

The Impact of R&D Alliance on the Survival of Newly Listed High Tech Firms

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Abstract

This paper investigates the extent to which R&D alliance participation affects the survival performance of newly listed high tech firms. The estimation strategy identifies the impact through changes on a firm's alliance status. Using longitudinal data on high tech firms that had an initial public offering in the United States, results suggest that R&D collaborating firms experience greater survival, relative to non-R&D collaborating firms. In particular, participation in an R&D alliance is associated with an attenuation of delisting due to poor financial performance.

Keywords: R&D alliance, Survival, Delisting, High tech firms, Initial public offering

1. Introduction

Firms are continually faced with the challenge to find ways to enhance their growth and survival. A key aspect of sustainable firm performance is to innovate – to develop new products that amplify market reach or to implement business methods and processes that reduce production costs. To do so, a firm must devote part of its resources to undertake research and development (R&D) activities. These can be as mundane, but fundamentally important, as appraising current technologies and capabilities, and as complicated as developing paradigm-shifting ideas. It is well established that research and development is a significant precursor to innovation (Hall et al., 2010; Baumann and Kritikos, 2016).

To perform R&D, a firm can decide to either do it alone, or to collaborate with other firms, in what is known as an R&D alliance. Essentially, an R&D alliance is a non-equity, contractual agreement among firms to jointly undertake R&D activities. The impetus for engaging in an alliance has economic merit: when firms collaborate, they share and concomitantly reduce the cost of R&D. More pertinently, participating firms can jointly manage the uncertainties associated with the innovation process and its eventual outcome (Mitchell and Singh, 1992;

Mahnke et al., 2006), tap each other's core competencies to exploit synergies (Teece, 1992; Mody, 1993; Ceccagnoli et al., 2010), and generate economies of scale and scope in R&D (Cockburn and Henderson, 2001; Grabowski and Kyle, 2008). From a welfare point of view, collaborative management of R&D enhances the incentive to innovate and deters wasteful duplication of research projects (Katz, 1986; Banerjee and Siebert, 2014).

The goal of this paper is to examine the extent to which participation in an R&D alliance affects firm performance. Of particular focus is its impact on the post-IPO (initial public offering) survival of high technology firms. Fama and French (2004) document high failure rates among newly listed firms, with more than 40% delisted within a decade due to poor performance. Firms operating in high technology industries, such as those in computers, software, and electronics, are not immune to this, posting reductions in earnings growth. The pronounced increase in high tech IPOs is correspondingly paralleled by significant attrition. Since high tech firms derive their competitive advantage mainly by innovating, examining the extent to which R&D alliances can help sustain their survival provides an important policy perspective for enhancing post-IPO performance. However, despite the acknowledged advantage and increasing trend towards collaborative R&D activities, there is scant evidence that characterizes the specific impact of alliances on survival.

Much of the empirical literature on R&D alliances analyzes its impact on the research productivity it confers to participating firms. The overwhelming consensus is that firms are generally better off collaborating with each other if they want to enhance their innovative performance. In a sample of firms in the electric and electrical equipment industry, Noseleit and de Faria (2013) find that collaboration can help firms enhance the efficiency of their internal R&D for generating innovations. Branstetter and Sakakibara (2002) examine the impact of research consortia on the patenting behavior of Japanese firms and report an increase in registered patents among collaborating firms relative to stand-alone (non-collaborating) firms. Using patent citations as a measure of the extent to which firms share and promote technological knowledge, Gomes-Casseres et al. (2006) provide evidence that firms engaged in an R&D alliance show a higher degree of knowledge flow than those otherwise.

In this paper, I evaluate the specific impact of R&D alliance using information on the firm's listing duration and earnings profile. The estimation strategy identifies the impact through changes in the firm's alliance status. I employ Cox and piecewise hazard duration models to ascertain the link between R&D alliance participation and the survival of high tech firms. Using a sample of 586 high tech firms newly listed in the United States over the period 1990-2000, I find evidence suggesting that R&D participating firms experience higher survival rates. On average, alliances in R&D is associated with attenuating the risk of poor firm performance and eventual delistment by 8.51%. The economic insight appears broadly consistent with model specification.

