Innovation Exit: Why Entrepreneurs Pull the Plug on their Innovations

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ABSTRACT

We analyze how economic factors relate to the continued production versus exit of innovations developed by entrepreneurs. We develop an economic theory in which sunk costs, uncertainty, and effects on profits should condition decisions to commercialize an invention and then to continue production or exit after commercialization. The model guides an empirical analysis of data on actual inventors' decisions. Expected price significantly reduces the probability of exit after commercialization, while R&D uncertainty and expected competition from imitators significantly increase the probability of exit. The results are consistent with an important role of economic incentives in inventor behavior. The findings also indicate risk-seeking or (in cases of high uncertainty) over-optimism on the part of inventors.

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Key words: innovation, entrepreneurs, inventors, survival, sunk costs, entry, exit

1. Introduction

It is non-controversial to claim that entrepreneurs are the lifeblood of modern economies and, in particular, important in driving the expansion of the North American market. For example, the self-employment rate increased markedly in North America since the mid 1970's with self-employed constituting approximately 10% of nonagricultural employees in the U.S and about 18% in Canada in 1997, with a recent rapid growth in Canada from approximately 14% in 1989 (Manser and Picot, 1999). Similarly, entrepreneurs constitute an important source of technological change with the percentage of U.S. patents granted to U.S. independent inventors at approximately 13% in 1996 (USPTO, 1997). However, since entrepreneurs do not fit neatly into a static model of competition, the process of entrepreneurship is not well understood by economists.

Schumpeter (1934) paved the way by elucidating the role of entrepreneurs as both recognizing and opening new competitive opportunities. Recent work on entrepreneurs' opportunity assessments, however, questions whether entrepreneurs are economically well calibrated. Arabsheibani *et al.* (2000) find that entrepreneurs are unrealistic optimists in that they greatly overestimate their abilities/probabilities to succeed as entrepreneurs. Hamilton (2000) finds a median earnings differential of 35% for observationally similar entrepreneurs and self employed. Åstebro (2003) finds that 60% of inventions that reach the market realize negative returns and the median realized return on invention by independent inventors is -7%. Given these results some economists argue that entrepreneurs are wishful thinkers (e.g. de Meza and Southey, 1996), others conclude that entrepreneurs are mostly motivated by non-pecuniary benefits (Hamilton, 2000), yet others raise the possibility that entrepreneurs are "skewness lovers" w ho, while realists, are attracted to unfair gambles with negative expected values because of the skew distribution of innovative returns (Åstebro, 2003).

Notwithstanding these various interpretations of recent findings regarding entry, we know little about why entrepreneurs might exit the market. Are entrepreneurs wishful thinkers on the exit side as well as on the entry side? Or, are they merely uninformed about their abilities when entering and rapid learners after entry, as suggested by Jovanovic (1982)? In essence, can a simple model based on a zero-profit condition explain innovation exit by entrepreneurs? We pose the latter question and use a unique data-set on the survival of innovations introduced by Canadian inventors to investigate the question empirically.

Previous research has mainly focused on the survival of new small firms/plants with attention on predictors such as firm age and size (e.g., Dunne et al., 1989). Researchers studying entrepreneurs have focused on the effect of owner characteristics such as human capital on business survival (e.g., Holtz-Eakin et al., 1994). Some studies have assessed the impact of the underlying technology on small business survival at an industry-aggregate level (Audretsch, 1991; Audretsch and Mahmood, 1995). This study focuses on the effect of innovation attributes on survival.

We use a simple non-symmetrical model of entry and exit of an innovation to elucidate our empirical analysis of why entrepreneurs decide to exit the market. The model considers entrepreneurs as rational economic agents. We model the survival of innovations as a process where exit in a given year is driven by next year's expected profitability. Using the model we decompose the incentive to exit and test the impact of several innovation-specific and product-market characteristics on innovation survival.

To test our model and hypotheses we obtained data from 1,091 inventors on their inventions. Successful commercialization of these inventions constitutes rare events: only approximately 7% of the inventions reach the market. However, once these reach the market the mean survival time (correcting for censoring) is approximately 10 years, a surprisingly long duration. We also obtained data on the characteristics of the innovations at an early stage of development, as rated on several dimensions by an analyst paid by the entrepreneur to conduct an independent review of the prospects of their invention.

