Competition, Innovation, and Product Exit

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Abstract

Why do products exit markets? This paper integrates rationale for product exit from a number of different literatures and compares the statistical and substantive effect of these explanations. We use a novel dataset covering every product introduced into the desktop laser printer industry since its inception. Using hedonic models, hazard rate models, and count models, this study generates three main findings. First, innovation does not drive products out of market per se. Managers do not pull products off the market when they innovate. Rather they seem keep the incumbent products on the market and add the newer, more innovative products to the marketplace. Second, competition has a large impact on driving products out of markets. These non-innovative products remain in the product portfolios of companies until competition and cannibalization drive the products out of markets, not managerial decisions. Third, holding other factors constant, fixed cost and process innovation, while sometimes statistically significant, has a small substantive effect on product exit. This is may be because in differentiated product markets, firms of varying costs can survive.

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I. INTRODUCTION

Why do products exit markets? The short answer is that the products are no longer profitable. But what makes products no longer profitable? The academic literature puts forth a number of reasons why products that were once profitable, are no longer so. The first stream of literature argues that as time progresses, more firms and products enter the market, thus pushing down prices. A firm that was once alone in a market or market niche encounters many competitors that erode the incumbent's market power, and push down prices (Stavins 1995). A second stream of literature argues that a firm's products prey on its other products and result in cannibalization. A multi-product firm must thus optimize its portfolio to minimize cannibalization. This means exiting products that do not enhance the value of the portfolio as a whole (Greenstein and Wade 1998). Another vein of literature examines fixed cost. If there are significant fixed costs, then scale is important in order to distribute fixed costs across more units. Products belonging to small firms will fail in this environment because their costs cannot become competitive (Audretsch and Mahmood 199x, Stigler 1968). Yet another literature argues that it is not fixed costs that doom products, but improvements in marginal costs. Firms acquire learning or capabilities that can allow them to consistently improve the cost structure of their products. Firms that are unable to dynamically improve their learning or capabilities over time will find their products uncompetitive (Klepper 1996, Teece et al 1997, Jovanovic and MacDonald 1994, Jovanovic and Lach 1989). This literature is a superset of a related literature on innovation and product life cycle. This work in innovation argues that firms will invest in process innovation late in the product life cycle, after a dominant design is establish, in order to push down costs. Firms that do not, will find themselves and their products at a distinct disadvantage (Abernathy and Utterback 1975, Klepper 1996). In this sense it is similar to the capabilities literature. Yet, another aspect to the product life cycle literature is that firms will invest in product innovation in order to enhance the quality, characteristics, and commercialization potential of products. If firms do not, their products will be weeded out by more innovative products (Christensen 1997, Gort and Klepper 1982).

While each of these disparate, yet related literatures has demonstrated its relevance and importance to scholars, there has not been an integrative study that compares these factors and rigorously examines *product* exit. To date, nearly every single study has studied *firm* exit (e.g. Hannan and Carroll 1994, Barnett 1996, Henderson 1994, Christensen et al 1998, Jovanovic 1994, Tushman and Anderson 1986, Ghemawat and Nalebuff 1983). However, the theories that explain firm exit have their microfoundations in product markets and strategies. Hence, to gain a deeper understanding into the firm survival condition, we must understand what is happening at the product level, and how choices at the firm level affect product entry, exit, and profitability outcomes.[1] To this end, this study attempts to bring these varied literatures together, and examine what are the most important factors for product exit—managerial decision making or the outside environment. It is also the first study to examine product evolution from the inception of the industry.

Why do products exit markets? This paper integrates rationale for product exit from a number of different literatures and compares the statistical and substantive effect of these explanations. We use a novel dataset covering every product introduced into the desktop laser printer industry since its inception. Using rigorous statistical methods, this study has three main answers to this question. First, innovation does not drive products out of market per se. Managers do not pull products off the market when they innovate. Rather they seem keep the incumbent products on the market and add the newer, more innovative products to the marketplace with longer expected lives. Second, competition has a large impact on driving products out of markets. These non-innovative products remain in the product portfolios of companies until competition and cannibalization drive the products out of markets, not managerial decisions. Third, holding other factors constant, fixed cost and process innovation, while sometimes statistically significant, has a small substantive effect on product exit. This is likely because in differentiated product markets, a market may be able to support firms of varying costs. We explore other alternatives in the paper as well. Overall, the results in this paper are consistent with literature on product proliferation. However, instead of having strictly horizontal differentiation (Schmalensee 1987, Judd 1985), there is product proliferation on the innovative vertical differentiation dimension as well (Shaked and Sutton 1987)

In the next section we lay out more concretely the hypotheses of the paper, and simplify and categorize the literature so that it can be tested. In the third section of this paper, we describe the desktop laser printer industry, and explain why it is a good arena in which to compare theories empirically. We describe our data, method, and hypothesis operationalization in Section IV. In Section V, we offer our empirical results. In Section VI, we describe some extensions, and we conclude in Section VII.

II. WHY DO PRODUCTS EXIT MARKETS?

[1] Only two studies to date (Greenstein and Wade 1998, Stavins 1995) examine product exit.

Product exit receives prominent attention in the theoretical literature, yet is often overlooked in the empirical literature. One reason is that product population data is extremely difficult to obtain. Second, most theories assume single product firms. Yet, if we are to understand firm behavior, we must understand what happens to their product portfolios.

In this paper, we attempt to bring together, simplify and integrate a number of streams of literatures to explain why products exit markets. What makes some products so unattractive that managers choose to discontinue them, or markets and technology drive them out? We test the relative importance of four main factors in product exit, using an integrative perspective that speaks to multiple literatures.

The first reason that products exit markets is because price competition is too fierce, for a given cost. A product enters under the expectation of achieving and maintaining a price point. However, if competitors enter the market space, the market power that the initial product enjoyed disappears, and the product becomes less profitable. Thus, we expect to see higher product exit rates the fiercer is competition.

H1: Greater competition will result in higher product exit.

A second reason products may exit markets is because of a high cost position. There are two types of costs that can be reduced on a product basis—the marginal cost and allocated fixed cost. The marginal cost is reduced through various process innovations and learning. The fixed cost per unit is reduced by either reducing the overall fixed costs, or increasing the number of units over which the fixed cost is allocated. Some of fixed cost can be allocated across multiple products (such as a factory that makes multiple products), and while other fixed costs can be allocated across each unit of the brand (brand advertising). Thus, for a given industry with substantial fixed costs, we expect to see firms with higher market share obtaining a better cost position, and therefore have lower per unit cost of product for their products. This means that firms with higher market share will have products with lower probability of exit.

H2a: There will be lower product exit rates for firms with higher market share.
H2b: There will be lower product exit rates for firms with lower marginal cost position.

A third reason products exit markets is because of product portfolio reasons. That is, in a multi-product firm, the product does not maximize the profits of the entire product portfolio.[2] We see this effect most prominently stated in the literature on cannibalization, where one product can cannibalize sales of another product. If this is the case, the firm is often better off exiting one of the products. Thus, the higher the probability of cannibalization, the higher the probability of product exit.

H3: Product exit rates will be higher the more products a firm has in a given a product niche.

