Group, Inc.* 149 F.3d 1368. (Fed. Cir. 1998).

economic consequences of having those patents.<sup>4</sup> Concerns were been expressed by many scholars about the potentially low quality of granted business method and software patents as a consequence of inadequate examination procedures of the USPTOised by numerous authors (Dreyfuss 2000, Hunt 2001, Merges 1999, Wagner 2005). In response to criticism from academics, practitioners, and policymakers, the USPTO moved to tighten the examination procedures and standards for patents filed in USPTO Class 705, the principal classification for business method patents (USPTO 1999).<sup>5</sup>

Despite the debate on the consequences of granting large numbers of poor quality business method and software patents, their impact on economic outcomes — such as incentives to innovate and the pace of technical change — in affected industries has received little attention. These outcomes are very difficult to measure directly, but some insight into the economic significance of these patents may be gained from looking at whether or not they can affect the improve the economic performance of firms that obtain them.

Much of the literature on the value of patents has focused on indirect measures of their impact on profitability, such as stock market value of the firm. Relatively little systematic evidence has been gathered on relationships between patenting and more basic indicators of firm performance such as growth and survival. These may be particularly useful for small or new firms, where the signal conveyed by market valuation of intangibles may be particularly difficult to identify against the noise generated by high levels of uncertainty about future growth prospects, thin trading and very volatile asset prices.

One notable exception can be found in recent paper by Mann & Sager (2005). Here the authors combine data on the venture capital financing of software start-ups with data on the patents held by those firms in order to analyze the relation between patenting and their ability to obtain venture financing, as well as and their progress through the venture cycle. They find some correlation between patenting and different proxies for success but also acknowledge that the private value of holding software patents varies greatly between firms even within the same industrial subsegment.<sup>6</sup>

Here we tackle a similar question — is there a private benefit from patenting business methods and software? — with a somewhat different research strategy. Analyzing a set

---

<sup>4</sup>Outcomes of these cases have been mixed. In the *Priceline.com vs. Microsoft/Expedia* case, Priceline.com obtained an undisclosed settlement payment from Microsoft leading to a 30% increase in its stock market capitalization. But in another widely followed dispute, Amazon.com attempted to enforce a patent on “one-click” on-line purchasing against Barnesandnoble.com with only limited success: though Amazon.com succeeded in obtaining a preliminary injunction enjoining Barnesandnoble.com from using the Express Lane feature on its website during the busy Christmas buying season, this was quite quickly vacated on appeal in the face of persuasive evidence questioning the validity of Amazon.com’s patent. *Amazon.com v. Barnesandnoble.com, et al.* Civ. Act. No. 00-1109, 239 F.3d 1343 (Fed. Cir., February 14, 2001).

<sup>5</sup>While tighter scrutiny of applications through “second pair of eyes” procedures, recruitment of appropriately qualified examiners, and improved access to relevant prior art may have raised the quality of granted patents in this class, it is not clear whether the rate at which business method patents are being issued has fallen. Applicants are likely to have reacted to this tightened scrutiny of applications in class 705 by framing the content of the application in a way that increases the likelihood of it being directed to a different part of the Patent Office.

<sup>6</sup>In a comment on a closely related paper by Mann, Bessen (2005) points out that some of these findings have to be interpreted with caution.

of dot.com firms pursuing business models closely tied to internet services and software, we relate patent holdings to the survival of these firms as publicly traded companies. The survival analysis framework we employ for this purpose has been widely used in previous empirical studies of firm failure and industry dynamics. Compared to a relatively sparse theoretical literature<sup>7</sup>, IO economics is rich in empirical evidence on entry and exit, and there is a well-established set of ‘stylized facts’ on firm survival. Geroski (1995), Sutton (1997) and Caves (1998) provide comprehensive surveys. Considering firm characteristics, the most common result is that survival is positively related to firm size and to firm age. Most studies find that small firms (who are more likely to operate below the minimum efficient scale) exhibit higher failure rates. Moreover, younger firms have higher failure probabilities and Audretsch (1995) argues that firm age is a proxy for the accumulation of information about technology, markets and a firm’s own cost function. A greater stock of accumulated information should lead to higher survival chances. In addition to these firm characteristics, industry characteristics and the competitive environment have also been studied in depth. In particular, the point in the product/industry life cycle in which a firm operates has been found to be an important determinant of firm survival (Agarwal & Gort 1996, 2002). Further, failure is positively related to overall rates of entry in an industry (Mata et al. 1995, Honjo 2000) and also to average price-cost margins (Audretsch 1991, Audretsch & Mahmood 1995).

A number of recent papers have focused on the cohort of young high-tech firms that went public during the stock market bubble of 1998-2001. These studies seek to characterize both the extraordinary conditions of the equity markets at that time as well as the innovative activities of the new firms, relating these to firm survival after the IPO. Audretsch & Lehmann (2004), for example, analyze the survival times of a sample of 341 firms from various industries listed on the German *Neuer Markt*<sup>8</sup> as a function of firms’ human capital and intellectual property assets. Modelling the length of time a firm was listed on the stock market before it was delisted, the authors find that the likelihood of survival is positively related to firm size, the human capital accumulated in the board of directors, and the number of German patents held by a firm. Moreover, Audretsch & Lehmann (2004) find that failure rates are negatively affected by the investment share of venture capital firms prior to IPO. In a related study, Jain & Kini (2000) find that the presence of venture capitalists prior to going public improves the survival prospects of IPO firms.

Other studies have focused on the survival of firms that are based on a business model that relies on the internet to perform transactions, distribute products or provide services, and interact with customers. For instance, Kauffman & Wang (2003) analyzed survival times of 103 such “internet firms” listed on the NASDAQ.<sup>9</sup> Employing a competing risks specification

---

<sup>7</sup>Among the few theoretical treatments of firm turn-over are Jovanovic (1982) and Hopenhayn (1992) who suggest that in a theory of learning and noisy selection, firm age and size are important determinants of survival. In a recent paper, Cooley & Quadrini (2001) introduce financial markets to this model and analyze the effect of market frictions on firm survival.

<sup>8</sup>*Neuer Markt* was launched as market segment for high-tech and internet start-ups by the German Stock Exchange on March, 10<sup>th</sup>, 1997. Six years later on June, 5<sup>th</sup>, 2003 *Neuer Markt* was closed in a re-segmentation of the German Stock Exchange — most likely due to dramatic losses in market capitalization and loss of investor interest.

<sup>9</sup>The authors are not completely clear on whether their sample consists exclusively of NASDAQ-listed firms, but given the US context this seems highly likely.

they found that firms which distribute physical goods via the internet (as opposed to firms provided digital services) and firms which target both consumer and business markets have longer survival times until either a merger or a delisting occurs. Botman et al. (2004) analyzed survival of 326 internet firms listed on the NASDAQ between 1996 and 2001, as a function of variables intended to characterize market conditions at the time the IPO took place, the reputation of the management and the investment bank leading the IPO as well as firm characteristics such as financial condition and age. Their results show that surviving firms are associated with lower risk indications in the IPO prospectus, higher underwriter reputation, higher investor demand for the shares issued at the IPO, lower valuation uncertainty, higher insider ownership retention, a lower NASDAQ market level, and a higher offer-to-book ratio compared to non-survivors. Regarding the survivors versus acquired firms they find that acquired firms are smaller in size and have a longer operating history.

Our study focuses on the relevance of patents for the success of dot.com companies. In particular, we seek to analyze the extent to which these firms took advantage of the changing legal landscape with regard to the patentability of business methods, and the impact of these decisions on competitive outcomes. Our study therefore combines data on firm characteristics like age, financial condition, and market environment with detailed information on their patent holdings. The patent portfolios of firms in our sample are characterized not just by counting the number of patents held, but also by measures of patent quality based on citations and international filing patterns.

