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# Markets for Technology, Vertical Integration, and Industry Dynamics: Efficiency and Foreclosure in the Laser Printer Industry

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Abstract

An important unanswered question in strategy research is: how does vertical integration affect industry evolution? Foreclosure and efficiency theory both predict that vertical integration by one firm can increase the exit rate of non-integrated rivals, but offer competing predictions for the cause of this increase. A related question is how upstream markets for technology affect downstream firm and industry performance ? i.e., to what extent does a thick upstream market for key technological inputs reduce foreclosure and reduce the efficiency benefits of integration? This paper attempts to answer these questions by a developing a series of predictions regarding the effect of vertical integration patterns and upstream markets for technology on downstream pricing, entry rates, and exit rates. We test these predictions empirically with unusually detailed data on the U.S. laser printer and laser engine industries between 1984 and 1996. We exploit both cross-section and time-series variation in governance of laser engine procurement among laser printer firms to explore the effects of vertical integration on entry, exit, and pricing dynamics in each segment of the industry.

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## Abstract

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The Dynamics of Vertical Integration and Markets for Technology: An Empirical Analysis of the Laser Printer Industry

## I. INTRODUCTION

Over the last several decades, scholars have made great strides in understanding industry evolution. Despite this progress, the research is still relatively silent on the question: how does vertical integration affect industry dynamics? One reason for this silence is that most theories of industry evolution do not directly address vertical integration, while equilibrium theories of vertical integration do not address industry dynamics.

This paper attempts to answer three key research questions. First, how does competition in a core upstream industry affect markets for technology and the evolution of a focal industry? Second, how do governance relationships across vertically related industries affect performance in the downstream industry? Third, how does the co-evolution of industry and the governance decisions made over time by firms in the industries affect final pricing in the markets for heterogeneous products?

To answer these questions, this paper integrates the literature in economics, strategy, and innovation to develop a number of theoretical predictions of how the evolution of markets for technology and vertical integration affect firm performance and downstream product markets. We then examine the predictions using a dataset covering every product introduced into the desktop laser printer industry, across 24 distinct product segments, from its birth in 1984 until 1997. We track the upstream industry, the downstream industry, vertical governance relationships, and the evolution of prices.

We find evidence that increases in the (upstream) laser engine supplier base are associated with reduced exit rates of printer firms, that increases in the number of vertically integrated rival printer firms is associated with increased exit rates, and that vertically integrated printer firms appear to drive down prices within their segment. We also find suggestive evidence that vertically integrated firms undertake systemic innovation more rapidly than their non-integrated rivals. These results are more consistent with efficiency than with foreclosure.

The next section positions this paper within the extant literature. Section III develops a theoretical framework and a series of predictions. Section IV describes the data and method. Section V presents our empirical results. We conclude in Section VI.

## II. LITERATURE

How does the structure of upstream input markets affect the evolution of downstream product-market competition? How is this affected by vertical integration that spans these markets? There is a voluminous literature on industry evolution and perhaps an even larger literature on vertical integration. (For a summary of the former, see Audretsch 1995; Agarwal and Gort 2002; Caves 1998; for a summary of the latter, see Perry 1989; Bresnahan and Levin 2012). For the most part, however, the industry evolution literature has examined industries in isolation, while the modern vertical integration literature has focused on intra-firm rather than industry-related effects of integration decisions. Thus, until recently these literatures have been relatively silent on these questions.

Recently, however, a set of papers has begun to make headway on these questions. Hortacsu & Syverson's (2007) study of the cement industry outlines the tension that exists between the two main economic rationales for vertical integration: efficiency vs. foreclosure. According to the efficiency rational, firms integrate to gain efficiency from better coordination and economies of scale. According to the foreclosure rationale, firms integrate to extend market power from one stage of production to another. Both rationales imply that vertically integrated firms will impose greater competitive pressure on their rivals. As Hortacsu & Syverson note, however, efficiency-based competition will play out through lower prices while foreclosure-based competition will play out through higher prices.[1] Hortacsu & Syverson use panel methods on five semi-decennial censuses with detailed data on cement and ready-mixed concrete producers to test whether the competitive effects of vertical integration are consistent with vertical foreclosure theory or with theories of efficiency-driven vertical integration. Their evidence favors efficiency theory – increases in vertical integration within geographic submarkets was associated with lower prices and higher quantities of cement, implying that the attendant higher exit rates found among non-integrated firms were driven by efficiency gains rather than by foreclosure.