A final cause of product exit is product innovation. The effect of product innovation on the probability of product exit is not obvious, because a more innovative product may enter, which may result in an older product exiting or not. We consider four cases for the innovative product and incumbent product: (H4a) hold, exit; (H4b) enter, exit; (H4c) hold, no exit; and (H4d) enter, no exit. In the first case, the firm has a more innovative product, but chooses to

[2] Note that the individual product, in this case, could be profitable, but it may diminish the profitability of the product portfolio as a whole.

wait to enter. Meanwhile, it exits the current product. We think this is not interesting (nor an equilibrium) or extremely unlikely, because it argues that the firm is better off exiting the current product and having no products in the market, controlling for competition, cost, price, and current portfolio. This is a case that should not happen provided at least one product is profitable, because the firm would be better off with some kind of profitable market in the market, than no product in the market. The second case, is where the firm exits the incumbent product, and replaces it with a more innovative product. This is because the firm believes that the replacement product will be more profitable than the incumbent product individually, or both products together in the market. The third case is where the firm chooses to innovate, but to wait on entering. This is because the old product is more profitable than the new product and more profitable than having both products in the market. The final case is where the firm enters the innovative product, but does not exit the incumbent product. This is because the profit generated from having both products in the market, exceeds the profits from any individual product in the market alone.

We codify this in Figure 0.

H4a-d: Firms will choose product entry-exit strategy doubles to maximize the value of the portfolio. (see Figure 0)

H4e: More innovative products will have lower product exit rates.

III. THE LASER PRINTER INDUSTRY

We have chosen the desktop laser printer industry in which to examine these hypotheses for a number of reasons. First, the characteristics of laser printers are constantly improving, buffeted by the forces of innovation, and can be easily seen and measured. Second, the printer industry has numerous product entries and exit, since its inception in 1984, and we are able to track each one, with a comprehensive dataset. Third, the competitive environment varies across the industry, and therefore we can account for competitive and price effects. Fourth, there are heterogeneous firms of different sizes, which contributes to variance in firm type. Finally, and perhaps most importantly, the laser printer industry is like a number of other high technology industries, such as personal and mainframe computers, disk drives, fax machines, retail electronics, and the like. The products are differentiated; there is an innovation frontier; there is an important mass market; and product and firm turnover is prevalent. Thus the insights from this study we believe will be applicable to broad sectors of the economy. We discuss each point in further below.

As the personal computer market expanded in 1980s, so too did the market for the desktop printers. The first desktop laser printer (available on the retail market) was introduced by Hewlett Packard in 1984. By the end of 1985, 17 firms had introduced over 23 models of printers. Figure 1 illustrates the number of firms and models in the industry from the beginning of the industry in 1984 to 1996. At its peak in 1991, the industry had 143 firms. Since that time, the number of firms has fallen off to 97.

Three types of firms populate the industry. There is a large number of relatively big, diversified firms such as Ricoh, IBM, Hewlett Packard, Canon, and Xerox. There is also a small number of medium sized firms that specialize in multiple printer technologies, such as Lexmark, Kyocera, Genicom, and Kentek. Finally, there are over 100 very small "fringe" firms, which produce few printer models, ship very few units, or appear in the industry only briefly. Hewlett Packard is the dominant firm in the industry, and has maintained between 45% and 65% market share for most of the industry's history. Table 1 documents the concentration ratios of the top 1, 5 and 10 firms in the industry (noted as the C1, C5, and C10 ratios, respectively).[3] If a firm has appeared in any year of the sample in the C10 ratio, then we code that firm as a dominant firm. All other firms are considered fringe firms.

At the product level, there has been a large amount of product entry and exit by year. The number of products on the market peaked at 230 product models in 1996. In Figure 2, we illustrate the amount of product entry and exit by year. Figure 1 and Figure 2 together suggest that a smaller number of firms are offering more diversified product portfolios. The average number of products per firm is 12.5 in 1996, up from 2.8 in 1988.[4] We explore this result further in the econometric analyses.

Although printers can be characterized on a number of dimensions, our research has found that two most common measures of printer performance are speed, measured by pages per minute (PPM), and resolution, measured by dots per inch (DPI).

We define a product as a product model as defined by the vendors. On the surface, this definition may seem problematic. Vendors may have incentives to put many different product model numbers on the same printer in order to proliferate models in the product space (Judd 1985, Schmalensee 1978). Alternatively, they may make very small changes to a printer and market it as a different product. We have examined this possibility and found, with the exception of the addition of Postscript features (which in fact are substantial enhancements)

[3] The quantity data we possess seems to be sufficiently good to make determinations about the largest firms in the industry. Unfortunately, its coverage of fringe firms and individual models is lacking.

[4] In defining the industry, we appealed to the data and to industry experts and trade journals. These sources consistently define the desktop laser printer industry as laser printers that print 0-12 PPM, can be attached to a personal computer, and are small enough to fit on a desk. This industry definition has remained constant over the time period. When we analyzed our data, we excluded printers that were particularly fast, exceeded certain weight and size measures, or were not designed to communicate with any type of personal computer. Our statistical analyses are robust to small definitional changes.

printers with different model numbers generally do have different features. In addition, unlike some product markets, firms do not change printer attributes once the product has been introduced. Rather, they introduce new products.

IV. DATA AND METHOD

A. SOURCE OF THE DATA

The information on laser printer characteristics, entry, and exit come from a variety of sources. The primary source is Dataquest's SpecCheck analysis of page printers. Dataquest follows each manufacturer's product and records a variety of product characteristics, including ship date, speed, resolution, and other features. We found the data were incomplete for many models. Therefore, we supplemented our data with information from trade journals, private analysts' reports, and general industry data provided to us by a private consulting firm. We believe the dataset, which covers the industry from its inception in 1984 to 1996, is the most comprehensive available on the desktop laser printer industry. Over this 15-year period, we are able to record 833 printer introductions covering nearly 2835 printer-year observations. In the econometric analysis, we examine 1986-1996, because too few models were introduced in the early years of the industry to permit identification of the econometric models. Though we have attempted to be as thorough as possible, there remain some printers for which we cannot identify all of the independent variables. These have been dropped from the analysis. All data are recorded annually.

B. PATTERNS IN THE DATA

We begin by examining patterns in the data to describe the industry. We consider two dimensions of the product space: speed, measured as the number of pages per minute (PPM), and resolution, measured as the number of dots per inch (DPI). Printers are bunched tightly in groups in the performance space. For example, there are many printers that are 4PPM and 600 DPI. There are a few at 5PPM and 600 DPI, and then there are many at 6PPM and 600 DPI . Figure 3 presents our categorization of 20 discrete product classes (or niches) in terms of these two characteristics, based on the clear grouping of printers. In doing this, we are able to measure the competitive effect of products that are proximate in DPI-PPM space.

We turn to an analysis of the dynamics of the industry. Figure 4 offers a scatterplot graph where each circle is a printer model. The x-axis is the year, and the y-axis is DPI. Note that over time, newer printers have higher resolution. This is what we will call a single-edged product innovation frontier, where firms are pushing the envelope on resolution. This is akin to most the findings of most studies which study product improvement (e.g. Christensen 1997, Henderson 1995, Greenstein and Wade 1998).

Figure 5 shows the same types of graph as earlier for printer speed (PPM). In this time series, we see a different pattern. During this time period, and especially in 1986-1993, firms introduced printers that were faster as well as printers that were slower than those introduced in 1984, the first year the product was developed. The top frontier of faster printers is as one would expect. Namely, that firms constantly increase the speed of printers through product innovation. However, the bottom frontier (or double edged frontier) is not found in other academic studies, but likely exists in many industries. Why do we see this?

It is likely, from our investigation of the industry, that this second frontier is technologically driven by process innovation.[5] That is, in order to reach a mass market, manufacturers have to drop the price of their printers. In order to do this, not only do they have to economize on product features, but they also have to engage in substantial process innovations in order to achieve a lower cost, and hence price, position. Thus, products on this frontier do not just have less expensive features, but they also are attempts by manufacturers to reach a mass market. This type of innovation is rarely discussed in the literature, and this is the first paper we are aware of that illustrates this second–edged frontier. We exploit this second frontier to examine the role of process of innovation. This is discussed further below.