## 3 Data and Descriptive Statistics

### 3.1 Data

To address these questions, we gathered data on 356 firms that made an Initial Public Offering of shares on the NASDAQ stock exchange between February 1998 and August 2001. These firms were characterized by IPO.com, a popular financial research service, as operating in the Internet Services, Internet Software and Computer Software Segments. We were able to obtain comprehensive information on these firms including listing information, financial figures, firm age and a variety of measures with regard to their patent holdings. The data were obtained from different sources including the Delphion, USPTO, Compustat, CRSP and Venture-Xpert databases as well as firms' 10K filings and IPO prospectuses. In this subsection we briefly comment on the variables contained in our dataset before presenting descriptive statistics in the subsequent subsection.

**Listing Information.** For each firm we obtained detailed information on its listing on the NASDAQ stock exchange from the Center for Research on Security Prices *CRSP*-database. This data contains not only the date of the IPO (*ipodate<sub>i</sub>*) for each firm *i* but also information whether or not a firm is still listed on the NASDAQ. If trading in a firm's stock was discontinued, we are able to distinguish between firms which were *delisted* due to business

Table 1: Breakdown of firms by segment. Table includes selected examples of firms in each segment.

Segment	Firms	Examples
Internet Services	210	1-800-Flowers.com, 24/7 Real Media, Autobytel.com, Buy.com, Drugstore.com, eBay, E-loan, Freemarkets, Genuity, MP3.com, Priceline.com, Razorfish, Verticalnet
Internet Software	82	Critical Path, Entrust, Portal Software, Web-Methods
Computer Software	64	Inktomi, Manhattan Associates, Onyx Software, Perot Systems, Quest Software, Red Hat
<b>Total</b>	<b>356</b>	

failure<sup>10</sup> and firms which *merged* with other companies. In both cases, we compute the total length of the listing period on the NASDAQ as the time between the date of delisting and the date of the IPO. This “length of listing period” is used as the duration measure in the survival analyses.

**Industrial Classification.** Based on the classification used by IPO.com we distinguish between three different industrial segments: Internet Services, Internet Software and Computer Software. Dummy variables are included in the multivariate survival analyses using firms belonging to Computer Software as the reference group. These categories are far from precise, assignment of firms to segments may be questionable, and some firms may in fact be operating in more than one industry segment. Table 1 shows the breakdown of firms by segment, and lists some high profile examples of firms operating in each segment.

**Financial Data.** We obtained financial data on a quarterly basis from the *Compustat North America* database. Compustat provides information on operating income sales for each firm  $i$  in quarter  $t$ .  $op\_income_{it}$  and  $sales_{it}$  are treated as time-varying coefficients in the multivariate survival analysis of Section 4.<sup>11</sup>

**IPO Characteristics.** Our dataset contains information on a firm’s age when going public ( $age\_ipo_i$ ). It is measured as the difference between its  $ipodate_i$  and the date of legal incorporation which was obtained from the *Venture-Xpert* database. If the date of incorporation was not available from *Venture-Xpert* it was obtained from publicly available documents such as 10K reports and IPO prospectuses filed with the SEC. Information in the *Venture-Xpert* and *SDC New Issues* databases we used to determine whether or not each firm was venture capital backed before its IPO. Further, we obtained firms’ total assets reported in the quarter when going public ( $assets\_tot\_ipo_i$ ) from the *Compustat North America*-database.

<sup>10</sup>This category comprises firms which were delisted due to bankruptcy and firms which have been delisted for trading persistently below the minimum price of \$1 per share required by NASDAQ regulations.

<sup>11</sup>In rare cases, these variables are not available for occasional single quarters. We interpolate missing values by averaging the preceding and subsequent quarters’ value.

We include this as a measure of a firm’s capital endowment at “birth” in our multivariate analysis.

**Market Environment.** Capital markets in general, and the market for technology related IPOs in particular, were characterized by quite extraordinary “bubble” conditions throughout the period of this study. Investor “exuberance” created market conditions in which large amounts of capital could be raised at remarkably low prices, and with relatively little scrutiny. In order to control for these conditions, we include the average value of the NASDAQ Composite Index in the quarter prior to quarter in which a firm’s IPO took place (*nasdaq\_ipo\_lag<sub>i</sub>*) as a control variable in our regressions. Lagging this variable by one quarter allows us to control for timing of IPOs as response to a favorable market environment. It may also be informative about the underlying quality of the firms that sought to access public markets as a source of capital.

**Patent Information.** Various variables that describe a firm’s patent portfolio such as number of patents, international scope of filings, and proxies for patent value were collected from USPTO and other data maintained by Delphion Inc. For each firm in the dataset, Delphion’s databases on issued patents and published applications were searched by hand using the company name, along with word stems, common abbreviations, and obvious variations in spelling of companies’ names. “Weak” matches were verified by inspecting the inventor names, address information, citations to other patents, and the content of abstracts. In principle, this procedure captured all patent applications and issued patents for which the firm in question was the assignee. Nonetheless is likely that some patents controlled by the firms in this sample were not captured in this search. The search process relies heavily on USPTO’s coding of assignee names, and does not capture patents re-assigned to a firm after issuance, exclusively licensed from the inventor, or held in subsidiaries that we were not able to recognize. It is also possible that a significant number of pending applications have been missed in the search, either because the applicant chose to forfeit filing rights outside the US, thus avoiding publication of the application entirely, or because the 18-month period before publication was still in force at the time the search was performed.

Interestingly, notwithstanding many contemporary commentators’ beliefs that business method and software patents were trivially easy to obtain during this period, no issued patents or applications could be found for more than half of the firms in this sample. Dummy variables were coded to indicate whether firms in a particular segment did not apply for or hold any patents.

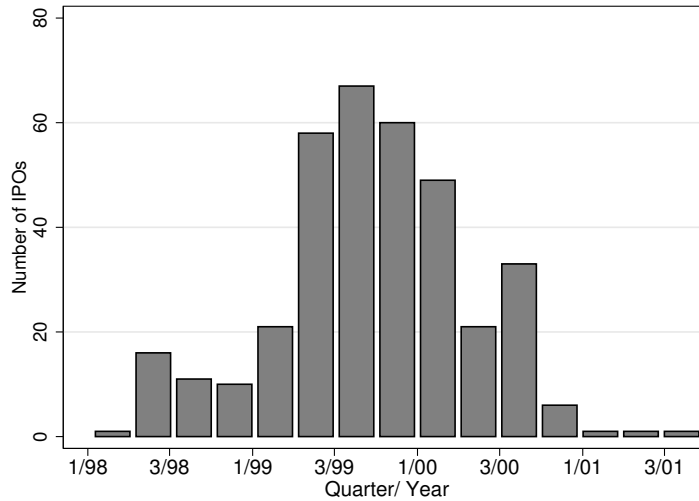
Various measures of the size and characteristics of each firms’ patent portfolio were computed. These include the number of USPTO patent applications and grants, as well as counts of applications and grants at the European and Japanese Patent Offices, plus variables which are correlates to patent value: the average family size of a firm’s USPTO patents, the average number of forward citations received per grant or application, and the number of forward citations per claim.<sup>12</sup>

---

<sup>12</sup>Lanjouw & Schankerman (2001) argue that this measure is superior to simple counts of forward citations. Note that this measure is computed using only granted patents since the number of claims



Figure 1: Distribution of the IPO dates of the 356 firms in our sample.



It is well-known that the value distribution of patents is highly skewed (Harhoff et al. 1999, 2003) and value measures averaging the number of cites per claim over patent portfolios largely obscures that fact. In order to capture a basic element of the skewness of the value distribution, the number of patents in a firm’s patent portfolio which received 7 or more forward citations (which is approximately the upper quartile of the distribution of number of forward citations in this sample) was also computed.