This paper contributes to the literature along three strands. First, it provides empirical evidence for R&D alliance as a channel for sustainable firm performance. Second, it builds on studies that analyze IPO failure risk by highlighting the potential role of cooperative R&D

agreements in deterring the hazards of poor performance. Finally, this paper reinforces insight from management and organizational studies that advocate development of capabilities through interfirm collaborations.

Empirical support for the advantage R&D alliances confer on firms, in particular, high tech IPOs, is sparse, considerably more so for its likely effect on post-IPO survival. Capron and Mitchell (2007), for instance, examine survey data on executives from the telecommunications industry and report that firms survive longer by closing the capability gap. This means that alliances, such as R&D and marketing partnerships, enable firms to obtain and develop desired capabilities. Also, Mitchell and Singh (1996), using logistic regression, find that alliances related to licensing, marketing, and distribution help firms survive longer. The potential impact of R&D alliance participation on firm survival draws upon the idea of firms learning their capabilities through R&D (Jovanovic, 1982; Klepper, 2002). Those that are able to discover and develop their capabilities increasingly become productive and survive, whereas those unable to do so fail. A way to facilitate these would be through cooperative R&D activities with other firms. Collaboration provides a channel for efficient learning because the acquisition and development of capabilities for any firm acting alone can be lengthy and complicated.

The rest of the paper is organized as follows. I review the literature espousing the hypothesized effect of R&D alliances on survival in section 2. I describe the construction of the data and variables used in the estimations in section 3. The empirical framework and the results are discussed in section 4. The paper concludes in section 5.

2. Hypothesis

I posit that participation in an R&D alliance enhances the survival of newly listed high tech firms. I draw upon three essential advantages that R&D alliances confer to participating firms that provide salience to this hypothesis: (i) containment of uncertainty and tolerance for risk, (ii) complementarities, and (iii) economies of scale and scope in R&D.

Containment of uncertainty and tolerance for risk: High tech firms mainly rely on new product development as a way to create, sustain, and boost brand recognition and market reach. Apart from the fact that production must be efficiently implemented to keep costs at bay, high tech firms attempt to introduce new products that not only meet consumer enthusiasm, but also generate market demand. The increasing complexity and vagaries of consumer tastes, coupled with the rapid obsolescence of technological capabilities and product innovations, create uncertainties and risks which necessitate firms to search for mechanisms that enable them to cope with competitive benchmarks. The creation of new products and technologies and the adoption of experimental processes are uncertainties and risks that firms face in order to succeed in the market (Mitchell and Singh, 1992). To create the seeds of innovation that can potentially reinforce growth and survival, firms must pass the hurdle of venturing into the unknown (uncertainties of whether or not the idea is implementable and novel enough to stimulate market interest) and the hazard of failure (risk that the idea gets shelved before, during, and after the innovation process because of, say, financial constraints or lack of sufficient expertise).

Participation in an alliance provides a mechanism or structure that allows firms to jointly manage the uncertainty of the innovation process and tolerate the risks involved. Unlike their stand-alone counterparts, those involved in an alliance are able to open up mixed options of jointly creating, designing, testing, and implementing products and processes that would have otherwise been constrained or suppressed because of the uncertainties and risks. Collaboration acts as an enabling mechanism in that firms can realize uncertain technologies with limited individual risk exposures. Mahnke et al. (2006), for instance, document that firms in the mobile technology industry engage in R&D alliances in order to jointly manage the risks and uncertainties of the innovation process. Robertson and Gatignon (1998) find empirical support for this: firms that face greater technological uncertainty, such as those in high technology industries, are more likely to (i) engage in an alliance than to develop the innovation single-handedly, (ii) pursue paradigm-shifting ideas, and (iii) introduce innovations at a faster rate. Robinson (2008) similarly report that alliances are commonly established in inherently riskier industries (in particular, high tech) and that the risk of the alliance activity is comparably greater than the risk of individual firm projects, suggesting that the alliance as a whole can tolerate greater risk for expectations of greater reward, despite limited investment exposures by participating firms.