C. VARIABLE DEFINITIONS

We define a product exit as the first year that the product drops out of the dataset. This means that none of the sources reports the printer is being shipped to retailers, although it may still be available in some outlets from inventory. If any one of the sources reports the printer is still being shipped, we record it as still on the market.

One alternative measure of product exit is to register an exit when product sales have ceased. We have collected the best data available from a private company on the quantity of models shipped by manufacturers for 7 years (1990-1996), and we found they are incomplete and biased in favor of popular models.[6] Our analysis confirms that the data do not record units sold for low volume models or for models of smaller vendors. We know of no source of data that tracks the quantity over the entire time period for truly all models on a model level. This data

[5] This double-edged frontier could be driven by consumers some of whom value speed more than others.

[6] Greenstein and Wade find similar problems with the IDC data in mainframe computing (1998: p. 779, ftn 13-15).

does seem to be realistic at the aggregate sales level for individual product niches, but its precision may still be suspect. As extensions to the main regression, we re-run the data using the quantity data in Section VI.

The right-hand-side variables are grouped into four categories, and are defined in Table 2. The first category of variable is the product characteristic variables. These include variables like MODEL AGE, DPI and PPM. The second set of variables measure firm characteristics, such as DOMINANT FIRM, OWN ALL MODELS, PATENTS and FIRM AWARD. A third set of variables measure the market structure, such as TOTAL MODELS, SAME NICHE, and SAME DPI/PPM. A final set of variables measures other factors such as the impact of complements and substitutes and the impact of firm entry.

The descriptive statistics are found in Table 3. These statistics provide some rich description of the data. The average product stays on the market for four years, and costs almost $3000. The most prevalent standard is HP-PCL, followed by Postscript (a proprietary Adobe standard). Although the average printer has increased its resolution, the average speed of the printers has remained constant from the beginning of the industry, reinforcing our earlier data on a two-edged frontier in PPM-Time space.

As a preliminary step in our statistical analysis, we assessed the value of various product features, so we could see if products with valuable features survive longer in the marketplace. In order to measure value, we ran a simple hedonic model. The results are in Table 4. In this model we see that quality adjusted list prices have been dropping at about 15% per year, beginning in 1988, to the point today that quality adjusted prices are about 30% of their 1986 levels. The regression shows that HP actually receives a 14% list price discount relative to other firms.[7] The hedonic model also calculates the imputed value of each type of feature. While each PPM increases the value of the printer by 17%, each 100 DPI decreases the value by 2%. This is likely an artifact of the competitive dynamics in the industry, which we discuss later. HP-PCL standards adoption tends to decrease the price of the printer by 14% relative to Postscript. Firm effects are rarely individually statistically significant, and are not jointly significant.

D. METHOD

We use an exponential hazard rate specification to examine the determinants of product exit over the product life cycle. The flexibility of this method in accounting for censoring, as well as time variant and time invariant independent variables, makes it attractive to study product failure.

In this specification, the individual model is the unit of analysis. The likelihood function for any given observation, i, can be written as:

$$L_i = G_i(t_i)[\mu_i(t)]^{\phi}$$

where $G_i(t)$ is the survivor function, $\mu_i(t)$ is the hazard rate, ϕ is a variable that is one for uncensored cases and zero otherwise, and t_i is the number of periods that product *i* is in the market (Tuma and Hannan 1984). We begin by assuming a constant hazard rate of $\mu(t) = \gamma$ (the

[7] Kyle and de Figueiredo (2000) find that dominant firms on the whole had lower prices, but they also entered classes later. When this late entry is accounted for, it seems dominant latecomers charge higher prices than fringe firms that enter with a similar delay. Therefore one explanation for the finding that dominant firms' products are less expensive is that fringe products are the most advanced and first to market, while dominant firms follow and enter at lower prices than existing fringe products.

exponential distribution). The survivor function is then $G(t) = \exp[-\gamma t]$. The following specification is used:

$$\mu(t) = \exp[X(t)\alpha(t)]$$

where $\mu(t)$ is the instantaneous hazard rate for a system at time t and X(t) is a vector of time-varying independent variables. Each $\exp[X(t)\alpha]$ can be thought of as multipliers of the hazard rate, and α can be estimated using maximum likelihood techniques (Carroll 1983, Tuma and Hannan 1984). Because we have data from the beginning of the industry, left censoring is not a problem. We omit all observations for products that were introduced before 1986 (the first year of the econometrics). The estimation procedure accounts for right censoring.[8]

E. OPERATIONALIZING THE HYPOTHESES IN THE LASER PRINTER INDUSTRY

Given the importance of understanding the micro-foundations of firm behavior, we must operationalize the theory to determine why products exit. In particular, is it due to market conditions or managerial choice? Given the four hypotheses stated earlier, we expect to see certain coefficients on the independent variables. We describe the effects here and summarize them in Table 5. The first hypothesis predicts we will see higher product exit rates the higher competition. This suggests that the more product models in the industry, and in the niche, the higher the hazard rate. Thus we expect to see positive coefficients on TOTAL MODELS and

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[8] Unfortunately, we do not have the sufficiently detailed price and quantity data to estimate consumer demand at this time. Indeed, our analysis here is not structural. At this early stage in our data collection and analysis we feel it appropriate to rely on reduced form for analysis. Patterns in the data have yet to be established statistically, and structural estimations that are sensitive to specification error and measurement error are likely to pose challenges for data and interpretation. However, we do believe that the development of structural models that are tailored to understanding the demand and cost structures might be a useful path to follow in the future.

NICHE MODELS. If there is competition from neighboring niches, we would expect to see SAME PPM CLASS and SAME DPI CLASS also to have positive coefficients.

The second hypothesis predicts that firms with a lower cost position will have lower probability of product exit. We operationalize this by expecting negative coefficients on the variable that measures firm size. Thus DOMINANT FIRM should have a negative coefficient. We also expect PPM-SQUARED to have a negative coefficient. This is because process innovations manifest themselves on the lower frontier of the PPM curve, as firms attempt to reach a mass market with their products. Those products which do successfully reach that mass market are likely to benefit from production innovations. This would give slower products on the frontier higher survival rates, driving the coefficient on PPM-squared to a negative value.

The third hypothesis predicts a product portfolio that cannibalizes the firm's other products is likely to result in higher product exit rates. This means products which have many same-firm products in the same niche as the focal product are likely to have higher probability of product exit. Thus, the coefficients on OWN NICHE MODELS should be positive.

The innovation hypothesis is complex and multipart. If managers pull less innovative products before they pull more innovative products, then there are some kind of returns to innovation. If this is true, we should see the coefficients on PPM and DPI to be negative. As a second measure of innovative ability of the firm, we use PATENTS. We don't have strong priors about the way firms behave. However, we hope to narrow the possibilities. If H4a or H4b is true, the we should see a positive sign on the PATENTS coefficient; if H4c or H4d is true, we should see a negative or zero coefficient on the PATENTS variable.

Table 5 summarizes the predictions. In addition, with these predictions, we can not only test an integrative theory of product exit examining product-level data, but we can compare the magnitude of these four main causes of product exit using these methods. While there is some agreement that all of these effects could happen theoretically (and in some cases, demonstrated empirically), the relative magnitude of these effects has not been systematically examined. Our methods allow a comparison.

V. RESULTS

A. SPECIFICATION

We present in Table 6 five models. The first number next to each variable name is the hazard ratio (or multiplier of the hazard rate). A value of less than one indicates that an increase in the variable lowers the hazard rate; a value of more than one indicates that an increase in the variable increases the hazard rate. (In the remainder of the paper, we will sometimes refer the multipliers less than one as “negative coefficients”, and multipliers greater than one as “positive coefficients.”) The asymptotic t-statistics are presented in parentheses below the coefficient estimate. The significance is shown for two-tailed t-tests at the 95% and 90% significance levels.