We provide empirical evidence on the significant predictors of market exit. Expected price significantly reduces the probability of exit after commercialization, while R&D uncertainty and expected competition from imitators significantly increase the probability of exit. The results are consistent with an important role of economic incentives in inventor behavior. The findings also indicate risk-seeking or (in cases of high uncertainty) over-optimism on the part of inventors.

2. The Survival of Innovations

There have been comparably few studies on the survival of innovations compared to studies on the survival of new firms. The dominant conclusion from studies on new firm/plant survival is that the likelihood of survival is positively related to firm size and age (e.g. Dunne *et al.,* 1989).

Klepper (1996) formulates a theory of new product entry, exit and growth and industry evolution that explains these empirical results. In several companion pieces Klepper and Simons (1997; 2000a; 2000b) proceed to test this theory on detailed product-level survival data. These tests show that a “shake-out” pattern of industry evolution can be explained by R&D cost-spreading which imparts an advantage to both size and being an early entrant as early entry allows greater size through growth. According to this theory the probability of entry decreases with time as incumbents grow and price is pushed down whereas there is no particular pattern of exit probabilities. In fact a uniform exit probability distribution over time is assumed as well as confirmed in empirical test.

Asplund and Sandin (1999) discover that new beer brands with low and decreasing market shares have higher hazard rates and that products from firms with the largest market shares face a greater risk of being withdrawn. The first result is theorized to depend on the unpredictable nature of consumer demand, where firms gradually learn about preferences over time (Jovanovic, 1982). The second result may be product market specific. Results may be attributed to large beer producers trying to squeeze out smaller producers by repeatedly releasing (and withdrawing) new products (Schmalensee, 1978). Interestingly, Asplund and Sandin (1999) could not reject the hypothesis of a constant hazard over time implying an exponential duration distribution.

It has been noted that the probability of new business survival as well as the probability of new product survival differ across industries. In particular, the retail and transportation industries are associated with higher rates of exit of new small businesses (Bruderl *et al.*, 1992; Cressy, 1996; Bates, 1990; Gimeno *et al.*, 1997). There are several reasons for inter-industry differences in the survival of start-ups. One important driver of small business exits is scale economies: industries that require larger minimum efficient scale of operations are associated with higher rates of exit of new small firms as small new entrants likely operate at a cost disadvantage (Audretsch, 1991; Mata and Portugal, 1994; Åstebro and Bernhardt, *forthcoming*). Audretsch (1991) also establishes that the larger the rate of innovation by small firms in an industry the greater the survival chances of new small firms. Several other traditional measures of inter-industry differences in competitive conditions and costs, such as capital intensity, growth rate, wage costs, and unemployment rates, also add to the explanation of inter-industry differences in survival rates of new businesses (Audretsch, 1991; Mata and Portugal, 1994; Wagner, 1994; Audretsch and Mahmood, 1995).

3. Model and Hypotheses

As a tool to think about the role of economic incentives to the behavior of inventor-entrepreneurs, we present a simple model embodying the most obvious economic components of the investment decision. The model pertains to inventors (and their financiers) who face a decision whether to invest in bringing an invention to market, and then whether to remain in production or exit the market. The model allows for differences in the circumstances of inventors and their inventions, as well as unpredictability in the development process and in the eventual markets for inventions.

Let the entrepreneur's profit function be

$$\Pi_i = \int_0^{T_i} e^{-\rho t}\left((\kappa_i^{-1}p_i - c_i)Q_i - F_i\right)dt - S_i, \qquad (1)$$

where Π_i is the discounted profit of company i discounted at rate ρ, $\kappa_i^{-1}p_i$ is its price, c_i its average unit production cost, Q_i its number of units demanded (and produced) per annum, F_i its a fixed cost flow, and S_i its sunk costs accrued before time 0 ($T_i,\rho,\kappa_i,p_i,c_i,Q_i,F_i,S_i > 0$).1 Market competition is measured by the index κ_i. Profits accrue from the outset of the market at time 0 to a final time T_i. Let $\pi_i = (\kappa_i^{-1}p_i - c_i)Q_i - F_i$ denote the current-valued profit flow after time 0. For simplicity the price, cost, demand, and fixed cost are assumed to be constant over time. Therefore equation (1) becomes

$$\Pi_i = \left((\kappa_i^{-1} p_i - c_i) Q_i - F_i\right)\tilde{T}_i - S_i, \tag{2}$$

where $\tilde{T}_i = \frac{1}{\rho}(1 - e^{-\rho T_i})$. The price $\kappa_i^{-1} p_i$, unit cost c_i, and output Q_i are those that result from whatever process the entrepreneur uses to choose a market-clearing output; they may represent the result of an optimal output decision subject to demand and cost curves faced by the entrepreneur.