Complementarities: Interfirm R&D agreements are established to collaboratively discover and develop technologies that result in productive ventures for the firm. While the set of firm responsibilities and group tasks in which R&D activities are organized and outcomes are achieved may broadly differ across alliances, the aim of successful innovative performance among participating firms is a common thread that forges alliances. This implies that alliances are not random collections of firms. Alliances evolve through a grouping together of firms with dissimilar, but complementary skills, knowledge, and expertise. Because alliances are mainly driven by project-specific goals, participating firms learn each other's distinct capabilities and create a pool of knowledge from which they can draw and harness the skill necessary to implement research ventures. Rothaermel and Boeker (2008) report evidence that projects aimed at discovering and developing human therapeutic drugs have involved alliances between pharmaceutical and biotechnology firms. These collaborations were forged mainly on the basis of accessing each other's complementary capabilities to ensure drug success.

Access to complementarities is the operative word for R&D alliances (Teece, 1992; Mody, 1993; Ceccagnoli et al., 2010). The pursuit of a successful innovative outcome that elevates firm survival necessitates a high tech firm to have a considerable amount of multi-disciplinary knowledge and expert capabilities. Singularly obtaining and learning these can be costly, inefficient, and unwieldy for any particular firm. Participation in an alliance provides an avenue for firms to focus on their core competencies and to access each other's specialized knowledge. Using a sample of over 2,000 German manufacturing firms that were asked about their innovation activities over the period 1990-1992, Becker and Dietz (2004) find that firms collaborate in order to complement existing R&D capabilities and that this results in higher research productivity and more product innovations.

Economies of scale and scope in R&D: While it is acknowledged that R&D is a key input to

the innovation process, resources spent on discovering novel ideas and implementing these into commercial ventures do not, by themselves, necessarily translate to a successful innovation outcome. Such success entails a high intensity of quality research and development principally driven through economies of scale and scope (Grabowski and Kyle, 2008). This distinction is important. Cockburn and Henderson (2001) provide empirical evidence that while the research aspect of R&D is successfully initiated through economies of scale, its development phase is successfully implemented through economies of scope. This generally imbues large firms an advantage in R&D in that their size enables them to reduce the unit cost required for these activities and to exploit the synergy of having different functional groupings inherent in their organizational structure. But not all firms are large, and large firms do not necessarily possess a limitless amount of resources and the skill and experience needed to successfully conduct R&D.

It is in this context that R&D alliances play a central role as the bridge or mechanism that enables participating firms to achieve economies of scale and scope in R&D. Collaboration engenders (i) economies of scale in the sense that it creates a network of firms pooling their resources together and drawing upon each other's capabilities and embedded knowledge and (ii) economies of scope in the sense that it creates a cross-functional linkage of firms, assigning tasks according to firm specialization and integrating the outcome into other areas at minimal or zero marginal cost. Danzon et al. (2005) empirically document a role for alliances in enhancing research productivity. Using data on drugs being developed and clinically tested at various stages, they find that while the effect of individual firm experience on drug development and testing varies in stages, drugs developed in an alliance between pharmaceutical and biotechnology firms are more likely to advance through clinical tests and completed. Lerner et al. (2003) provide evidence of the significance of scale economies in alliances, reporting that sufficiently funded biotechnology alliances have a faster time to develop new products and obtain product approval.

3. Data and Variable Description

I use a panel of 586 firms that became publicly listed in the United States for the first time over the period 1990-2000. This sample is a merger of four different datasets. I assembled information on (i) initial public offerings (IPO), (ii) R&D alliances, (iii) stock exchange delisting, and (iv) financial data.

The sample of IPOs was obtained from the SDC Platinum Global New Issues database, which collects information on public offerings made worldwide. To make the analysis manageable and achieve focus, I restricted my data to firms that went public in the United States from 1990 to 2000. The sample IPO period is meant to characterize newly listed firms; with reference to their IPO date, these firms are relatively young in that a firm is at least 1 year old (it had its IPO in 2000) and no more than 10 years old (it had its IPO in 1990).