Model 1 presents the data with the variables related to age (MODEL AGE, TIME TREND), product characteristics (POSTSCRIPT, HP-PCL, MODEL AWARD, DPI, PPM, PPM-squared, PRICE), and firm characteristics (FIRM AWARD, OWN ALL MODELS, OWN NICHE MODELS). Model 2 adds the market structure variables. In Model 3, we include the additional innovation variables. Model 4 adds the REPLACEMENT variable. This variable is equal to 1 if the firm entered a product into the same product class at the same time it exited a product, and 0 otherwise. Given that the entry decision is probably endogenous to the exit decision, we include this specification cautiously, mainly as a discussion point, rather than a definitive answer of the relationship between entry and exit. Unfortunately, hazard rate models have not yet been developed that allow for an endogenous variable on the right hand side.

Across the four models the coefficient estimates are remarkably stable in both their magnitude and statistical significance. A log likelihood ratio test indicates Model 4 has more explanatory power at the 95% level, than Models 1-3.

We can now turn understanding the performance of the four theories in explaining product exit. It was predicted in the first hypothesis that competition would drive products out of markets. We do find evidence for this hypothesis. The multiplier on TOTAL MODELS is greater than 1 and statistically significant, and the multiplier on SAME NICHE is greater than 1 and marginally statistically significant. These results suggest that each additional product on the market results in a 1.8% greater probability of focal product exit. Controlling for product density, each additional product in the niche increases the probability of exit by another 1.8%. Neighboring product niches (SAME PPM, SAME DPI) do not increase the probability of exit, and might actually decrease the probability of focal product exit. This is consistent with H1, and its magnitude is relatively significant, given the large number of products on the market.

The second hypothesis examines whether firms with lower cost position are more likely to have their products survive longer on the market. We bifurcated this test into two parts: distributing fixed costs across a large number of products, and process innovations that allow firms to reach a mass market. While we find a negative coefficient on DOMINANT FIRM, as predicted by the fixed cost hypothesis, in only one specification is the coefficient statisitcally significant. Note, however, that its magnitude is quite large, at over a 40% lower hazard rate from other firms' products. The second variable, PPM-squared, which proxies for process innovation, does have a hazard ratio of less than one, and is statistically significant at the 95%

level. It suggests that firms that engage in process innovation will enjoy products of longer life. The results are consistent with H2b on process innovation, but cannot confirm the hypothesis on fixed cost, H2a. The magnitude of effect for process innovation is very small (on the order of 1% for each 1PPM increase).

The third hypothesis centers on cannibalization. It predicted that firms that had many products in the same niche would have higher probability of focal product exit from that niche. The hazard ratio of OWN NICHE MODELS is greater than one, as predicted, and statistically significant in some of the regressions. Its magnitude suggests that each additional product in the niche increases the probability that a given product will exit by 10%. This is consistent with the cannibalization hypothesis, and its magnitude is relative large.

The final hypothesis is on innovation. Do more innovative firms have their products last on the market longer, or is it a race to turn products? As we expect in high technology industries, older products have higher hazard rates. Examining the PPM, PPM^2, and DPI variable coefficients, we see that products on frontiers, whether the top frontier or lower frontier, have better survival prospects than products behind the frontier.[9] This is consistent with innovative firms keeping their products are the markets longer (H4e). In addition, we have four hypotheses related to product exit. The coefficient on PATENTS is small and not statistically significant in any specification.[10] This allows us to reject H4a and H4b, which argue that racing behavior results in an innovation lead that is constantly updated. That is, in this industry, the "innovator" tends to rest once innovation has occurred. Innovative firms do not exit products

[9] We have also used dummy variables for each PPM Class, and the rank order of the coefficients support the specifications being suggested here.

[10] We have chosen these patent classes because it is our understanding from interviews that most recorded laser printer innovations occur in these patent classes. The coefficient could be insignificant because a) there are software innovations which are not patented, b) laser printer innovations occur in other patent classes which we have missed, c) firms do not patent laser printer innovations, d) other technologies, on top of laser printer innovations, appear in these patent classes, or e) patents are a poor measure of innovation in this industry.

from markets at higher rates than their less innovative counterparts. In the next section, we examine whether H4c or H4d are more likely outcomes.

In Model 4, we examine replacement, subject to earlier caveats. We see that he coefficient on replacement is less than one, but not statistically significant, suggesting exit is not more likely when there is replacement. However, this result, because of the potential endogeneity of the variable, must be viewed cautiously.

PCs are complements for printers, so perhaps it is not surprising that higher PC sales result in lower hazard rates for laser printers. Every additional million PC sales decreases the hazard rate by almost 2%, though this coefficient is only marginally statistically different from zero. Increases in inkjet prices are related to higher exit rates for laser printers. While this is the opposite effect one might expect of a substitute product, it is likely that the price of inkjet printers reflects the advances in that technology that allows ink-jets to compete with low-end laser printers.

Overall we find, that competition and cannibalization has a big impact on the survival rates of products. Cost seems to be less important, as measured in this study, in determining product exit decision. However, innovation is potentially quite important. We explore innovation further in the next section.

VI. REFINEMENTS

In this section, we introduce three refinements to the empirical work that explore the importance of innovation, cannibalization, and competition in determining product survival rates. The first refinement examines demand. It might be reasonable to expect that in product niches where there is strong (and perhaps growing) demand, products that have high cost, high price, or poor quality, may survive longer than products that are in niches with slowing demand. To examine this possibility, we included in the hazard rate model a variable called NICHE DEMAND, which is the number of units sold in the product niche in that year. Earlier in the paper, we noted why we believe this variable may be not precisely measured. However, we have included it in Model 5 of Table 6. This variable is available beginning only in 1990. Thus, we are required to drop printers from the dataset that were introduced before 1990. Model 5 illustrates that the coefficient on NICHE DEMAND is negative and statistically significant. This result is consistent with a story that increases demand in a given niche decreases competition (holding other factors constant), and thus reduces product exit. This further refines our analysis of competition, though on a shorter time series.

A second extension is an examination of dominant and fringe product survival rates. We showed that in some cases dominant firm products have longer survival prospects than fringe firm products. However, it would be interesting to know if part of the reason for longer survival of dominant firm products is because dominant firms stay in the industry longer. That is, fringe firm product exit is partially due to fringe firm exit. In Figure 6, we create a frequency distribution for fringe product survival and fringe firm survival, and dominant product survival and dominant firm survival. While the fringe firm survival is almost uniformly distributed across the years, dominant firm survival is severely skewed toward longevity. Thus, it is reasonable to think that firm exit is related to product exit. The relationship between firm and product exit would be an interesting question for future study.

A final extension is a refinement of the innovation hypothesis. In Figure 0, we argued that there were four potential outcomes for innovation. In the hazard rate model, we show that patents have little effect on product exit. This result supports Hypothesis 4c and 4d. However, it would be nice to know if we could begin to sort out which of these two hypotheses holds.

To this end, we examine we conduct an analysis of entry. In this analysis, a model or product entry occurs when it first appears in our database. This is normally the first ship date reported by analysts. We count the number of product introductions for each firm for each class for each year, so each observation is a firm-class-year observation. Once a firm has entered the market, a firm becomes at risk for entry into any class, and it remains at risk for all time periods that it has a printer still on the market.[11] The dependent variable is the count of products entered by the firm in a given class-year.

Many of the independent variables to describe market structure are the same as in the previous section, such as the degree of competition in the focal class and the total number of printers in the same DPI class and PPM class. We also use many of the same firm variables, such as awards to the firm and dominant firm status. We include two additional variables. WAGE is the average wage of a Level 4 engineer as defined by the Bureau of Labor Statistics. An entry decision may be affected by the product development cost. Engineers are required to design new products, but are less important when the printer is actually in manufacturing. LAG OF ENTRY is the lag of the count of products of a firm's entry in the class.