Both product development and market outcomes are in part unpredictable. Their unpredictability is embodied in the model by assuming that S_i and Q_i are random variables. The variables have means $E[S_i] = \nu_i$ and $E[Q_i] = \mu_i$, standard deviations ω_i and σ_i respectively, and probability density functions $g(S_i; \nu_i, \omega_i)$ and $f(Q_i; \mu_i, \sigma_i)$ respectively. The entrepreneur and investors know in advance the distributions of S_i and Q_i, but they observe actual outcomes only after time 0 once sunk costs have been incurred and production has begun. The entrepreneur and investors pay for the sunk costs of product and market development if this yields positive expected profit, i.e., if

$$\left((\kappa_i^{-1} p_i - c_i) E[Q_i] - F_i\right)\tilde{T}_i > E[S_i]. \tag{3}$$

Once the sunk cost has been paid and the market entered, production is continued if and only if $\pi_i > 0$.

Implications

Ceteris paribus, the entrepreneur and investor pay the sunk costs if and only if

[1] All values in the model, including the sunk cost S_i, are measured in monetary units at

$$E[Q_i] > \frac{1}{\kappa_i^{-1} p_i - c_i}\left(F_i + \frac{E[S_i]}{\tilde{T}_i}\right). \tag{4}$$

(Note that $\kappa_i^{-1} p_i - c_i > 0$ if entry occurs, since otherwise the discounted profits would be negative.) Hence the expected sunk cost creates a selection effect. Ceteris paribus, the higher is an entrepreneur's expected sunk cost, the higher is the minimum bound on $E[Q_i]$. After production has begun, though, the current profit flow is independent of the sunk cost. Continued production occurs if profits turn out to be positive, that is, if and only if

$$Q_i > \frac{F_i}{\kappa_i^{-1} p_i - c_i}. \tag{5}$$

Hence among entrepreneurs that enter the production stage, those with larger expected sunk costs tend to be less likely to exit:[2]

H1. Greater expected sunk cost is associated with reduced probability of exit.

Figure 1 illustrates this selection effect for hypothetical inventors i and j, identical except in their expected values of production. The curves labeled i and j are probability density functions for the output of these inventor-entrepreneurs with means 4 and 6 and both with standard deviation 2. After entry, entrepreneur ℓ exits if $Q_\ell \le \frac{F_\ell}{\kappa_\ell^{-1} p_\ell - c_\ell} = 2$, i.e., if production turns out to fall within the shaded region. In this example, the shaded region makes up 14.3% of the probability density for inventor i but only 0.4% for inventor j, so

time 0.

[2] It may be possible to construct pathological formulae for $f(\cdot)$ such that hypothesis 1 does not hold under certain circumstances, but this is unlikely for densities arising in practice.