I relied on NAICS codes (North American Industrial Classification System) that constitute the high tech industries, which include pharmaceuticals, semiconductors, and electronics. The sample of high tech IPOs is then merged with the SDC Platinum Joint Venture/Alliances database, which provides information on firms that entered into R&D alliance agreements

domiciled in the United States. I used the Center for Research in Security Prices (CRSP) database to identify delisted firms. These are firms that are removed from the exchange due to poor financial performance, as when a company files for liquidation or bankruptcy proceedings. I used the Compustat-WRDS financial and accounting database to obtain information on firm profits, R&D expenditures, cash flow, and outstanding shares, among others. These are used to construct the covariates essential for the empirical framework described in the succeeding section. Less than half of the total number of firms engages in R&D alliances. While R&D alliance participating and non-R&D alliance participating firms exhibit similar listing rates, firms that collaborate report lower delisting rates. Of those delisted, 65% are firms with no alliances.

To examine the impact of R&D alliance on firm survival, I define the indicator variable R&D alliance = 1 to indicate that a firm engages in a contractual, non-equity cooperative R&D agreement with other firms, and 0 otherwise. Firm survival is gauged by recording the listing duration of firms, which is measured from the time a firm had its IPO to the time it was delisted. This provides an empirical framework for assessing a firm's proneness to failure and eventual delisting. Since IPOs are recorded until 2000, I selected 2005 as the last window year to reasonably observe listing durations that available data permit.

I use Tobin's q as a measure of profitability. Tobin's q provides an economically meaningful perspective on profits in that it generates insight on expected profitability and a firm's incentive to invest in the future. Following Kaplan and Zingales (1997), this is calculated as Tobin's $q = \text{market value of assets} / \text{book value of assets}$. I use the following as control covariates of firm survival: (log) Sales, to account for the idea that large firms presumably have greater access to resources and opportunities (Klepper, 1996); Debt/Assets, following the empirical finding that highly leveraged firms are more likely to experience stunted growth (Lang et al., 1996); Cash flow/Assets, in that internally generated funds relieve firms of financial constraints, raising the opportunity to embark on productive ventures and projects (Carpenter et al., 1998); and (log) R&D expenditures, given that firms which devote resources to research and development activities are more likely to explore new ideas and find ways to implement and commercialize their innovation. I measure Debt/Assets as book value of total debt/market value of assets and Cash flow/Assets as cash flow before interest/book value of assets.

Table 1 provides summary statistics for the variables used in the estimation. On average, firms engaged in an R&D alliance remain listed for 7 years compared with 6 years for those that do not have an alliance. These listing averages are taken at face value as they are unable to capture censored listing durations; there are firms in my sample whose exact delisting times are unknown. These censored observations will tend to overestimate listing times. A duration technique is introduced in Section 4 that can account for this situation.

Table 1: Overall Summary Statistics

Variable	Firms in an R&D Alliance		Firms not in an R&D Alliance		Two sample
	Obs	Mean (std. dev.)	Obs	Mean (std. dev.)	<i>t</i> -test <i>p</i> -value
Tobin's <i>q</i>	1 923	4.318 (6.931)	1 705	3.023 (3.495)	0.000
Sales (in millions \$)	1 991	319.033 (1 763.832)	1 727	101.367 (252.349)	0.000
R&D expenditures (in millions \$)	1 897	54.216 (264.960)	1 523	12.039 (17.735)	0.000
Debt/Assets	1 923	0.055 (0.116)	1 701	0.093 (0.169)	0.000
Cash flow/Assets	1 990	-0.188 (0.741)	1 725	-0.179 (0.453)	0.663
Listing Duration (years)	1 992	7.136 (2.843)	1 713	6.162 (3.189)	0.000

Collaborating firms reported higher economic profit, as measured by *Tobin's q*. These firms also reported higher sales and R&D expenditures and lower debt. Table 1 also provides *p*-values for the two-sample *t* test of means. Except for cash flow, the *p*-values for the rest of the variables are well below the 1% level of significance, reinforcing the impression that participation in an R&D alliance enhances firm survival.

4. Estimation Strategy and Results

The economic thrust of this paper is to examine whether participation in an R&D alliance mitigates the risk or hazard of firm failure in high tech industries due to poor post-IPO performance. I use the standard Cox (1972) and piecewise hazard duration models as framework for regression. My sample data consist of firms that became publicly-listed for the first time over the period 1990-2000. Once listed, these firms either continue to become going concern entities or become delisted from the stock exchange due to poor financial performance. Given data on the year in which the firm had its IPO at the exchange and the date in which it was delisted, I have a record of how long the firm remained listed. My estimation strategy relies on these survival or duration distributions to examine whether participation in an R&D alliance can help attenuate the risk of poor firm performance and eventual delistment.