Arora & Nandkumar (2008, 2011) examine this relationship using a different lens: markets for technology. The authors develop a model in which an upstream input affects the fixed cost of downstream production, and in which upstream technological capabilities can substitute for downstream technological capabilities. Thus, increased competition in the input market reduces the cost of entry downstream, and also subsequently devalues technical capabilities in the downstream market. Consequently, increased competition upstream will lead to increased entry and increased exit, downstream. Arora & Nandkumar test the model's predictions by examining entry and exit of firms in the information security industry based on changes in the amount of (upstream) encryption technology available on the market (as measured by the number of university security patents). Using a hazard-rate model approach on data from 1989 to 2004, they find support for their predictions: downstream entry and exit are both positively associated with the presence of a higher market supply for technology.

The final two papers, which perhaps most tightly integrate vertical integration and industry dynamics, stem not from the economics literature but from sociological roots. Negro &

[1] Hence, the efficiency rationale is seen as pro-competitive while foreclosure is viewed as anti-competitive.

Sorenson (2006) and de Figueiredo and Silverman (2012) both use an organizational ecology lens to study the effects of vertical integration on legitimation and competition in the evolution of industries. Using hazard-rate techniques, these papers together find that vertical integration changes the dynamics of competition: vertically integrated firms exert more competitive pressure than non-integrated firms, and are themselves buffered from competitive pressure. However, vertical integration seems to have limited effect on legitimation. Although these papers explicitly link the competitive effects of vertical integration to the industry evolution literature, they do not disentangle the dueling rationales of efficiency vs. foreclosure.

Our paper differs from these predecessors in a number of ways. Theoretically, we consider simultaneously vertical integration and markets for technology, which have generally been treated separately to date. Empirically, our data enable us to contrast efficiency vs. foreclosure effects of vertical integration using survival analysis, whereas previous scholars have not been able to do so. In addition, because we observe the identity of the upstream supplier when upstream inputs are purchased, we can gain further insight into pricing dynamics by exploring variation in printer price across printer firms that incorporate the same engine model.

## III. THEORY

### A. INTUITION

To analyze the effect of markets for technology and vertical integration on industry evolution, we build a formal model, outlined in the Appendix.[2] Here we give the basic intuition. Consider an industry in which firms enter if they expect earn profits, and then stay if this expectation is met and exit if not. Assume that there is an input to this industry that is provided by an upstream industry, such that the price paid for the input becomes part of a downstream firm's marginal cost. Greater competition in the upstream industry will lower the price of the input, which will lower the marginal cost of production in the downstream industry. This will in

[2] Due to space constraints for submission to DRUID, we have omitted the formal Appendix. The basics of the model are included above.

turn lead to lower prices in the downstream industry, and therefore to more demand, which will, in turn, increase the number of firms that can survive in the downstream industry for a given level of economies of scale. Thus, greater upstream competition will lead to greater entry and lower exit downstream.

Now suppose that a firm can integrate backward (or an upstream firm can integrate forward). In this case, the production by the captive upstream firm is no longer available to the industry through the market for technology; instead, its downstream unit has first claim on the production. The presence of a captive upstream firm will contribute less to upstream competition (and thus will have less impact on downstream marginal costs), than will the presence of an independent upstream firm.

Finally, downstream rivals that are vertically integrated are likely to generate more competitive pressure than non-integrated rivals, either due to the putative efficiency benefits of vertical integration or due to the ability of integrated firms to disrupt rivals' access to inputs. Both of these effects will, as explained below inhibit entry and hasten the exit in the industry. However, in an efficiency story, this will be because of lower prices charged by the efficient firms in a more competitive environment. In a foreclosure story, this will be because of foreclosure of supply by a vertically integrated competitor which will, in turn, raise prices after exit.

## B. FRAMEWORK

We analyze an upstream and downstream market without vertical integration, using a classic Jovanovic-style (1982) model of entry downstream. There exists a pool of potential entrants to a downstream industry. Entry entails incurring a sunk cost to enter, s, plus marginal costs and recurring fixed costs of operation. Firms differ in efficiency, which is summarized as q and is distributed in the population with distribution function F(q). The expected profit function of a firm is $(p – c)*q - \theta$, where p is equal to the price, c is equal to the marginal cost of production, q is quantity produced and θ is a fixed cost. If $(p - c)*q - \theta - s > 0$, then the firm will enter.

A firm's actual costs differ from its expected costs. The firm's actual fixed cost is $\theta + \varepsilon$, where ε is i.i.d. Therefore, the actual *ex ante* profit function of the firm is $(p - c)*q - (\theta + \varepsilon) - s$. Firms do not observe ε until after entry, so although an entrant's cost structure is drawn from a known distribution of costs, it is not known by the entrant *ex ante*. After entry, the firm learns its true costs *ex post*. If the firm has low costs, such that $(p - c)*q - (\theta + \varepsilon) \geq 0$ , then it earns positive profits and stays in the industry. If the firm has high costs, such that $(p - c)*q - (\theta + \varepsilon) < 0$ , then the firm exits. Note that the sunk cost, s, has no impact on the firm's decision to stay/exit, since by definition this cost is sunk. Demand D(p) is decreasing in p. Firms are assumed to know the equilibrium price sequence in the industry over time, but are not sufficiently powerful to affect industry price.