### 3.2 Descriptive Statistics

Before advancing to our multivariate analysis of firm survival in Section 4 we briefly present major descriptive statistics of the sample. In total, our sample contains 356 firms that went public between February, 25<sup>th</sup>, 1998 and August, 6<sup>th</sup>, 2001. These 356 firms make up about 74% of the total number of IPOs reported by IPO.com in the three industry segments considered. (The remainder are firms for which reliable matches were not possible to the databases on NASDAQ trading, venture funding, or financial information.) The distribution of the IPO dates of these firms (Figure 1) shows that most of them went public in the years 1999 and 2000. Strikingly, this distribution tracks the movement of the NASDAQ composite index during this period (see Figure 2).

In total, NASDAQ trading in more than 60% of the firms in our sample had been discontinued by March 1st 2005, the end of the observational period. Table 2 clearly shows that firms from the Internet Services segment exhibit highest exit rates with 69.5% compared to 59.7% for Internet Software and only 46.9% for Computer software firms. The average time elapsed until trading was discontinued is also presented in Table 2. Note that the average time until firms exited as a result of merger is significantly shorter than the time until delisting due to business failure. Moreover, this difference is much more pronounced for firms from the Computer Software segment compared to firms with a business model related to the internet.

---

is not reported for patent applications.

Figure 2: NASDAQ composite index for the period 1998 to 2001.

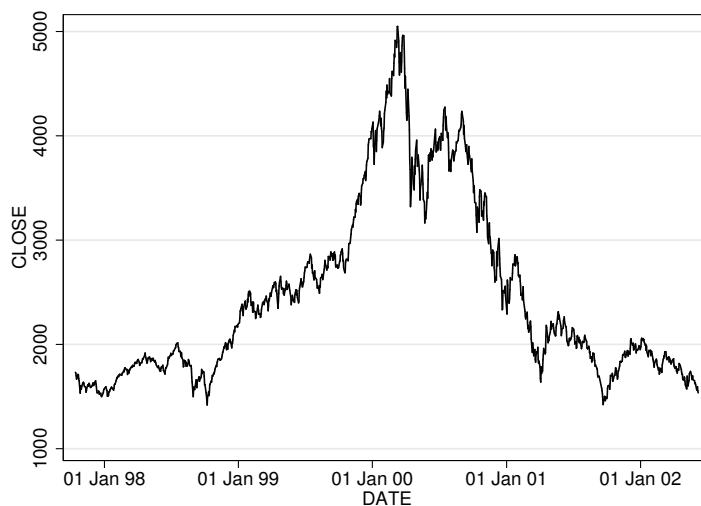
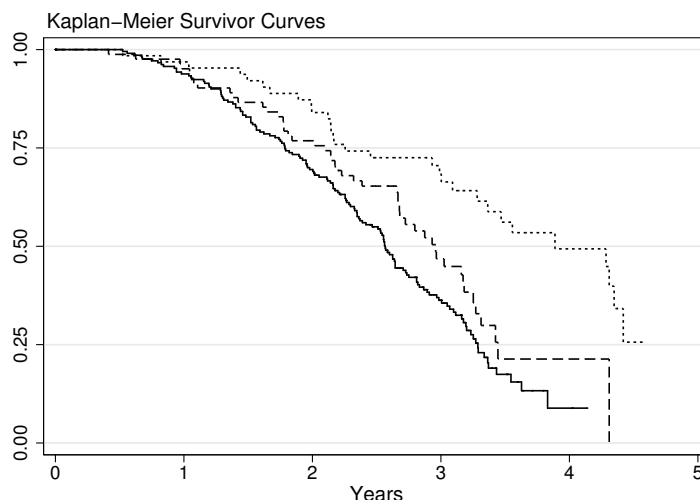


Table 2: Crosstabulation of industrial classification and the listing information for the firms contained in our sample. The second line of each row contains the average listing duration. Note: In a Pearson  $\chi^2$ -test the differences between firms of different industrial classifications turned out to be significant at the 5% level ( $\chi^2(4) = 11.57$ ).

<b>Classification</b>	<b>Listing Information</b>				<b>Total</b>
	<b>Still trading</b>	<b>Merged</b>	<b>Delisted</b>		
Internet Services	64 (30.48%)	87 (41.42%)	59 (28.10%)		210
	.	2.0 Yrs	2.3 Yrs		
Internet Software	33 (40.24%)	31 (37.81%)	18 (29.95%)		82
	.	2.1 Yrs	2.4 Yrs		
Computer Software	34 (53.13%)	18 (28.12%)	12 (18.75%)		64
	.	2.2 Yrs	3.1 Yrs		
<b>Total</b>	<b>131 (36.8%)</b>	<b>136 (38.2%)</b>	<b>89 (25.0%)</b>		<b>356</b>
	.	2.1 Yrs	2.4 Yrs		

Figure 3: Kaplan-Meier Survivor Curves for the firms in the sample. (—) Internet Services, (- - -) Internet Software, (· · ·) Computer Software.



In addition to the average survival times we also present Kaplan-Meier product-limit estimates of the survivor functions of the firms in our sample in Figure 3 (Kaplan & Meier 1958). The survivor curves again show that firms with internet-based business models drop out much earlier than Computer Software firms. Moreover, after one year the survivor curves for the three groups do not intersect, indicating that the proportionality assumption of Cox’s Proportional Hazard model is likely to hold with regard to the different classifications of our firms (Kalbfleisch & Prentice 2002).

Table 3 summarizes some of the important observable characteristics of the firms at the time of their IPO. First, consider the age of the firm. (Recall that age is measured as time elapsed from the date of incorporation until the date of the IPO.) While the average firm is 5.91 years old when the IPO takes place, firms from the Internet Services segment have a prior firm history of only 4.72 years, while firms from the other industry segments are significantly older: firms in the Internet Software segment averaged 6.78 years since incorporation, and those in Computer Software averaged 8.69 years. There are also differences across segments in the extent to which the IPOs of these firms were backed by venture capital firms. In particular, IPOs in the Internet Software segment were more frequently venture-backed (64%) than Internet Services firms (55%) or Computer Software firms (56%). Differences across industry segments are also apparent in the sales and operating profits reported by the firms for the quarter in which their IPO took place. On average, firms in the Computer Software segment realized the highest sales (US\$17.45 million) and made only minor operating losses of US\$0.5. Internet Services firms achieved somewhat lower sales, averaging US\$12.95 million, and Internet Software firms averaged even less, at US\$7.55 million in their first quarter as a public company. Moreover, when going public these internet-related firms were highly unprofitable with operating losses averaging US\$9.5 million per quarter in Internet Services and US\$5.6 million per quarter in Internet software (see Table 3).

Turning to information on the patenting activities of the firms in the sample, Table 4 reports the distribution of patent applications across technology classes, using the US Patent

Table 3: Mean values of major firm characteristics for the quarter when their IPO took place.

Firm Characteristics	<b>Internet Services</b> (n=210)	<b>Internet Software</b> (n=82)	<b>Computer Software</b> (n=64)	<b>Total</b> (n=356)
Age (Years)	4.72	6.78	8.69	5.91
Venture-backed	0.55	0.64	0.56	0.58
Sales (\$MM)	12.95	7.55	17.45	12.51
Op. Income (\$MM)	-9.50	-5.56	-0.49	-6.97
Assets (\$MM)	164.09	84.49	84.89	131.52
Proceeds from IPO (\$MM)	149.49	150.58	112.33	143.06

Classification scheme, and classifying patents based on the primary USPC code. Not surprisingly, classes that are relevant to the e-commerce and the internet (networking, databases, cryptography etc.) are well represented. Interestingly Class 705 (in which most business method patents should be classified) accounts for only 11.4% of the 1198 applications in our dataset.<sup>13</sup>

As noted above, a substantial fraction (53.8%) of the firms in our sample did not patent at all prior to March 2005, with significant differences across industry segments: 65.2% of the Internet Services, 51.2% of the Internet Software firms and 45.3% of the Computer Software firms had not filed a published patent application at the USPTO, the EPO, or the JPO.