A useful, indicative way to assess the impact of R&D alliances would be to compare the survival distribution of firms that engage in an alliance with those that do not. I estimate the survival functions for these two types of firms using the Kaplan-Meier estimator, which intuitively gives the estimated proportion of firms listed and surviving at a given period of time (Hosmer and Lemeshow, 2008). The Kaplan-Meier estimator is a consistent estimator of firm survival, accommodating the situation that not all firms in my sample have experienced

delistment. Figure 1 plots the survival distributions of R&D participating and non-R&D participating firms. It shows that the survival curves monotonically decrease over time. Both types of firms exhibit similar survival rates for the first three years after IPO in that there are relatively few delistments. By the fifth year, however, a systematic pattern emerges: the survival curve of participating firms lies distinctly above those that do not engage in R&D collaborations. While half of non-R&D participating firms have survived at least 13 years, at that median survival time, 70% of R&D participating firms are still listed and surviving. By the 15th year, the survival rate for participating firms is twice that of their non-participating counterparts. R&D collaboration appears to mitigate the hazard of firm failure.

I use the Peto-Prentice test (Hosmer and Lemeshow, 2008) to evaluate whether the observed separation of these two curves is statistically significant. This is a chi-square test with one degree of freedom of the null hypothesis that the two survival curves are the same, against the alternative that the survival curve for collaborating firms is monotonically above that of non-collaborating firms. The Peto-Prentice test is not particularly sensitive to censoring patterns that can potentially distort detection of differing survival curves. The resulting *p*-value is practically zero, reinforcing the graphical impression that collaborating firms experience higher survival rates.

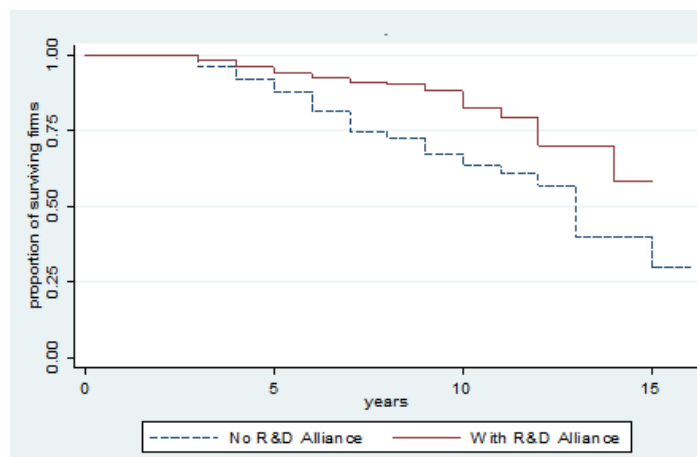


Figure 1. Kaplan-Meier Survival Estimates by R&D Alliance Status

I use the standard Cox (1972) hazard regression analysis to better gauge the link between R&D alliance participation and the listing duration of high tech firms. As a robustness check for functional specification, I also use the piecewise exponential model. These regression methods estimate the hazard of poor performance and eventual delistment faced by a firm as a function of R&D alliance participation and firm-specific characteristics (profitability, debt, cash flow, and firm size). The Cox model, in particular, has the following hazard specification

$$h(t, x_{it}) = h_0(t) \exp(\beta_1 R\&D \text{ alliance}_{it} + \beta_2 (\log) R\&D \text{ spending}_{it} + \beta_3 R\&D \text{ alliance}_{it} \times (\log) R\&D \text{ spending}_{it} + \sum_{k=1}^K \lambda_k x_{it}^k)$$

where $h(t, x_{it})$ is the hazard of poor performance and eventual delistment faced by firm *i* at

time t . The hazard is characterized by a baseline hazard $h_0(t)$ and is influenced by participation in R&D alliance and the specified set of control variables. The indicator variable R&D alliance = 1, denotes firms collaborating in R&D; 0, otherwise. The time subscript indicates that participation in an alliance varies over time for a given firm. I include an interaction effect between the R&D alliance variable and R&D expenditures. This accounts for the idea that the differential effect of the alliance variable is not constant with the level of R&D spending; it is likely that it depends on the amount of R&D expended by participating firms. The vector of control variables x_{it} represents firm-specific characteristics (profitability, debt, cash flow, and firm size) as well as industry and IPO year indicators that are likely to affect listing duration.