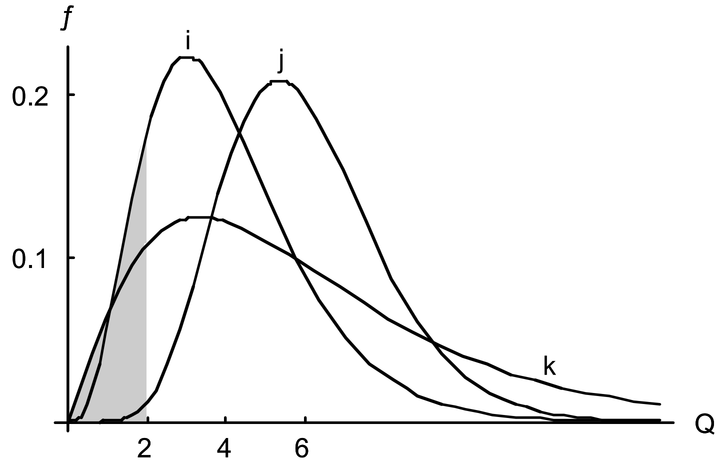

Figure 1. Distributions $f(Q_i)$, $f(Q_j)$, and $f(Q_k)$ for inventors $\ell = i, j, k$ with means $\mu_i = 4$, $\mu_j = 6$, and $\mu_k = 6$, and standard deviations $\sigma_i = 2$, $\sigma_j = 2$, and $\sigma_k = 4$, but otherwise identical parameters. The shaded region indicates values of Q_i, Q_j, and Q_k for which exit occurs after entry, because $Q_\ell \le \frac{F_\ell}{\kappa_\ell^{-1} p_\ell - c_\ell} = 2$.

that i is far more likely to exit than j.[3] If inventors like i are discouraged from entry by an increase in expected sunk cost, leaving inventors who like j have a low probability of exit, the exit rate among all entering inventors is decreased.

Unpredictability of demand, as measured by the standard deviation of the quantity produced, also affects the probability of exit. With a greater standard deviation, Q_i is more likely to take on very low or very high values, and hence firm i's value of Q_i tends more often to fall at or below the lower bound of $\frac{F_i}{\kappa_i^{-1} p_i - c_i}$ indicated in the condition (5) required for continued production.[4] Hence:

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[3] In Figure 1, it is assumed that $\frac{F_\ell + E[S_\ell]/\tilde{T}_\ell}{\kappa_\ell^{-1} p_\ell - c_\ell} < 4$ (i.e., $\frac{E[S_\ell]/\tilde{T}_\ell}{\kappa_\ell^{-1} p_\ell - c_\ell} < 2$) for both inventors, so that both have the incentive to enter. The pdf used is the two-parameter gamma distribution.

[4] It is possible to construct pathological formulae for $f(\cdot)$ such that hypothesis 2 does not hold under certain circumstances (for example by choosing a pdf $f(\cdot)$ with a very high

H2. Greater demand uncertainty is associated with increased probability of exit.

Figure 1 illustrates this selection effect for hypothetical inventors j and k, identical except in their standard deviations of production. The curves labeled j and k are probability density functions for the output of these inventor-entrepreneurs with standard deviations 2 and 4 and both with mean 6. After entry, entrepreneur ℓ exits if $Q_\ell \le \frac{F_\ell}{\kappa_\ell^{-1} p_\ell - c_\ell} = 2$, i.e., if production turns out to fall within the shaded region. In this example, the shaded region makes up 0.4% of the probability density for inventor j but 12.4% for inventor k, so that k is far more likely to exit than j.

Risk associated with product development, as measured by ω_i, has no direct effect on the probability of exit. Once the sunk cost has been paid, and the entrepreneur begins producing the product, neither S_i nor ω_i can impact the profit flow. Moreover, if entrepreneurs and their investors are risk-neutral and unbiased as portrayed in the model, then ω_i also has no effect on which firms pay the sunk cost of product development. Inequality (4), which determines whether the sunk cost is paid, does not depend on ω_i. Hence:

H3a. If entrepreneurs and their investors are risk-neutral and unbiased, then product development risk is unrelated to exit.

However, there is some evidence to suggest that inventor entrepreneurs might be risk-seeking or that they make erroneously optimistic assumptions (Arabsheibani et al., 2000). The opposite effect might arise if risk-averse investors determine whether most inventions can receive necessary start-up funds. Risk aversion raises the hurdle for entry, while risk-seeking behavior (or over-optimism in cases in which costs are difficult to

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expected value but with a substantial mass of probability at value near zero), but this is predict) lowers the hurdle, affecting the profit distribution for entrants. Since profit less than zero results in exit, risk aversion decreases the probability of exit (conditional on entry), while risk seeking increases the probability of exit (conditional on entry):

H3b. If entrepreneurs are risk-seeking (or over-optimistic in difficult-to-predict cases) in ways not prevented by investors, then greater product development risk is associated with increased probability of exit.

H3c. If investors force risk-averse decisions upon entrepreneurs, then greater product development risk is associated with decreased probability of exit.