Table 5 gives summary statistics of the patenting activities of firms that did file at least one published patent application. Firms from the Computer Software segment are most active patentees, averaging 12.29 USPTO applications per patenting firm, compared to 9.62 for Internet Software patenting firms, and only 4.92 USPTO applications for patenting firms in Internet Services.<sup>14</sup> Table 5 also reports the extent of international patenting activity by the sample firms. On average, EPO and JPO applications and grants are significantly lower than at USPTO, with smaller differences across industry segments. Curiously, despite being the least active patentees in terms of the average size of their patent portfolio, the share of international patentees is highest in the group of Internet Services firms, with the opposite effect visible for Computer Software firms.

In addition to the patent counts, Table 5 also reports measures of the value or quality of these firms' patent portfolios. The average number of claims for the patents held by the firms in our sample is 23.43 with small differences across groups. The average patent family size is 5.24. However measures which are correlates to patent value are of highest interest. Interestingly, we observe significant differences in the average number of forward citations per patent, which are highest for Computer Software firms with 7.32 compared to 5.14 for Internet Services and 4.60 for Internet Software firms. Similarly, the average proportion of firms' portfolios that is made up of highly cited patents (7 or more citations received) is

<sup>13</sup>These patents are held by 14 firms classified to Internet Services, 2 firms from Internet Software and only 1 firm from Computer Software.

<sup>14</sup>It is possible that these differences are a consequence of differences in firm age. However, the correlation coefficient between the number of USPTO patent applications and the firm age when going public is 0.06 and not significant.

Table 4: Classification of the USPTO patent applications of the firms in the sample.

<b>Class</b>	<b>Description</b>	<b>Patents</b>	<b>Share</b>
709	Electrical computers and digital processing systems: multi-computer data transferring	188	15.69%
705	Data processing: financial, business practice, management, or cost/ price determination	137	11.44%
345	Computer graphics processing and selective visual display systems	134	11.19%
707	Data processing: database and file management or data structures	122	10.18%
713	Electrical computers and digital processing systems: support	111	9.27%
704	Data processing: speech signal processing, linguistics, language translation, and audio compression	42	3.51%
380	Cryptography	38	3.18%
370	Multiplex communications	37	3.09%
434	Education and demonstration	37	3.09%
375	Pulse or digital communications	35	2.92%
379	Telephonic communications	33	2.75%
725	Interactive video distribution systems	26	2.17%
.	Other classes with less than 20 applications (2%)	258	21.54%
<b>Total</b>		<b>1198</b>	<b>100%</b>

Table 5: Mean values of major patent characteristics of firms who applied for at least one published patent application at the USPTO, EPO, or JPO. Firms without any patenting activities are excluded from the computation of average values. (+ indicates statistics only computed for granted USPTO patents since the number of claims is only available for granted patents.)

Patent Characteristics	<b>Internet Services</b> (n=74)	<b>Internet Software</b> (n=42)	<b>Computer Software</b> (n=35)	<b>Total</b> (n=151)
Share of firms with 0 applications	0.65	0.51	0.45	0.58
USPTO applications	4.92	9.62	12.29	7.93
USPTO grants	4.28	9.14	10.91	7.17
EPO applications	2.86	3.00	2.94	2.92
EPO grants	1.79	2.19	1.23	1.79
JPO applications	0.28	0.60	0.31	0.38
JPO grants	0.23	0.30	0.23	0.25
Share of international patentees	0.64	0.57	0.54	0.60
Family size at USPTO	4.89	5.36	5.86	5.24
USPTO claims <sup>+</sup>	22.42	23.91	25.00	23.43
Cites per patent	4.60	5.14	7.32	5.39
Share of patents with $\geq 7$ cites	0.21	0.27	0.35	0.26
Cites per claim <sup>+</sup>	0.50	0.56	0.64	0.55

highest in Computer Software, as is the average across portfolios of the number of citations received per claim. While it is tempting to interpret these as evidence of higher average quality or value of patents in the Computer Software segment compared to Internet Services or Internet Software, it is important to recognize that some of this variation may simply reflect differences across segments in the nature of technology or citation practices, and most importantly, in the size of the population of potentially citing patents.<sup>15</sup>

Finally, Table 6 summarizes our dependent variable of the multivariate analysis of Section 4 (the time between the IPO and the delisting of a firm) within different categorizations of important independent variables. Comparing the average duration for firms which filed at least one patent (opposed to firms which did not apply for a patent in the US) we find that patenting is associated with longer survival times. The same is true when distinguishing firm which obtained venture capital funding prior to their IPO with firms which did not. Having obtained venture capital financing is also positively related to the duration of the listing period on the NASDAQ. Finally, we relate financial characteristics like operating income and total assets when going public. We categorize these variables in the quartiles of their respective distribution and find that both influence survival chances. The relation between operating income and survival time is straightforward: Firms generating income in the top quartiles tend to exhibit longer survival times than firms from lower quartiles. The relation between assets reported when going public and survival is more complex. On average, we

<sup>15</sup>Interestingly, though, these differences do not appear to be driven by the age of firms and the age of their patents. Since older patents can be cited for a longer period of time than younger patents, they ought on average to receive more citations. However, the correlation coefficient between the number of citations received and firm age when going public is 0.03 and not significant.

Table 6: This table presents the time between IPO and delisting (duration) measured in years broken down by different categories of independent variables. Note that the table contains only the 225 firms which have been delisted from the NASDAQ within our observational period.

Variable	Merged Firms		Delisted Firms		Total	
	Duration	Obs	Duration	Obs	Duration	Obs
<b><i>Patents</i></b>						
At least one patent application	2.14	48	2.59	33	2.32	81
No patent application	2.01	88	2.32	56	2.13	144
<b><i>Venture Capital</i></b>						
VC funding obtained	2.25	46	2.54	40	2.39	86
No VC funding obtained	1.95	90	2.32	49	2.08	139
<b><i>Operating Income</i></b>						
1st Quartile	1.74	40	2.11	29	1.89	69
2nd Quartile	1.94	36	2.31	25	2.09	61
3rd Quartile	2.27	27	2.77	28	2.52	55
4th Quartile	2.37	33	2.67	7	2.43	40
<b><i>Assets at IPO</i></b>						
1st Quartile	2.25	36	2.44	24	2.33	60
2nd Quartile	1.92	36	2.56	23	2.17	59
3rd Quartile	1.91	38	2.33	17	2.04	55
4th Quartile	2.17	26	2.33	25	2.25	51

observe a U-shaped relation with firms belonging to the top and the lowest quartile having longer survival times than firms from the middle quartiles. However, firms which delisted their shares due to bankruptcy exhibit longest survival times if their reported assets lie in the 2nd quartile. In order to disentangle the effects of the different independent variables we conduct a multivariate survival analysis based on Cox Proportional Hazards model in the following Section.

## 4 Multivariate Survival Analysis

We now proceed to analyze the influence of various firm characteristics, specifically financial data and patent holdings, on firm survival.

### 4.1 Methodology

In order to analyze the determinants of firm survival we consider survival time as a nonnegative random variable  $T$ .<sup>16</sup> A basic concept for the analysis of survival times is the hazard function  $\lambda(t)$ , which is defined as the limit

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{P(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t}$$

and measures the instantaneous failure rate at time  $t$  given that the individual survives until  $t$ . In the following, different survival models are estimated where the hazard function depends on a set of covariates  $x' = (x_1, \dots, x_p)$  that influence the survival time  $T$ .