Table 2 summarizes the estimation results. Two sets of column estimates are given for the Cox (columns 1 and 3) and piecewise (columns 2 and 4). Also, to account for possible serial dependence of the firm observations, I use robust standard errors computed using the Huber-White variance estimator for panel data, specifying the correlation of disturbances within firms as a cluster. The standard errors allow for arbitrary forms of heteroskedasticity and serial correlation.

Table 2: Cox and Piecewise Exponential Hazard Estimates

Dependent Variable: Hazard of Delistment Due to Poor Financial Performance				
Explanatory Variables	Cox (1)	Piecewise (2)	Cox (3)	Piecewise (4)
R&D Alliance	0.351 (0.392)	0.402 (0.350)	-1.003 (0.884)	-0.926 (0.937)
(log) R&D expenditures	-0.216 (0.073) ^{***}	-0.211 (0.073) ^{***}	-0.269 (0.075) ^{***}	-0.245 (0.076) ^{***}
R&D Alliance × (log) R&D expenditures	-0.229 (0.106) ^{**}	-0.247 (0.098) ^{**}	0.383 (0.220) [*]	0.370 (0.231)
Tobin's q	-0.309 (0.056) ^{***}	-0.354 (0.056) ^{***}	-0.044 (0.096)	-0.065 (0.118)
Debt/Assets	1.967 (0.544) ^{***}	2.163 (0.544) ^{***}	1.883 (0.762) ^{**}	2.005 (0.801) ^{**}
Cash flow/Assets	-0.894 (0.113) ^{***}	-1.010 (0.114) ^{***}	-0.383 (0.254)	-0.434 (0.299)
(log) Sales	-0.242 (0.041) ^{***}	-0.230 (0.042) ^{***}	-0.201 (0.049) ^{***}	-0.197 (0.051) ^{***}
Observations	3 185	3 185	2 696	2 696

robust standard errors in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Column 1 reports parameter estimates using the Cox model. The estimated effect of R&D

alliance participation is given by $\exp[\beta_1 + \beta_3(\log)\text{R\&D spending}] - 1$, where β_1 is the parameter associated with R&D alliance. The alliance effect varies based on particular values of (\log) R&D spending. A meaningful way to pin this down is to report the average partial effect, which is calculated by adding up the estimated individual effects for each firm-observation and taking the average. The calculated value yields $\exp[0.351 - 0.229(\log)\text{R\&D spending}] - 1 = -16.496\%$. This suggests that R&D alliance participation can negate the hazard of delisting due to poor financial performance by about 16%. The p -value for testing the joint hypothesis $\beta_1 = 0, \beta_3 = 0$ is significant. Also, the control covariates are individually significant. In particular, the estimate for Tobin's q shows that profitable firms are more likely to remain listed and survive. On the other hand, highly-leveraged firms may be more susceptible to delisting. This effect is denoted by the variable Debt/Assets. It appears that large firms, as measured by (\log) Sales, and those with a steady stream of internal funds, as denoted by Cash flow/Assets, are better able to attenuate problems associated with poor financial performance. Also, several regressions were performed using IPO year effects and industry dummies, which are suppressed for brevity (Benninga et.al., 2005).

To investigate the robustness of the alliance effect, I also estimated a piecewise duration model that partitions the baseline hazard into segmented or piecewise slopes. The Cox model does not assume a specific parametric distribution for the hazard, whereas the piecewise uses the exponential distribution. That is, the time horizon is subdivided into J time intervals, with breakpoints $0 = b_0 < b_1 < \dots < b_J = \infty$. For each interval $[T_{j-1}, T_j)$, a separate baseline hazard is estimated, which is specified as constant within the interval, but differs across time intervals. We use an exponential distribution to obtain constant hazards for each interval, so that for $t \in [b_{j-1}, b_j)$, the hazard is $h_0(t) = k_j > 0$. With reasonable choice of breakpoints, the piecewise model can be flexible enough to approximate the overall shape of the baseline hazard. Table 2 reports 12 time intervals, each having a length of one year and approximating the hazard using closely-spaced boundaries. I also conducted regressions with 4 time intervals, and obtained comparable parameter estimates.