Thus empirical outcomes have the potential to probe the risk-seeking or risk-averse behavior associated with commercialization of independent inventions.

Other model parameters affect both the expectation of profit before entry occurs, and realized profit once the sunk cost of entry has been paid. Three such parameters are in the model: p_i measures price potential, κ_i is the competition intensity measure, and F_i is the fixed cost flow while production occurs. Since $\frac{\partial \pi_i}{\partial p_i} > 0$, $\frac{\partial \pi_i}{\partial \kappa_i} < 0$, and $\frac{\partial \pi_i}{\partial F_i} < 0$ (and the analogous derivatives of Π_i have the same sign), profits increase with price potential and decrease with competition intensity and fixed cost.

How do these parameters affect the probability of exit? Ceteris paribus, greater price potential, or lower competition intensity or fixed cost, has two effects on exit probabilities. First, for inventions that would have been introduced anyway, the greater profit increases the probability that $\pi_i > 0$, thereby reducing the probability of exit by the same (absolute) amount. Second, the increased profit opportunity impels more entrepreneurs to pay the sunk cost of development and enter production. With typical

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unlikely for densities arising in practice.

skew distributions for the market size Q_i, the marginal entrants have an exit probability of over 50%. The net effect on the probability of exit is ambiguous, and depends on the population-wide distribution of characteristics of inventors and inventions.

H4a. If there is a low number of potential entrants at the margin of deciding whether to commercialize their invention (relative to entrants), then (i) greater price potential, (ii) lower competition intensity, and (iii) lower fixed cost are all associated with reduced probability of exit.

H4b. If there is a high number of potential entrants at the margin of deciding whether to commercialize their invention (relative to entrants), then (i) greater price potential, (ii) lower competition intensity, and (iii) lower fixed cost are all associated with increased probability of exit.

In either case, all three parameters must operate in one of these two ways to affect the probability of exit. It is not possible for a mixture of hypotheses H3a andH3b to occur, because all affect the entry and exit decisions only through π_i:

H5. If price potential has a positive (negative) effect on the probability of exit, then competition intensity and fixed cost have a negative (positive) effect on the probability of exit.

Thus, the empirical outcomes again have the potential to probe an issue, in this case related to the skewness of the distribution of inventions and inventors and how it impacts exit at the margin. Moreover, hypothesis 5 provides an additional check on the validity of the basic economic model as a guide to the behavior of entrepreneurs.

4. Data

4.1 Data Collection Method and Sources of Data

We used the Inventor's Assistance Program (IAP) at the Canadian Innovation

Centre (CIC) in Waterloo, Canada to find data on inventions. The IAP helps inventors evaluate a specific idea or invention *before* it has reached the market. The purpose of this evaluation is to advise the potential entrepreneur on whether and how to continue efforts.[5]

1,095 responses were obtained from a telephone survey to primarily Canadian inventors that had invented between 1976 and 1993, representing a response rate of 75%. The sampling procedure is described in Åstebro and Gerchak (2001). In the telephone survey we inquired about the entry date (month and year) and the exit date (month and year) for inventions that were commercialized.

An overwhelming majority of inventors who responded are male (89%) and a plurality of their inventions are consumer-oriented (47%). Most are for household and general consumer use (28%), followed by sports and leisure applications (15%). A list of successful inventions reviewed by the IAP includes a new milk container design, an impact absorbent material sewn into the back of a T-shirt for hockey players, a meat tenderness tester, and a toilet tissue holder. However, a significant fraction of "high-tech" (6%) and industrial equipment (6%) inventions are also reviewed by the IAP (CIC 1996), such as an industrial-strength crusher of recycled cans, a new method for repairing worn feed rolls in sawmills, a re-usable plug to insert in wooden hydroelectric poles after testing for rot, and a computerized and mechanically integrated tree harvester. The majority of inventors (72%) are from the Province of Ontario. A number of tests were conducted to establish that the variation in sampling and response proportions across the year of submission, province in Canada, gender, and IAP rating were random, and indeed no selection bias was detected (Åstebro, 1997).

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[5] For further descriptions see Udell (1989), Udell et al. (1993) and Åstebro and Gerchak (2001).