The reference model for multivariate survival analysis is Cox's proportional hazard (PH) model (Cox 1972) where the hazard rate is assumed to be the product

$$\lambda(t, x) = \lambda_0(t) \exp(x_1\beta_1 + \dots + x_p\beta_p) = \lambda_0(t) \exp(x'\beta).$$

In this model the baseline hazard rate  $\lambda_0(t)$  remains unspecified and, through the exponential link function, the covariates  $x$  act multiplicatively on the hazard rate. We use a specification which includes both time-variant regressors  $x_{it}$  like the quarterly operating income or sales and also time-invariant regressors like firm characteristics at the IPO and the patent characteristics  $x_j$ . Hence, the specification we have to estimate is of the form

$$\lambda(t, x) = \lambda_0(t) \exp(x_j\beta_j + x_{it}\beta_i).$$

As noted above, we are able to observe different modes of exit from the sample: firms can either be delisted as a result of bankruptcy or minimal market value, or cease trading as a result of a merger or takeover. We therefore report estimation results from both a pooled model that does not distinguish between different outcomes, as well as a competing risks model that explicitly takes into account the different modes of exit.

### 4.2 Results

The results of our multivariate estimations are reported in Tables 8 through 10 at the end of the paper. Table 7 gives descriptive statistics for the regressors.

In Table 8 results are reported for pooled and competing risks models for two different sets of explanatory variables. The first specification (left part of Table 8) contains only firm-specific characteristics, the level of the NASDAQ composite index in the quarter preceding the IPO, and the dummy variables indicating whether a firm is from the different segments

---

<sup>16</sup>Recall that the survival time is defined as the time between the first listing of a firm and the discontinuation of share-trading at the NASDAQ.



have filed at least one patent application or not. In the second specification (right part of Table 8) we control for characteristics of firms' patent portfolios using the variables described above.

Column (1) of Table 8 contains the estimation results from the pooled model, which does not distinguish between different exit modes. Large and strongly significant effects are estimated for sales, total assets, the level of the NASDAQ composite index and the no-patent dummies. Unsurprisingly, firms with higher sales exhibit higher survival probabilities. An additional \$10MM per quarter in sales (sample average of \$21.96MM) increases the probability of survival by over 6%. Curiously, the small but strongly significant effect of assets at the time of IPO indicates that firms that were able to raise larger amounts of capital were somewhat more likely to exit. Older firms have a lower risk of failure, with an additional year of pre-IPO existence increasing the probability of survival by about 3%, though the estimated coefficient is not significant. The results for level of the NASDAQ composite index are also interesting, and confirm previous findings. Firms that went public during periods of higher market valuations for high-tech firms have markedly lower survival chances. The estimated coefficient implies that an additional 1000 points on the NASDAQ at the time of IPO would reduce the probability of survival by almost 30%. Not having applied for any patents is also a strong determinant of failure. Firms that did not file any patent applications have a 58% higher probability of exit relative to baseline.

Controls for industry segment show very large (and for Internet Services firms, highly significant) differences in the hazard rates. Firms in Internet Services are twice as likely to exit via a merger as firms in Computer Software. However, we find no significant effect for firms in Internet Software compared to the reference group.

The results from pooled model conceal some interesting differences across modes of exit from the sample. Results from the competing risks model which distinguishes between delistings due to acquisition or merger of the firm and delistings due to business failure (Columns (2) and (3) of Table 8) are revealing.<sup>17</sup>

While the effect of the operating profits was — somewhat surprisingly — not statistically significant in the pooled risks specification, the competing risks specification clearly shows that this result is due to two offsetting effects. The estimated effect of operating profits is positive and significant for firms that have merged or been acquired since their IPO, but negative and significant for firms whose shares have been delisted due to business failure. Moreover, we also observe different effects for the dummy variable indicating whether firms were venture capital backed prior to their IPO. While venture-backed firms are much more likely to exit via merger/acquisition (Column 2), they exhibit lower (albeit insignificantly different from baseline) hazard rates with regard to a delisting due to business failure (Column 3). Firms that were older at the time of their IPO have a marginally significantly lower hazard rate for being delisted due to business failure, with no effect on the hazard of exiting via merger/acquisition. Turning to the effect of assets at the time of IPO, very substantial

---

<sup>17</sup>A formal test of whether exits to different states are behaviorally distinct is presented in the Appendix. The null hypothesis of proportionality of cause-specific hazards is strongly rejected  $\chi^2(10) = 327$  for the models in columns (1) through (3), and  $\chi^2(15) = 336$  for the models in columns (4) through (6).

differences are apparent in the hazards for different modes of exit. No statistically significant effect is found on the hazard of exit via merger/acquisition, however a large and strongly significant effect is found for the hazard of delisting due to business failure. Puzzlingly, this effect is positive: having another \$100MM at the time of IPO (compared to the sample average of \$126MM *raises* the likelihood of exit through business failure by over 10%).

The effects described above remain largely unchanged once the variables characterizing the patent portfolios held by these firms are introduced (see right part of Table 8). In the pooled risks model (Column 4) estimated hazard ratios on most of the firm characteristics are very similar in magnitude, although some lose significance. Firms which were younger, were not venture-backed, were less profitable, had higher assets, and IPO'd when the NASDAQ was at a higher level were less likely to survive. Very similar differences between firms that exited as a result of business failure and firms that were merged/acquired are also apparent. Introducing the patent portfolio characteristics has only a small effect on the “no patents” coefficients, which become somewhat smaller in magnitude.

Among the patent portfolio variables, only the total number of patent applications filed at the USPTO is a significant determinant of firm survival. Applying for one more patent lowers the probability of exit by almost 5% in the pooled risks model. A marked difference in this effect is seen in the competing risks model: firms with more patent applications had a 10% lower hazard of exiting via merger/acquisition, but no significant effect is seen on the hazard of exiting via delisting.

Disappointingly in the light of evidence on correlation between patent quality measures and patent value in other contexts, no significant effects for the variables describing characteristics of the patent portfolios beyond the number of applications were found in the pooled risks model. The same is true for the competing risks model (Columns 5 and 6 of Table 8) with one interesting exception. Having a portfolio with a higher fraction of highly cited patents had a positive and marginally significant effect on the probability of exiting via merger/acquisition. We (cautiously) interpret this as evidence that highly cited patents are a very valuable asset, or a signal that the exiting firm's technology/business model is high quality. (Though the inverse effect is found on the hazard of being delisted due to business failure, this effect was not significant.)

Turning to the issue of Business Method Patents (defined as patents filed in USPTO Class 705), Tables 9 and 10 present results from re-estimating the models of Table 8 columns (4) to (6) with a distinction drawn between “705” patents and “non-705” patents. Patents held or applied for by the firms in the sample were divided into two groups, those with USPC class 705 (“Data Processing: financial, business practice, management, or cost/price determination”) appearing anywhere in the list of patent classes, and those where 705 appeared nowhere.<sup>18</sup> Panel I of Table 9 repeats the estimation, but with the patent portfolio characteristics computed only from the non-705 patents. In Panel II *only* the patent variables are constructed only from the Class 705 patents. In these estimates we include only a dummy

---

<sup>18</sup>This is slightly more expansive definition of a Business Method Patent, capturing an additional 55 patents beyond the 137 that have 705 as their primary USPC class. It does not, however, capture any patents that have been carefully worded to avoid the extra scrutiny applied by the USPTO to business methods applications since 2000.

variable for firms which had not applied for any Class 705 patents, and do not distinguish between different industry segments.<sup>19</sup> The estimated hazard ratios in Panel I are almost identical to those obtained in Table 8. The new “no patents” dummy has statistically significant coefficients reflecting the findings from Table 8. In Panel II, where the non-705 patents have been removed from consideration, the “no patents” dummy loses significance, and the estimated effect of number of patent applications falls essentially to zero. We conclude, therefore, that the Class 705 patents seem to have very little effect on the survival of firms, with the possible exception of patents with a high number of citations received per claim. The coefficient on this variable implies a large, positive, and strongly significant estimated effect on the probability of exiting via merger/acquisition: raising citations per claim by one unit (compared to a sample average of 0.23) increases the hazard of exit via merger by almost 80%. Note that there is no significant effect of this variable on the hazard of exiting via delisting.