To estimate these equations, we begin with the assumption that the count variables are Poisson distributed. Unfortunately, specification tests (Cameron and Trivedi 1986) indicate there is overdispersion in the data. Overdispersion occurs when the Poisson model assumption that the conditional mean of the event counts equals the variance is violated. To allow for this,

[11] We have coded the data in this way because we believe that the decision to enter the market at all is fundamentally different than a decision to continue in the marketplace.

possibility, we assume a negative binomial distribution to estimate the model.[12] It sets the condition mean at $E(y_i \mid x_i) = u_i = \exp[x_i\beta]$, but allows the variance to take the form $V(y_i \mid x_i) = (1+\alpha)u_i$. Each of the parameters of $(\exp[x_i\beta])$ can be thought of as multipliers of the rate of product introduction.

Table 7 displays the entry regressions. Models 6 and 7 present the entry model. The incidence ratio or multiplier is presented with its asymptotic t-statistic beneath in parentheses. If the multiplier is more than one, an increase in the variable by one unit is associated with an increase in the number of product introductions; numbers less than one mean fewer product introductions. All coefficients are marked for statistical significance on two tailed asymptotic t-tests.[13] All coefficients are statistically significant at the 95% level of confidence.

Dominant firms are likely to introduce new products at three times the rate of fringe firms. In addition, each $1.00 increase in wage results in approximately 36% less product introduction. Competition (SAME NICHE) results in less entry as well, as expected.

The patent variable, PATENTS, which measure innovation and is the focus on the innovation hypothesis has a positive and statistically significant coefficient in Model 7. This suggests that firms that are more innovative are likely to have higher entry rates. Each 10 new patents in the key patent classes increases the rate of entry by about 1%. This result, along with the results of the hazard rate regressions, is consistent with hypothesis 4d: enter, no exit. That is innovative firms are not *exiting* their products more quickly than other firms, but they are *entering* at higher rates. Indeed, the magnitude of the effect on entry is substantial, given the average firm holds hundreds of patents.

[12] We have estimated the models using a linear tobit formulation and results are roughly the same.
[13] In specifications not reported here, we included variables for complements (PC sales) and substitutes (ink jet prices), but were unable to disentangle these effects from the wage effects.

This result is consistent with a prolific literature on product proliferation in differentiated product space to block entry (e.g. Schmalensee 1978, Scherer 19xx, Judd 1985) and with the marketing literature on brand extension. Innovators seem to using their innovative abilities to create a product portfolio that maximizes their returns.

VII. DISCUSSION

Why do products exit markets? Do managers choose to pull products after they introduce more innovative replacements, or are the incumbent products driven out? This paper suggests that managers of innovative companies are careful and strategic. Innovative companies have no greater propensity to pull their older products off the market than do non-innovative companies. Rather, they seem to innovate and enter, and leave their incumbent products on the market to be forced out by the competition and eventual cannibalization. This allows companies to proliferate products in the differentiated product space, to maximize profit. This may come through blocking entry, obtaining market power in the channel, or a host of other reasons not explored here. Competition is quite an important force in determining product exit rates. While fixed cost and process innovation results are sometimes statistically significant, substantively they do not have a big impact on product survival. Together, these results suggest managers have developed innovation strategies to take advantage of their competitive environment.

This paper has also made some initial findings unrelated to product exit. First, we have shown that there can be two innovation frontiers for a product, a top frontier which is the traditional “make it better, faster” product innovation frontier, and a bottom frontier which is the “make it cheaper, accessible” frontier. This study shows that products on either frontier have better survival prospects. These kind of dual frontiers probably exist in a number of industries, such as personal computers (with the Celeron), DVD players, and digital TVs, to name just a few. It would be interesting to document the frontiers in other industries, and examine in more detail what happens on the bottom frontier. Second, we have shown the importance of fringe firms in the marketplace. Nearly 50% of product introductions in the desktop laser printer industry are by fringe firms. As a number they represent 80% of all firms in the industry. Future studies should attempt to include these firms in the analysis, as they can have a big impact on the results of strategic interaction and competition. Third, we have demonstrated in Figure 7, the relationship between firm survival and product survival rates. Given the numerous studies on firm survival, it would seem that we would deepen our understanding by investigating the micro-foundations of firm survival at the product level.

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Figure 0: Hypotheses 4a-d

New Product	Old Product: Exit	Old Product: No Exit
Hold	H4a: $0 > \pi^D, \pi^N, \pi^O$	H4c: $\pi^O > \pi^D, \pi^N$
Enter	H4b: $\pi^N > \pi^D, \pi^O$	H4d: $\pi^D > \pi^N, \pi^O$

π^D = duopoly profit (both products in market)
π^N = profit of new product when alone in market
π^O = profit of old product when alone in market

Figure 1: Number of Firms and Products in Marketplace

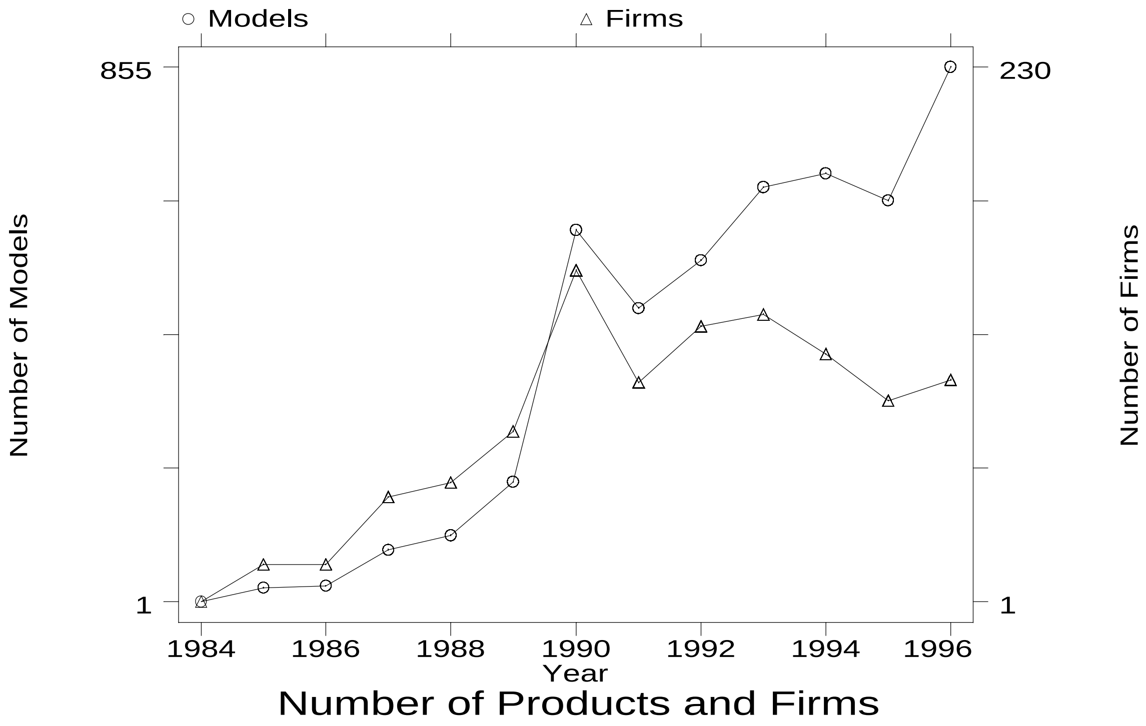
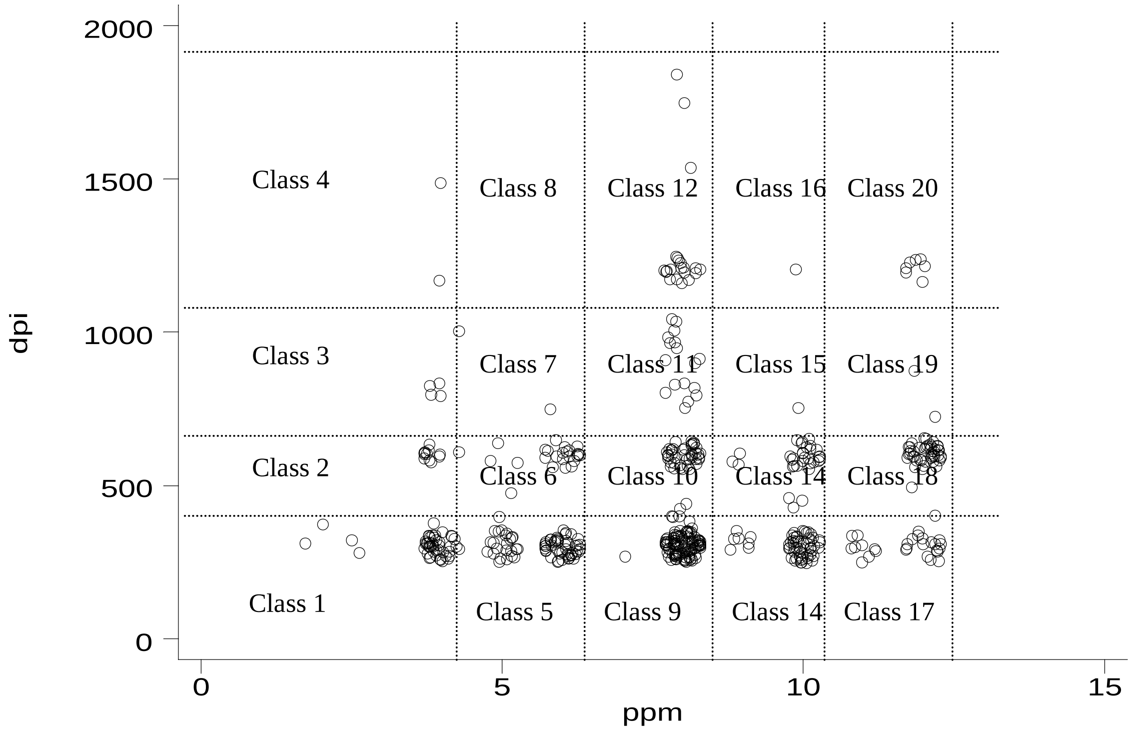