4.2 Independent Variables

An administrative record kept at the IAP included subjective ratings for several innovation and product-market characteristics for each invention. Staff members of the IAP evaluated each innovation in terms of criteria or attributes believed by the agency to be important to ultimate success of the innovation as a product in the marketplace. These evaluations were made well ahead of market launch. Åstebro (2003) reports an average lead time between evaluation and market launch of approximately two years. Evaluations were made on a three-point scale of “A” (Acceptable – favorable or satisfactory), “B” (Borderline – needs improvement or strengthening), or “C” (Critical Weakness – usually meaning that it may be necessary to discontinue the effort to commercialize the invention). The numerical equivalents assigned were 5, 4, and 3 (A through C). Data on the independent variables were consequently collected before outcomes were observed and independently of this study. We therefore avoid methods bias (Campbell and Fiske, 1959) and hindsight bias (Fischhoff, 1975).

The IAP employed the same chief evaluator between 1981 and 2000. All evaluators were trained by the chief evaluator in the evaluation procedure – the initial training took about two days and close supervision took place for an additional fortnight. A group meeting at the end of each review also mitigated potential erroneous classifications. Baker and Albaum (1986) test the reliability of the instrument used by the IAP across 86 judges and six products and find Cronbach alphas ranging from 0.84 to 0.96, implying highly comparable ratings across IAP personnel.

Measures of the key variables in our model were collected as part of the IAP evaluations. Table 1 reports the measures and their precise descriptions. Three of the measures, expected tooling cost, expected overall investment cost, and R&D cost

TABLE 1. Variables Assessed by the IAP

Variable Name	Description (as used by the IAP)
Tooling Cost	How great a burden is the cost of production tooling required to meet the expected demand?
Size of Investment	Is the total investment required for the project likely to be obtainable?
Development Uncertainty	What degree of uncertainty is associated with complete successful development from the present condition of the innovation to the market ready state?
Demand Uncertainty	How closely will it be possible to predict sales?
Price	Does this innovation have a price advantage over its competitors?
Manufacturing Cost	Does production at a reasonable cost level appear possible?
Competition from Imitators	Is this innovation likely to face new competition in the marketplace from other innovations that must be expected to threaten its market share?

uncertainty, were specifically assessed in ways that pertain only to sunk costs. The remaining measures, demand uncertainty, expected potential to charge a high price, expected rate of product imitation by competitors, and expected manufacturing cost, all pertain only to the period after entry.

4.3 Survival Data

For this paper we restrict our analysis to inventions developed between 1989 and 1993 that successfully reached the market by 1996. This leaves 48 observations, plus an additional observation for which the survival measure could not be obtained.[6] The innovations that were still selling as of 1996 (the time of the survey) are right censored, in that information on when and whether exit occurred is unavailable after a final date.

5. Results

Inventors that had exited the market by the time of survey were asked for the reason(s) for exit. Only a single response, the most important reason, was allowed.

[6] Unfortunately we could not include in our analysis inventions that earned royalties or sold the intellectual property rights as it was not possible to track these innovations' survival in the market. In most of these cases the original inventors obtained up-front fees and did not know how long the innovations survived in the marketplace. One percent of

These data are not used in the regression analysis since they are subject both to hindsight and recall bias. However, the responses are nevertheless interesting as they indicate the degree to which profit seeking behavior might be associated with the exit decision. Table 2 reports that the dominant factor associated with "pulling the plug" is low sales volume (20%), followed by personal reasons (8%) and that the inventor lost interest (8%). Six percent found the profit per unit to be too low, and a combined 6% exited because they sold or licensed the intellectual property. A sundry of reasons are tallied up in the "other" category representing 43% of the responses. Therefore, while the profit motive is a dominating factor, there are many other reasons for why innovations are discontinued, and many of these reasons are not primarily profit related.

TABLE 2: Reasons for Exit.

Why did you stop selling the innovation?	Number	Proportion
Profit per unit too low	3	6%
Sales volume was too low	10	20%
Lack of capital	3	6%
Lost interest	4	8%
Family or personal reasons	4	8%
Found better opportunities elsewhere	1	2%
Licensed the right to sell it	2	4%
Sold the intellectual property rights	1	2%
Other reasons	21	43%
Total	49	100%

We regress the dependent variable, survival time, on the independent variables using an exponential hazard function with no duration dependence while controlling for right censoring. The dependent variable thus represents the probability of failing in each

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the overall sample representing twelve percent of all innovations obtained royalties or sold the intellectual property rights.

time period conditional on surviving until that time. Letting λ denote the failure probability,

$$\lambda = \exp(\alpha + X'\beta), \tag{6}$$

where X is a vector of independent variables, α is a constant, and β is a vector of coefficients.