Table 10 evaluates differences between Class 705 and non-705 patents somewhat differently. Here the specification of the model is expanded to include two sets of patent portfolio characteristics: those computed from the applications in the Class 705 category, and those computed from the applications outside class 705. Again, separating out the Class 705 patents has little effect on the results. Estimated hazard ratios on all the firm characteristics are very similar to those obtained previously, and as in Table 9, the only strongly significant impact of Class 705 patents is the large positive coefficient on citations per claim in the competing risks model.

## 5 Conclusion

Many new enterprises were created in the 1990s based on innovation in internet-enabled business models and supporting software technologies. Some of these firms took advantage of the option opened up by changing legal doctrine to protect their competitive position by filing patent applications on their inventions. The 356 newly-listed firms studied here collectively filed at least 1198 US patent applications, however these applications were generated by only 42% of the firms in the sample. Our results suggest that the firms that were unable or unwilling to seek patent protection were much less likely to survive the collapse of the dot.com bubble after 2001. After controlling for age of the enterprise, sales, assets, profitability, as well as stock market valuations and venture capital backing prior to their IPO, we find that firms with no patent applications had a much higher hazard of exiting the sample. This is true for firms that exited either as a result of being delisted from the NASDAQ due to apparent business failure, or as a consequence of a merger or acquisition (which presumably reflects higher value of the firm’s assets in a different corporate context.)

Of course, these estimated effects may not just represent the value of patents as a competitive asset in these markets. The estimated positive association between patenting and firm survival may also reflect a correlation between patenting and the underlying quality of the firm’s products, business model, management, and other intangible assets. But it suggests

---

<sup>19</sup>This is a consequence of the fact that with three exceptions only firms from the Internet Services segment filed for Class 705 patents.

a significant role for patents in driving industry dynamics in these technologies, especially within Internet Software. Puzzlingly, though applying for additional patents is associated with lower probability of exit, conventional measures of the quality or value of the patents held by a firm have little explanatory power in our regressions, though we find a hint that highly cited patents may be an attractive asset for acquirers.

Interestingly for the debate about business method patents, we find that they have very little impact on survival compared to patents classified in other classes. There is one intriguing exception to this general result: firms which hold business method patents that attract more forward citations per claim appear to be more attractive targets for merger or acquisition.

Our estimates also point to some serious problems with adverse selection and the functioning of the US capital markets in the late 1990s. Firms that raised greater amounts of money before and during their IPO were significantly more likely to exit, particularly through delisting due to business failure. We also find a very large and significant effect of prevailing stock market valuations preceding the IPO: firms that went public at the height of the dot-com bubble faced much larger probabilities of being subsequently delisted.

## References

- Agarwal, R. & Gort, M. (1996), 'The Evolution of Markets and Entry, Exit and Survival of Firms', *Review of Economics and Statistics* **78**(3), 489–498.
- Agarwal, R. & Gort, M. (2002), 'Firm and Product Life Cycles and Firm Survival', *American Economic Review* **92**(2), 184–190.
- Allison, J. R. & Tiller, E. H. (2003), 'The business method patent myth', *Berkeley Technology Law Journal* **18**, 5.
- Arora, A., Fosfuri, A. & Gambardella, A. (2001), *Markets for Technology*, MIT Press, Cambridge.
- Audretsch, D. B. (1991), 'New-Firm Survival and the Technical Regime', *Review of Economics and Statistics* **72**(3), 441–450.
- Audretsch, D. B. (1995), *Innovation and Industry Evolution*, MIT Press, Cambridge.
- Audretsch, D. B. & Lehmann, E. E. (2004), The Effects of Experience, Ownership, and Knowledge on IPO Survival: Evidence from the Neuer Markt, Discussion Paper 04/10, Diskussionspapier der Forschergruppe (Nr. 3468269275) 'Heterogene Arbeit: Positive und Normative Aspekte der Qualifikationsstruktur der Arbeit', Konstanz.
- Audretsch, D. B. & Mahmood, T. (1995), 'New Firm Survival: New Results using a Hazard Function', *Review of Economics and Statistics* **77**(1), 97–103.
- Bessen, J. (2005), A comment on "Do Patents Facilitate Financing in the Software Industry?", Working paper. Available on <http://www.researchoninnovation.org>, latest visit on September, 27<sup>th</sup>, 2004.
- Bessen, J. & Hunt, R. M. (2004), An Empirical Look at Software Patents, Working Paper 03-17/R, Federal Reserve Bank of Philadelphia, Philadelphia.
- Botman, M., van der Goot, T. & van Giersbergen, N. (2004), What Determines the Survival of Internet IPOs?, Discussion Paper 2004/09, Department of Economics, University of Amsterdam, Amsterdam.
- Caves, R. E. (1998), 'Industrial Organization and New Findings on the Turnover and Mobility of Firms', *Journal of Economic Literature* **36**(4), 1947–1982.
- Cockburn, I. (2001), Issues in Business Method Patents, Conference Paper, Franco-American Conference on Economics, Law and History of Intellectual Property Rights 2004/09, UC Berkeley.
- Conley, J. M. (2003), 'The International Law of Business Method Patens', *Federal Reserve Bank of Atlanta Economic Review* pp. 15–33.

- Cooley, T. F. & Quadrini, V. (2001), ‘Financial Markets and Firm Dynamics’, *American Economic Review* **91**(5), 1286–1310.
- Cox, D. R. (1972), ‘Regression Models and Life Tables (with Discussion)’, *Journal of the Royal Statistical Society. Series B (Methodological)* **34**(4), 187–220.
- Dreyfuss, R. C. D. (2000), ‘Are Business Method Patents Bad for Business’, *Santa Clara Computer and High Technology Law Journal* **16**, 263–278.
- Gans, J., Hsu, D. & Stern, S. (2002), ‘When Does Start-Up Innovation Spur the Gale of Creative Destruction?’, *RAND Journal of Economics* **33**(4), 571–586.
- Geroski, P. A. (1995), ‘What Do We Know about Entry’, *International Journal of Industrial Organization* **14**(4), 421–440.
- Hall, B. (2003), Business Method Patents, Innovation and Policy, Working paper no. 9717, NBER.
- Harhoff, D., Narin, F., Scherer, F. & Vopel, K. (1999), ‘Citation Frequency and the Value of Patented Innovation’, *Review of Economics and Statistics* **81**(3), 511–515.
- Harhoff, D., Scherer, F. & Vopel, K. (2003), ‘Citations, Family Size, Opposition and the Value of Patent Rights’, *Research Policy* **32**(8), 1343–1363.
- Honjo, Y. (2000), ‘Business Failure of New Firms: An Empirical Analysis using Multiplicative Hazards Model’, *International Journal of Industrial Organization* **18**(4), 557–574.
- Hopenhayn, H. A. (1992), ‘Entry, Exits, and Firm Dynamics in the Long Run Equilibrium’, *Econometrica* **60**(5), 1127–1150.
- Hunt, R. (2001), ‘You can patent that? Are patents on computer programs and business methods good for the new economy’, *Federal Reserve Bank of Philadelphia Business Review* pp. 5–15.
- Hunter, S. (2003), Have business method patents gotten a bum rap? Some empirical evidence, Working Paper 182, Center for eBusiness@MIT.
- Jain, B. A. & Kini, O. (2000), ‘Does the Presence of Venture Capitalists Improve the Survival Profile of IPO Firms?’, *Journal of Business Finance & Accounting* **27**(9-10), 1139–1183.
- Jovanovic, B. (1982), ‘Selection and the Evolution of Industry’, *Econometrica* **50**(3), 649–670.
- Kalbfleisch, J. D. & Prentice, R. L. (2002), *The Statistical Analysis of Failure Time Data*, 2 edn, Wiley, New York.
- Kaplan, E. & Meier, P. (1958), ‘Nonparametric Estimation from Incomplete Observations’, *Journal of the American Statistical Association* **53**, 457–481.