Figure 2: Product Entry and Exit

Figure 3: Product Distribution and Classes



Note: Each small circle represents a printer.

Figure 4: DPI by Model

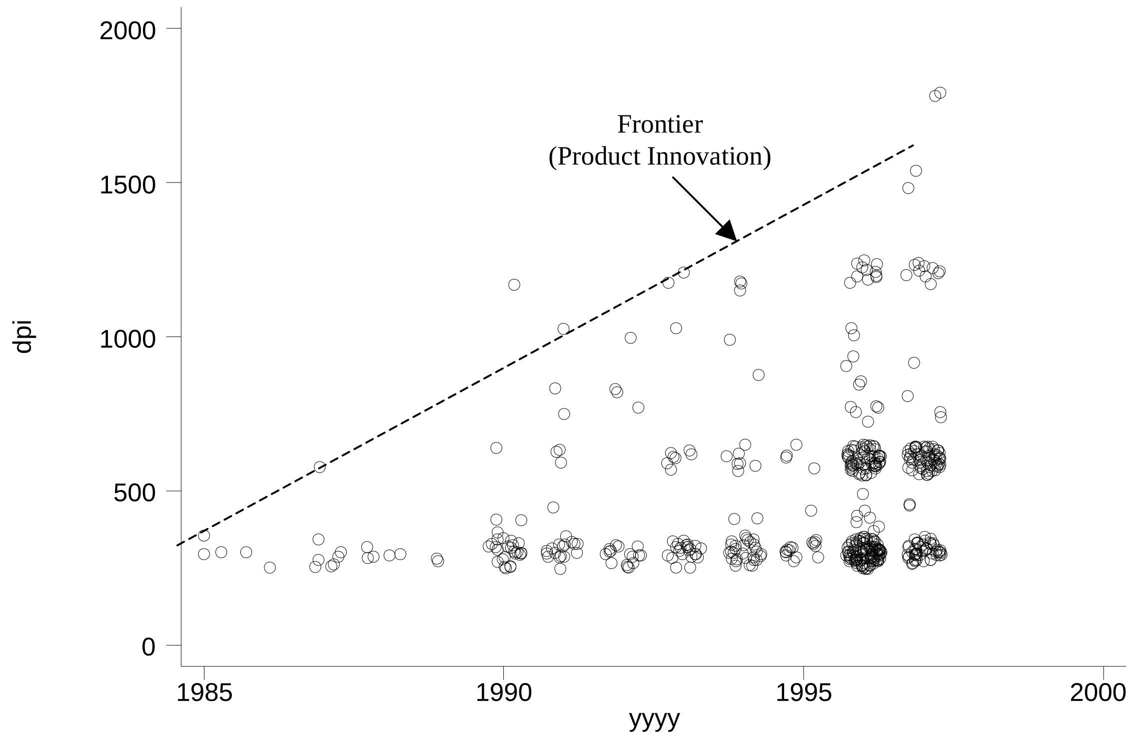


Figure 5: PPM by model

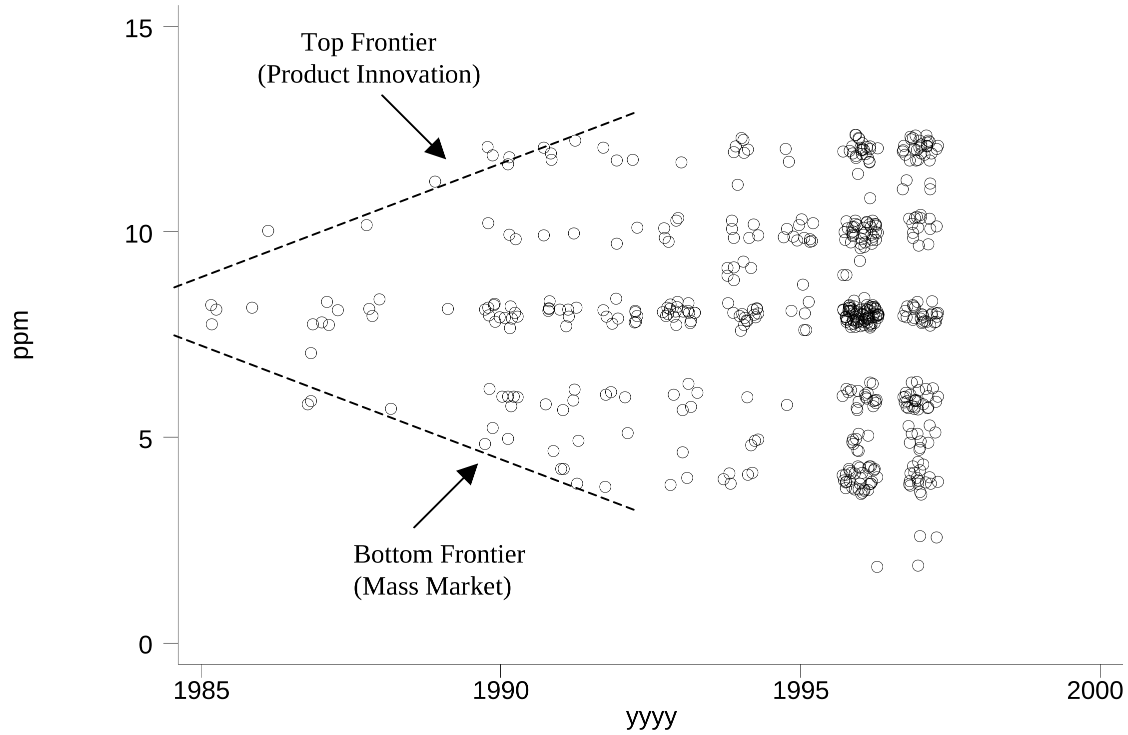


Figure 6: Printer and Firm Survival Rates

Fringe Product and Firm Survival Rates | Dominant Product and Firm Survival Rates