Maximum likelihood estimates of the exponential hazard model are shown in column (1) of Table 3. We used two measures of sunk costs: tooling costs and the overall size of the investment. Neither of the indicators is significant, although the sign of each is in the direction anticipated in hypothesis 1.[7] Higher sunk costs are associated with a lower probability of exit, consistent with the idea that high sunk cost projects must generate high expected profit streams to warrant paying the sunk costs. The next two variables measure R&D and demand uncertainty. Both have positive effects and are near significant with signs indicating that higher uncertainty is associated with higher exit probabilities. The results are consistent with hypothesis 2, consistent with the idea that greater uncertainty yields a greater fraction of unprofitable projects. The results also fit with hypothesis 3b, suggesting that the entrepreneurs might be risk-seeking or over-optimistic.

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7 We tried using just one of any of the two variables to improve, potentially, standard errors that may be inflated due to collinearity but were not successful.

TABLE 3: Regression Results.

	Proportional Hazard	Proportional Hazard	Accelerated Faiure Time
	Exponential (1)	Weibull (2)	Log-Logistic (3)
Intercept	5.59	5.52	-9.37
	(5.13)	(5.14)	(5.85)
Tooling Costs	-0.38	-0.40	0.31
	(0.65)	(0.66)	(0.56)
Overall Size of Investment	-0.53	-0.57	0.37
	(0.78)	(0.81)	(0.63)
Research and Development Uncertainty	0.94*	1.04*	-0.92*
	(0.53)	(0.55)	(0.53)
Demand Uncertainty	1.37	1.35	-1.82*
	(0.85)	(0.86)	(1.04)
Price	-1.58**	-1.75**	1.41**
	(2.40)	(0.80)	(0.71)
Manufacturing Cost	0.29	0.31	-0.39
	(0.80)	(0.81)	(0.72)
Competition from Imitators	1.92**	2.09**	-1.81**
	(0.77)	(0.85)	(0.69)
Log likelihood	-34.69	-34.50	-34.89
2*Log likelihood ratio	20.25***	20.35***	19.11***
N	48	48	48

* p < 0.10, ** p <0.05, *** p <0.01,

The next two variables assess expected price and manufacturing cost. A higher price is significantly associated with a reduced exit probability, while the expected manufacturing cost has no relationship to survival. Finally, a greater expected rate of imitation, a measure of competition, is significantly associated with a higher exit rate. The results are thus reasonably consistent with hypotheses 4a and 5, suggesting that the number of marginal potential entrants in the IAP sample is not so large as to obscure the direct effects of profit-related variables on survival. The lack of an effect of expected manufacturing cost is not consistent with the simple economic model used to represent inventors' motives. Of course the limited sample size suggests caution in interpreting these results. The variables are all equally scaled so the magnitudes of the coefficients speak directly to their relative importance. Competition from imitators has the strongest influence on exit probabilities, followed by price, demand uncertainty and R&D uncertainty. The model fit the data well with χ^2=20.25 (d.f.=7, p<0.01).

To investigate the assumption of a constant exit probability over time we fit two alternative models to the data. The Weibull model allows for a constantly increasing or decreasing exit probability with time, while the log-logistic model allows for more complicated duration dependencies as it introduces an extra parameter. Maximum likelihood estimates for the Weibull model are shown in column (2) of Table 3 and indicate similar results to that of the exponential model. The exponential model is a nested model of the Weibull model, so twice the positive difference in the log-likelihoods evaluates the fit of the Weibull over the exponential: χ^2=0.38, with p>0.10. In other words there is no significant difference between the fit of the exponential and Weibull models to the data. Maximum likelihood estimates for the log-logistic model are shown in column (3). The signs of coefficients are reversed because estimation was performed using an accelerated failure time specification. Signs are therefore consistent across estimations. The exponential model is not nested within the log-logistic model and so a likelihood-ratio test is not possible to conduct. However, the log-likelihood for the log-logistic is -34.89 which indicates a marginally less well fitting model than the exponential even though an extra parameter is used. It is therefore no reasonable to argue that the log-logistic model is preferable. In all, these alternative specifications indicate robust parameters. The results also indicate that the preferred model specification is without duration dependence. We obtain an expected survival time of 9.92 years for the exponential model implying a probability of exiting the market in any year of approximately 0.1.