- Kauffman, R. & Wang, B. (2003), Duration in the digital economy, *in* R. Sprague, ed., ‘Proceedings of the 36th Hawaii International Conference on Systems Science’, IEEE Computing Society.
- Lanjouw, J. O. & Schankerman, M. (2001), ‘Characteristics of Patent Litigation: A Window on Competition’, *RAND Journal of Economics* **32**(1), 129–151.
- Lerner, J. (2002), ‘Where does State Street Lead? A First Look at Finance Patents, 1971–2000’, *Journal of Finance* **57**(4), 901–930.
- Mann, R. J. & Sager, T. W. (2005), Patents, venture capital, and software start-ups, Law and Economics Working Paper 057, The University of Texas School of Law.
- Mata, J., Portugal, P. & Guimaraes, P. (1995), ‘The Survival of New Plants: Start-Up Conditions and Post-Entry Evolution’, *International Journal of Industrial Organization* **13**(4), 459–481.
- Merges, R. P. (1999), ‘As many as six impossible patents before breakfast: Property rights for business concepts and patent system reform’, *Berkeley Technology Law Journal* **14**, 577–615.
- Meurer, M. (2003), ‘Business method patents and patent floods’, *Washington University Journal of Law and Policy* **8**, 309–340.
- Narendranathan, W. & Stewart, M. (1991), ‘Testing the Proportionality of Cause-Specific Hazards in Competing Risk Models’, *Oxford Bulletin of Economics and Statistics* **53**, 331–340.
- Scotchmer, S. (2005), *Innovation and Incentives*, MIT Press, Cambridge, MA.
- Sutton, J. (1997), ‘Gibrat’s Legacy’, *Journal of Economic Literature* **35**(1), 40–59.
- USPTO (1999), Automated Financial or Management Data Processing Methods (Business Methods), White paper. Also available as <http://www.uspto.gov/web/menu/busmethp/whitepaper.pdf>, latest visit on September, 27<sup>th</sup>, 2004.
- Wagner, S. (2005), Business Methods Patents in Europe and their Strategic Use – Evidence from Franking Device Manufacturers, Working Paper, University of Munich School of Management.

# A Test of Proportionality of Competing Risk Specification

Narendranathan & Stewart (1991) provide a test of whether exits to different states are behaviorally distinct (rather than simply incidental) for continuous time proportional hazards models. This is a test of the hypothesis that the cause-specific hazards are all proportional to one another (i.e. that all parameters except the intercepts are equal across the hazards). The test statistic  $TS$  proposed by Narendranathan & Stewart (1991) is given by

$$TS = 2[\ln(L_{CR}) - \ln(L_{SR}) - \sum_j n_j \ln(p_j)] \quad (1)$$

where  $\ln(L_{RC})$  is the maximised log-likelihood from the competing risk model (the sum of those from the component risk models),  $\ln(L_{SR})$  is the maximised log-likelihood from the single-risk model,  $n_j$  is the number of exits to state  $j$  and  $p_j = n_j / \sum_j n_j$ , where there are  $j = 1, \dots, J$  destination states. The test-statistic is distributed Chi-squared with degrees of freedom equal to the number of restrictions.

For our basic models reported in Table 8, we can reject the null hypothesis of risk proportionality at 1% of significance both for the models not including patent characteristics ( $TS = 327.00$ ) as well as for the model containing patent characteristics ( $TS = 336.14$ ). Hence, we reject the hypothesis that the different forms of exit are behaviorally equal.

For our models containing only the set of no-705-patents and the set of 705-patent (as reported in Table 9), we can reject the null hypothesis of risk proportionality at 1% of significance for both specifications ( $TS = 334.08$  and  $TS = 330.03$ ). Hence, we reject that the different the hypothesis that the different forms of exit are behaviorally equal.

For our models distinguishing between no-705-patents and 705-patent (as reported in Table 10), we can reject the null hypothesis of risk proportionality at 1% of significance ( $TS = 337.65$ ). Hence, we reject that the different the hypothesis that the different forms of exit are behaviorally equal.



Table 7: Descriptive statistics on variables used in the regressions.

Variable	Obs	Mean	Std. Dev.	Min	Max
Age at IPO (years)	3671	6.013	4.481	0	29.351
Dummy for Venture-backed	3671	0.615	.	0	1
Operating Income (\$10MM)	3671	-0.832	3.244	-50.659	10.729
Sales (\$10MM)	3671	2.196	3.841	0	36.476
Total Assets at IPO (\$100MM)	3671	1.260	3.015	0.032	46.666
NASDAQ index prior to IPO	3671	2.687	0.721	1.691	4.428
Dummy for zero patent applications	3671	0.537	.	0	1
Dummy for any international applications	3671	0.276	.	0	1
No. of applications	3671	3.984	11.438	0	152
No. of applications outside class 705	3671	3.302	10.928	0	152
No. of applications in class 705	3671	0.682	2.573	0	25
Average forward citations per claim	3671	0.234	0.736	0	7.382
Average forward citations per claim (non-705)	3671	0.205	0.741	0	8.292
Average forward citations per claim (class 705)	3671	0.086	0.351	0	5.820
No. of patents with 7 or more forward citations	3671	1.079	3.888	0	56
No. of patents with 7 or more forward citations (non-705)	3671	0.873	3.674	0	56
No. of patents with 7 or more forward citations (class 705)	3671	0.206	1.096	0	16
Average family size	3671	2.508	5.037	0	45.257
Average family size (non-705)	3671	2.048	4.407	0	45.257
Average family size (class 705)	3671	1.310	4.026	0	34.929
Internet Services	3671	0.553	.	0	1
Internet Software	3671	0.235	.	0	1
Computer Software	3671	0.213	.	0	1

Table 8: Results from Cox Proportional Hazards Regression. Estimates from pooled and Competing Risks Specification are presented. Z-Values in parentheses. \*\* 1%, \* 5%, + 10% significant.