I report in column 2 estimates from a piecewise exponential model. The effect of participating in an alliance is $\exp[0.402 - 0.247(\log)\text{R\&D spending}] - 1 = -15.721\%$, which is less than a percentage point difference from the analogous Cox specification. Overall, the piecewise estimates do not exhibit any substantial dissimilarity from that estimated by the Cox model. A test of the joint hypothesis that $\beta_1 = 0, \beta_3 = 0$ produced a p -value of 0.0176, which indicate strong significance of the alliance effect. The p -value testing the significance of the two alternative time interval specifications is practically zero, suggesting that both

specifications reasonably approximate the baseline hazard. Regressions which control for the effect of industry and IPO year were also estimated, but these effects were not statistically significant for inclusion. The similarity of the Cox and piecewise estimates suggests the robustness of the hazard attenuating effect of R&D alliance participation. This effect was obtained controlling for firm heterogeneity in profitability, leverage, cash flow, and firm size. There may be other factors associated with R&D alliance participation that explain differences in survival rates, but are not accounted for in the model. Despite this, unobserved heterogeneity may be innocuous in the analysis. Explicitly accounting for its effect is important to the extent that interest lies in characterizing the shape or possible duration dependency of the baseline hazard. The principal motivation for this paper, however, is to examine the hazard-attenuating effect of R&D collaboration, and not to extract the shape of the baseline hazard. As Wooldridge (2002, p.706) notes, unobserved heterogeneity does not alter how an explanatory variable affects mean duration. Also, my use of robust standard errors is helpful in suppressing erroneous inferences.

Importantly, there may be feedback in that collaboration may just as well be a consequence as it is a cause of survival. While collaborative R&D helps firms lower susceptibility to failure, those which have a remarkably pronounced survival may be more predisposed to forge an alliance to sustain, say, market dominance. This creates an upward bias in the alliance estimate. Following Cozarenco et al. (2016), in the absence of an appropriate instrument, I lag by one year the alliance variable and its interaction, to circumvent the confounding effect of this feedback. Lagging helps make clear the direction of association and the interpretation is intuitive: alliances formed last year help firms attenuate the hazard of failure, with the effect taking place a year later, and making clear that surviving firms cannot form alliances that happened in the past. I also create one-year lags for the control covariates as they also vary over time.

Columns 3 and 4 present the results from the lagged specification. Column 3 reports estimates using a Cox model. Column 4 report piecewise estimates. While the alliance coefficient and its interaction lose statistical significance, economically, the estimates remain suggestive of previous results which suggest that collaborative R&D helps firms mitigate poor performance and eventual delisting. The Cox estimate reports about an 11% hazard attenuation, whereas the piecewise regression report about a 7%. Taken together, the hazard is attenuated by 8.51%, on average. The lagged estimates are comparably lower than those previously obtained, suggesting that feedback tends to amplify the impact of R&D alliance. When lagged control variables are used, leverage and firm size remained significant, with the former as hazard-increasing and the latter, hazard-decreasing. Tobin's q and cash flow remained negative, but were not significant.

5. Conclusion

The aim of this paper is to investigate the extent to which interfirm collaborations in R&D affect firm performance. Using a panel sample of 586 high tech firms newly listed in the United States over the period 1990-2000, I analyze whether R&D alliance participation helps attenuate the hazard of poor firm performance and eventual delisting from the stock

exchange. Using a Cox and piecewise hazard duration framework, I find evidence suggesting that R&D collaborating firms experience higher survival rates than their non-R&D collaborating counterparts. That is, R&D alliance participation retards the hazard of substandard financial performance that can result in delisting. This result accounts for possible feedback between survival and alliance membership, and is not particularly sensitive to model specification.

Taken together, the results of this paper provide policy insights on sustainable firm performance. Finding that R&D alliances help firms elevate their survival may call for opportunities to enhance cooperative agreements. It would be interesting to distinguish whether R&D alliances perform better and concomitantly confer more benefits to participating firms if they perform single or multiple projects. It is also informative to know how project tasks are assigned. Are they based on firm expertise or on the need to develop desired capabilities? These questions provide interesting topics for future research.

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