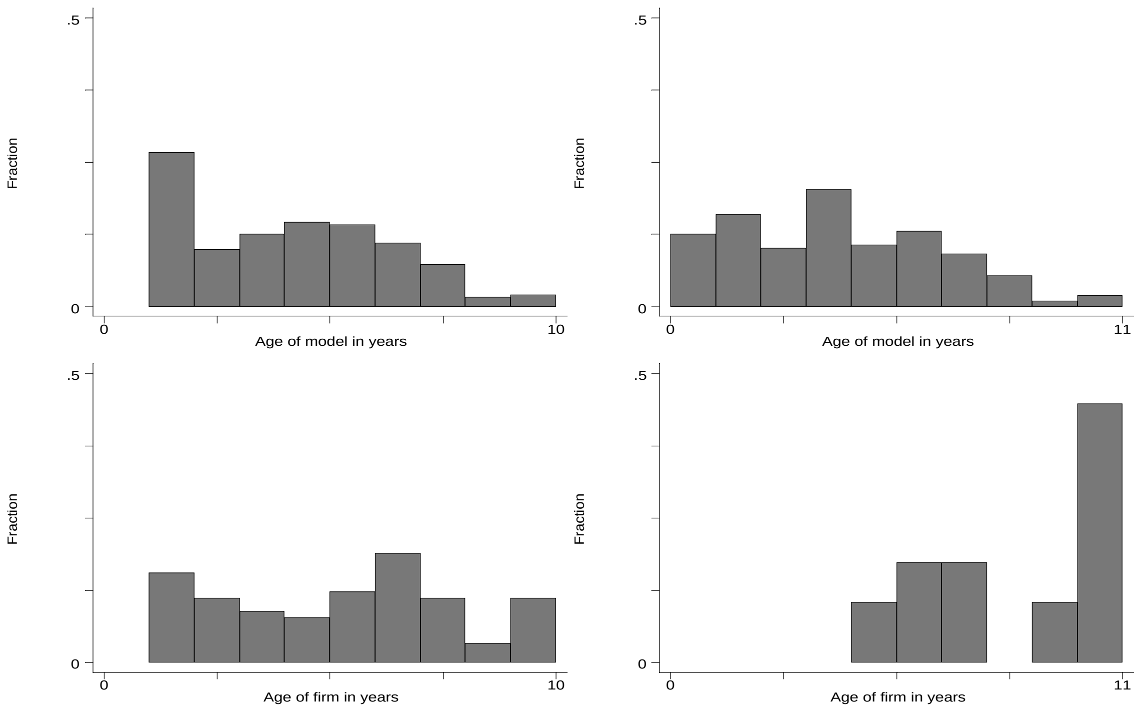


TABLE 1A: CONCENTRATION RATIOS AND TOTAL SHIPMENTS

Year	Hewlett Packard	C5 Ratio	C10 Ratio	Total Estimated Shipments
1987	58.12%	87.83%	100.00%	411,845
1988	61.66%	87.31%	99.28%	646,097
1989	49.68%	87.48%	98.47%	991,331
1990	54.89%	78.39%	87.44%	1,925,152
1991	48.80%	76.59%	90.13%	2,687,110
1992	50.58%	80.17%	92.89%	2,303,355
1993	57.08%	82.36%	92.92%	2,303,990
1994	55.88%	80.49%	94.42%	2,795,232
1995	60.53%	85.95%	99.62%	2,814,688

TABLE 1B: NUMBER OF YEARS IN TOP TEN IN SHIPMENTS

Firm	Years
HEWLETT-PACKARD_COMPANY	9
IBM/LEXMARK	9
DIGITAL_EQUIPMENT_CORP	8
PANASONIC/MATSUSHITA	8
APPLE_COMPUTER_CO	7
OKIDATA_CORP	7
TEXAS_INSTRUMENTS_INC	7
EPSON_AMERICA_INC	6
NEC_TECHNOLOGIES_INC	6
KYOCERA_UNISON	5
CANON	4
QMS_INC	4
XEROX_CORP	3
BROTHER_INTERNATIONAL_CORP	2
C-TECH_ELECTRONICS_INC	1
FUJITSU_AMERICA_INC	1
GCC_TECHNOLOGIES_INC	1
SUN_MICROSYSTEMS	1
TANDY_CORP	1

TABLE 2: VARIABLE DEFINITIONS

YEAR	Time trend variable to the beginning of the industry.
MODEL AGE	The age of the product measured as the number of years since introduction.
DPI	The resolution of the printer measured in dots per inch.
PPM	The speed of the printer measured in pages per minute.
PPM-squared	Speed of printer, measured in pages per minute, squared.
HP-PCL, POSTSCRIPT, DIABLO, and EPSON	Dummy variables for printing standards.
DOMINANT FIRM	A dummy variable equaling one if the vendor was one of the top ten of producers in terms of market share for at least two years in our sample, as defined in Table 1.
MODEL AWARD and FIRM AWARD	One measure of product quality is to examine whether the printer has won an award for price and performance. Every year, PC Magazine announces 4-10 printer awards for printers that they judge to be particularly good value across the spectrum of printers available, based on features and predicted reliability. MODEL AWARD equals one if the particular model won an award. FIRM AWARD equals one for all models manufactured by a firm if any of its models won an award in the prior two years.
TOTAL MODELS	The number of total models in the desktop laser printer market at the time.
OWN ALL MODELS	The number of total models the focal vendor currently has in the desktop printer market.
OWN NICHE MODELS	The number of models the focal vendor currently has in the focal class.
SAME DPI and SAME PPM:	The number of products that are at the same DPI (all classes covering the same DPI), and the number of products that are at the same PPM (all classes covering the same PPM).
SAME NICHE	The number of products competing in the same local PPM-DPI class as the product under consideration.
INK JET PRICE	The average price of ink jet printers.
PC SALES	The number of personal computers sold in the United States in millions.
PRICE	List price of the printer.
PATENTS	The number of new patents issued, by application year, in patent classes 271, 355, 359, and 395.
REPLACEMENT	Dummy variable = 1 if the firm entered a new printer model in the class in the given year.
ENGINEERING WAGE	The average wage of a Level 4 engineer as defined by the Bureau of Labor Statistics
LAG OF ENTRY	The lag of the count of products of a firm’s entry in the class

TABLE 3: DESCRIPTIVE STATISTICS

VARIABLE	MEAN	STD DEV
PRICE	22.82	19.83
LN OF PRICE	2.85	0.75
TIME TREND	10.82	2.56
AGE	3.98	2.10
POSTSCRIPT	0.50	0.50
HP-PCL	0.81	0.40
DIABLO	0.17	0.38
EPSON	0.21	0.41
MODEL AWARD	0.10	0.30
DOMINANT FIRM	0.59	0.49
DPI	471.86	259.45
PPM	7.98	2.48
LN STD MEMORY	0.85	1.23
OWN NICHE MODELS	2.69	1.90
OWN ALL MODELS	18.24	16.89
FIRM AWARD	0.22	0.42
PRICE	22.82	19.83
TOTAL MODELS	654.47	196.01
SAME PPM	81.13	37.99
SAME DPI	171.96	96.52
SAME NICHE	27.78	16.57
PC SALES	15.15	3.00
INK JET PRICE	2.42	1.55
ENGINE MANF	0.39	0.49
PATENTS	1376.84	3189.96
REPLACEMENT	0.24	0.43