Variables	Pooled	Competing Risks		Pooled	Competing Risks	
	(1)	(2)	(3)	(4)	(5)	(6)
		Merged	Delisted		Merged	Delisted
Age at IPO	0.9758 (1.38)	0.9891 (0.50)	0.9415 (1.90)+	0.9771 (1.31)	0.9921 (0.37)	0.9376 (1.99)*
Venture-backed	1.0971 (0.66)	1.3987 (1.80)+	0.8249 (0.87)	1.100 (0.67)	1.3673 (1.67)+	0.8421 (0.77)
Operating Income	0.9906 (0.44)	1.1883 (2.16)*	0.9629 (2.80)**	0.9861 (0.75)	1.1751 (1.99)*	0.9632 (2.78)**
Sales	0.8954 (3.42)**	0.9337 (1.95)+	0.7916 (3.62)**	0.9005 (3.17)**	0.9397 (1.72)+	0.7876 (3.58)**
Total assets at IPO	1.0578 (2.63)**	1.0352 (0.99)	1.1103 (3.94)**	1.0655 (3.01)**	1.0401 (1.14)	1.1133 (3.97)**
NASDAQ prior to IPO	1.3458 (2.83)**	1.1699 (1.16)	1.6964 (3.18)**	1.3809 (3.06)**	1.1998 (1.34)	1.7719 (3.35)**
Zero patent dummy	1.5810 (3.13)**	1.5783 (2.43)*	1.5313 (1.81)+	1.2881 (1.14)	1.4458 (1.27)	0.9546 (0.13)
No. of applications				0.9475 (2.03)*	0.8959 (2.43)*	1.0119 (0.37)
Int'l applications dummy				1.0007 (0.01)	1.0556 (0.18)	0.8619 (0.4)
Avg. forward citations per claim				1.0297 (0.28)	1.0855 (0.71)	0.9101 (0.39)
No. of patents with 7 or more forward citations				1.0598 (0.86)	1.1973 (1.89)+	0.9057 (0.89)
Average family size				1.0014 (0.05)	1.0269 (0.86)	0.9372 (1.13)
Internet Services	2.0822 (3.18)**	2.2124 (2.69)**	1.9576 (1.82)+	1.9578 (2.86)**	2.1624 (2.57)*	1.6817 (1.38)
Internet Software	1.6550 (2.04)*	1.7802 (1.83)+	1.4809 (0.99)	1.6403 (1.99)*	1.7838 (1.83)+	1.3603 (0.76)
Observations	3671	3671	3671	3671	3671	3671
Firms	356	356	356	356	356	356
Exits	225	136	89	225	136	89
Log Likelihood	-1154.17	-710.77	-431.39	-1150.07	-705.4	-428.91

Table 9: Results from Cox Proportional Hazards Regression. Estimates from pooled and Competing Risks Specifications. Note: Patent characteristics used in Panels I and II are computed from different sets of patents. Z-Values in parentheses \*\* 1%, \* 5%, + 10% significant.

Variables	I: No 705 Patents			II: Only 705 Patents		
	Pooled	Competing Risks		Pooled	Competing Risks	
	(1)	(2)	(3)	(4)	(5)	(6)
		Merged	Delisted		Merged	Delisted
Age at IPO	0.9754 (1.41)	0.9889 (0.52)	0.9371 (2.01)*	0.9804 (1.11)	0.9921 (0.36)	0.9493 (1.67)+
Venture-backed	1.1167 (0.78)	1.4031 (1.81)+	0.8418 (0.78)	1.0982 (0.66)	1.4002 (1.80)+	0.8058 (0.97)
Operating income	0.9837 (0.91)	1.1612 (1.77)+	0.9616 (2.87)**	0.9898 (0.45)	1.2044 (2.18)*	0.9633 (2.74)**
Sales	0.9049 (3.07)**	0.9469 (1.56)	0.7903 (3.48)**	0.9037 (3.05)**	0.9424 (1.64)	0.7877 (3.60)**
Total assets at IPO	1.0656 (3.03)**	1.0385 (1.09)	1.1142 (4.05)**	1.0577 (2.57)*	1.0358 (1.00)	1.1104 (3.88)**
NASDAQ prior to IPO	1.3708 (2.86)**	1.1911 (1.13)	1.7578 (3.26)**	1.3475 (2.82)**	1.1703 (1.15)	1.7117 (3.22)**
Zero patent dummy	1.7531 (2.36)*	1.9827 (2.12)*	1.3806 (0.88)	1.4164 (1.12)	1.8786 (1.46)	0.6562 (0.81)
No. of applications	0.9521 (1.77)+	0.8894 (2.28)*	1.0161 (0.49)	1.0227 (0.34)	1.0415 (0.52)	0.8928 (0.56)
Int'l applications dummy	1.0115 (0.04)	1.0910 (0.34)	0.8555 (0.47)	0.7343 (1.73)+	0.7880 (1.05)	0.6855 (1.28)
Avg. forward citations per claim	1.0076 (0.05)	1.0693 (0.43)	0.7637 (0.62)	1.5912 (1.73)+	1.7979 (2.38)*	0.1613 (1.24)
No. of patents with 7 or more forward citations	1.0493 (0.33)	1.3173 (1.30)	0.8052 (1.00)	0.9879 (0.06)	0.9859 (0.06)	1.7947 (1.02)
Average family size	0.9872 (0.46)	1.0081 (0.24)	0.9580 (0.84)	0.9472 (1.52)	0.9455 (1.27)	0.9605 (0.59)
Internet Services	2.0245 (2.97)**	2.2241 (2.63)**	1.7136 (1.41)	2.2630 (3.52)**	2.4504 (3.02)**	2.1208 (1.98)*
Internet Software	1.6915 (2.09)*	1.8505 (1.93)+	1.4028 (0.83)	1.6461 (1.98)*	1.7817 (1.81)+	1.5692 (1.08)
Observations	3671	3671	3671	3671	3671	3671
Firms	356	356	356	356	356	356
Exits	225	136	89	225	136	89
Log Likelihood	-1147.56	-703.21	-428.56	-1153.89	-709.76	-430.03

Table 10: Results from Cox Proportional Hazards Regression. Estimates from pooled and Competing Risks Specifications. Note: Z-Values in parentheses. \*\* 1%, \* 5%, + 10% significant.

Variables	Pooled	Competing Risks	
	(1)	(2) Merged	(3) Delisted
Age at IPO	0.9747 (1.44)	0.9868 (0.61)	0.9433 (1.83)+
Venture-backed	1.1240 (0.83)	1.4028 (1.81)+	0.7922 (1.03)
Operating income	0.9838 (0.88)	1.1684 (1.80)+	0.9635 (2.73)**
Sales	0.9070 (2.99)**	0.9460 (1.55)	0.7834 (3.58)**
Total assets at IPO	1.0667 (3.07)**	1.0390 (1.10)	1.1141 (4.00)**
NASDAQ prior to IPO	1.3906 (3.07)**	1.2136 (1.40)	1.7761 (3.34)**
Int'l applications dummy	1.0453 (0.19)	1.1574 (0.47)	0.8192 (0.53)
<i>Patent applications outside class 705</i>			
Dummy for zero patent applications	1.1113 (0.45)	1.1345 (0.40)	0.9519 (0.13)
No. of applications	0.9401 (2.12)*	0.8655 (2.62)**	1.0193 (0.53)
Avg. forward citations per claim	0.9857 (0.10)	1.0440 (0.27)	0.7187 (0.66)
No. of patents with 7 or more forward citations	1.1058 (0.70)	1.4122 (1.74)+	0.7971 (1.02)
Avg. family size	0.9905 (0.31)	1.0105 (0.30)	0.9599 (0.71)
<i>Patent applications in class 705</i>			
Dummy for zero patent applications	1.7116 (1.53)	2.3935 (1.76)+	0.7161 (0.57)
No. of applications	1.0260 (0.39)	1.0618 (0.84)	0.8413 (0.74)
Avg. forward citations per claim	1.6212 (1.86)+	1.8130 (2.43)*	0.1369 (1.36)
No. patents with 7 or more forward citations	0.9784 (0.11)	0.9926 (0.03)	1.9637 (1.10)
Average family size	0.9734 (0.69)	0.9740 (0.54)	0.9927 (0.10)
Internet Services	1.9619 (2.82)**	2.1497 (2.50)*	1.7444 (1.42)
Internet Software	1.6139 (1.89)+	1.7730 (1.78)+	1.4607 (0.89)
Observations	3671	3671	3671
Firms	356	356	356
Exits	225	136	89
Log Likelihood	-1148.41	-702.3	-428.31