6. Discussion

We chose to study the survival of innovations undertaken by independent inventors, a subset of all entrepreneurs. The survival duration can be reasonably described with an exponential distribution, which has a constant probability per year that a surviving producer exits the market. The dominant factor associated with "pulling the plug" on an innovation, as reported directly by the entrepreneurs, is low sales volume (20% of replies), followed by personal reasons (8%) and loss of interest (8%). A sundry of non-financial reasons are tallied up in the "other" category representing 43% of the responses. Therefore, while the profit motive is a dominant factor, other factors also influence whether innovations are discontinued. These results are to some extent consistent with the survey of 710 inventors by Rossman (1931) [quoted in Nelson (1959)] which found that for most inventors, inventing is creative self-expression, the two most frequently mentioned motives being "love of inventing" and "desire to improve." "Financial gain" was marked third. Following these results one might expect entrepreneurs to have a higher rate of entry than what is motivated by profit-seeking behavior, as suggested by Frey and Benz (2003) and Hamilton (2000).

Nevertheless, the alternative non-financial reasons for exit put forward by the entrepreneurs in this study do not undermine the economic components of entrepreneurial motivation. The stated importance of financial reasons for exit in many cases, along with the significant effect of economic variables on exit, makes us reasonably confident in an economic model of innovation exit. The diverse non-economic reasons for exit imply a large role played by the error term, but leave the rest of the explanatory power to economic variables.

Regression results revealed three robust predictors of survival: price, R&D uncertainty, and expected competition from imitators. Other variables have the hypothesized signs and are sometimes significant, lending further support to the decision model presented in Section 3. Overall, the results provide support for a simple non-symmetric model of entrepreneurial decision-making where exit decisions are influenced by expected profitability.

An interesting finding of this study is that R&D development uncertainty is associated with exit probabilities. An entrepreneur should not be concerned with R&D development uncertainty once entering the market, as the sunk cost of the development R&D has then been paid. Moreover if entrepreneurs are risk-neutral, neither should R&D uncertainty affect exit probabilities by acting as a sorting device, as the magnitude of sunk costs does. However, if the entrepreneurs are risk-seeking (or over-optimistic in difficult-to-predict circumstances) then an increased variance in development risk might induce entrepreneurs with marginal invention projects to enter, leading to an increased observed rate of exit. Risk-seeking behavior is of course a plausible alternative explanation to the observed low rates of return to entrepreneurship (Hamilton, 2000; Åstebro, 2003). Indeed, Åstebro (2003) argues that his results are consistent with a model of entrepreneurs as being "skewness-lovers," who, while realists, are attracted to unfair gambles with negative expected values because of a skew distribution of return with a miniscule probability of extreme gains. In this study the positive estimated effects of uncertainty in (pre-entry) R&D sunk cost likewise suggest that inventor-entrepreneurs may be risk-seekers or optimists.

Explanatory power may be reduced in our analysis because the early stage evaluation by the IAP provides the potential entrepreneur with advice on whether and how to continue R&D efforts, rather than predicting the probability of survival. In other words, the ratings for the explanatory variables for a specific invention may not stay the same after the evaluation if the inventor-entrepreneur makes efforts to improve some of the characteristics according to the advice provided by the IAP. If entrepreneurs work toward correcting problems identified by the IAP and then succeed in launching products, the explanatory power of our measures is reduced. In addition, the sample used for predicting survival was fairly small, 48 observations, leading to low statistical power. Finally, one should notice that the evaluation was done well ahead of market launch. Imperfect prediction of future values of parameters that affect profits limits the observed relationship between measures such as manufacturing costs on the one hand and exit on the other. Despite these reasons for underestimation of parameter effects, the evidence reported here usefully provides one of the first analyses of effects of economic parameters on the behavior of inventor-entrepreneurs.

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