TABLE 4: HEDONIC PRICING OF LASER PRINTER

PPM	**0.070**
	(6.09)
DPI	-0.0002
	(-1.45)
LN STD MEMORY	**0.404**
	(12.31)
HP-PCL	-0.140
	(-1.41)
DIABLO	0.122
	(1.34)
EPSON	0.048
	(0.54)
OTHER STANDARD	**0.435**
	(2.85)
HP	-0.144
	(-0.33)
1987	-0.112
	(-0.31)
1988	0.372
	(0.95)
1989	-0.215
	(-0.65)
1990	-0.285
	(-0.89)
1991	-0.447
	(-1.39)
1992	**-0.704**
	(-2.18)
1993	**-0.916**
	(-2.87)
1994	**-1.007**
	(-3.15)
1995	**-1.063**
	(-3.26)
1996	**-1.130**
	(-3.38)
Firm Fixed Effects	Not sig
N	354
R-Squared	0.7834

Note: Dependent Variable is Ln(ListPrice).
T-statistics beneath estimated coefficients.
Bolded coefficients are significant at 95% level.
Postscript is the omitted standard.

TABLE 5: OPERATIONALIZATION AND OUTCOMES OF TESTS OF HYPOTHESES

Hypothesis	Variable	Expected Sign	Results: Actual Sign	Results: Substantive Impact
H1: Competition	TOTAL MODELS	+	+	Large
	SAME NICHE	+	+	Large
H2a: Fixed Cost	DOMINANT FIRM	-	0	
H2b: Process Innovation	PPM^2	-	-	Small
H3: Cannibalization	OWN NICHE	+	+	
H4: INNOVATION				
H4a: Hold, Exit	PATENTS	+	0	
H4b: Enter, Exit	PATENTS	+	0	
H4c: Hold, No Exit	PATENTS	0	0	
	PATENTS IN ENTRY	0	+	
H4d: Enter, No Exit	PATENTS	0	0	Moderate
	PATENTS IN ENTRY	+	+	Large
H4e: Innovative Products	PPM	+	+	Large
	DPI	-	0	

Note: Bolded hypotheses are broadly confirmed by the data.
Actual sign is based on sign and significance level for Models 1-5.
Substantive impact is subjective based on magnitude of coefficients.

TABLE 6: HAZARD RATE MODELS FOR PRODUCT EXIT

VARIABLE	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
TIME TREND	**1.570**	0.714	0.685	0.676	***0.318***
	(6.39)	(-1.12)	(-1.18)	(-1.21)	(-1.94)
MODEL AGE	**1.246**	**1.176**	**1.165**	**1.153**	**1.225**
	(5.43)	(4.57)	(4.18)	(3.98)	(4.29)
POSTSCRIPT	0.942	0.905	0.852	0.826	0.946
	(-0.33)	(-0.67)	(-1.02)	(-1.20)	(-0.36)
HP-PCL	***0.697***	0.861	0.847	0.848	**0.627**
	(-1.67)	(-0.75)	(-0.84)	(-0.85)	(-2.18)
MODEL AWARD	***0.696***	**0.727**	**0.693**	**0.683**	**0.627**
	(-1.82)	(-1.99)	(-2.18)	(-2.25)	(-2.40)
DOMINANT FIRM	**0.596**	0.829	0.870	0.870	1.045
	(-2.12)	(-0.97)	(-0.74)	(-0.76)	(0.22)
DPI	1.000	0.999	0.999	0.999	0.999
	(-0.66)	(-0.90)	(-1.12)	(-1.07)	(-1.32)
PPM	**1.745**	**1.993**	**2.183**	**2.093**	**2.287**
	(2.74)	(3.02)	(3.43)	(3.27)	(2.87)
PPM^2	**0.966**	**0.958**	**0.954**	**0.957**	**0.952**
	(-2.62)	(-2.78)	(-3.15)	(-2.96)	(-2.56)
OWN NICHE MODELS	**1.107**	1.062	1.066	***1.089***	1.067
	(2.12)	(1.40)	(1.48)	(1.85)	(1.45)
OWN ALL MODELS	1.006	0.997	0.999	0.998	0.997
	(0.86)	(-0.61)	(-0.26)	(-0.43)	(-0.44)
FIRM AWARD	0.950	0.915	0.941	0.966	0.964
	(-0.31)	(-0.53)	(-0.35)	(-0.20)	(-0.19)
PRICE	1.008	1.010	1.010	1.011	1.006
	(1.01)	(1.38)	(1.31)	(1.49)	(0.74)
TOTAL MODELS		**1.017**	**1.018**	**1.018**	**1.029**
		(4.14)	(3.80)	(3.77)	(3.57)
SAME PPM		**0.991**	**0.991**	**0.991**	**0.990**
		(-2.53)	(-2.70)	(-2.60)	(-2.43)
SAME DPI		0.995	0.995	0.995	**0.992**
		(-1.57)	(-1.53)	(-1.49)	(-2.36)
SAME NICHE		***1.018***	***1.017***	1.015	**1.030**
		(1.80)	(1.64)	(1.51)	(2.12)
PC SALES		0.989	0.997	0.995	1.097
		(-0.12)	(-0.03)	(-0.05)	(1.07)
INK JET PRICE		**1.905**	**1.957**	**1.960**	**11.739**
		(3.86)	(3.37)	(3.33)	(2.70)
HEDONIC RESIDUAL		1.068	1.076	1.063	1.150
		(0.31)	(0.35)	(0.29)	(0.72)
ENGINE MANF			**0.685**	**0.682**	**0.725**
			(-3.08)	(-3.12)	(-2.54)
PATENTS			1.000	1.000	1.000
			(0.54)	(0.57)	(0.22)
REPLACEMENT				0.773	
				(-1.35)	
NICHE DEMAND					**1.000**
					(-2.39)
N	1074	1074	1074	1074	665
Log Likelihood	224.76	494.82	555.74	562.26	335.16

Note: All coefficients are hazard ratios. T-statistics are in parentheses below the hazard ratio.
Bolded coefficients are significant at the 95% level; bolded and italicized coefficients are significant at the 90% level.

TABLE 7: NEGATIVE BINOMIAL FOR ENTRY

VARIABLE	MODEL 6	MODEL 7
TIME TREND	**0.859**	**0.847**
	(-4.05)	(-4.35)
FIRM AWARD	**1.935**	**1.898**
	(3.78)	(3.65)
DOMINANT FIRM	**3.596**	**3.176**
	(8.95)	(7.68)
LAG ENTRY	**1.369**	**1.362**
	(12.95)	(12.67)
WAGE	**1.369**	**1.409**
	(2.26)	(2.46)
SAME DPI	**1.004**	**1.004**
	(3.71)	(3.82)
SAME PPM	**1.011**	**1.011**
	(4.46)	(4.61)
SAME NICHE	**0.983**	**0.983**
	(-2.11)	(-2.09)
PC SALES		
INK JET PRICE		
PATENTS		**1.001**
		(2.84)
PATENTS*DOMINANT FIRM		
N	15757	15757
Log Likelihood	533.270	561.27

Note: The dependent variable is count of model entry in each class by each firm.
All coefficients are presented as incidence ratios; the t-statistics are below the coefficients in parentheses.
Bolded coefficients are significant at the 95% level; bolded and italicized are significant at the 90% level.