We introduce into this model an upstream market for an input that will affect marginal cost in the downstream industry. This is in contrast to models such as Jovanovic and MacDonald (1989) and Arora and Nandkumar (2008, 2011), which focus on the effect of shocks to downstream firms' *fixed* costs and the consequent effect on entry, exit, and survival.[3] In this paper, we depart from this analysis in two ways. First, we examine how upstream component suppliers can change a downstream industry's *marginal* cost and its effect on entry, exit and survival. Second, we examine how an increase in the number of upstream input suppliers can increase the ability of downstream firms to differentiate their products by providing a broader variety of components.

Consider an upstream input j, whose price is a component of downstream marginal costs, so that $c = c(j)$. Increased competition upstream will reduce the price of the input, so that c is

[3] Inputs that affect marginal costs are prevalent in a very wide variety of manufacturing and services industries, including our empirical setting of laser printers.

decreasing in upstream competition. As c is reduced, the downstream entry constraint is relaxed, since as c become smaller and it is more likely that $(p - c)*q - \theta - s > 0$. Thus, an increase in upstream competition should yield greater rates of entry downstream, all else equal.

As for exit, two factors reduce the likelihood of exit. First, the lower marginal cost in the downstream industry will lead to lower product price. Since demand is decreasing in price, this will lead to higher industry sales, which will support a larger number of downstream firms. Second, as marginal cost falls, the size of sunk costs relative to ongoing costs increases. As is well established in the literature, the larger are sunk costs relative to ongoing costs, the more likely that firms will persist in an industry (e.g., Dunne & Roberts 1991). This is because the difference between the expected profits needed to induce entry, $(p - c)*q - \theta - s$ , and the actual profits needed to cover ongoing costs, $(p - c)*q - (\theta + \varepsilon)$ , is increasing in s. Consequently, an increase in upstream competition should yield lower rates of exit downstream, all else equal.

**H1a: The entry rate into a downstream market will be positively related to the degree of competition in the upstream market serving that market.**

**H1b: The exit rate in a downstream market will be inversely related to the degree of competition in the upstream market serving that market.**

Next, assume that firms can vertically integrate. We first examine the effect of vertical integration on the market for inputs. Whereas a non-integrated supplier is able to sell products to all downstream firms, a captive supplier sells only (or primarily) to its downstream subsidiary. In terms of the model, a captive supplier does not add as much competition upstream as a non-integrated supplier does (Negro and Sorenson 2006; de Figueiredo and Silverman 2012). Hence the presence of captive suppliers will reduce c(j) less than the presence of non-integrated suppliers.

**H2: The relationship between downstream exit rate (entry rate) and upstream competition will be strongest for suppliers that sell on the open market and weakest for captive suppliers.**

The previous hypotheses (H1a, H1b, and H2) have clear directional effects. However, if we are to more fully understand the how vertical integration influences competitive dynamics in industry evolution, we must elaborate implications of the dueling rationales for vertical integration: efficiency and vertical foreclosure, as discussed in Hortacsu & Syverson (2007).

The efficiency story is relatively straightforward. Vertical integration helps firms to achieve efficiencies through three main mechanisms. First, vertical integration can allow firms to achieve higher economies of scale and coordination across different parts of the value chain (Hortacsu & Syverson 2007). Second, vertical integration allows firms to avoid the "double marginalization" problem. Third, vertical integration allows firms to more efficiently address the hold-up problem and thus solve contractual problems that might arise in the market exchange relationship (Williamson 1975, 1985, 1996; Grossman and Hart 1986). These efficiency theories all yield similar predictions, though through slightly different processes. Firms that are more efficient (lower costs) will have an incentive to lower prices.[4] This will cause firms with formerly marginal efficiency (in a Jovanovic-type model) to lose money and exit. Lower prices will also make it less likely that a given potential entrant will have positive expected profits. Thus, entry downstream will decrease.

The second approach, "new" vertical foreclosure theory, argues that a vertically integrated firm will foreclose a downstream rival by charging a supracompetitive price for the upstream input. (Perry 1989, Salinger 1988, Hart and Tirole 1990, Rey and Tirole 2007). Assume there is one upstream firm (U1) and two downstream firms (D1 and D2), as in Figure 0, panel 1. Assume that D1 and D2 each need one unit of input from U1 to produce one unit of their downstream product. In this case, U's optimal strategy is to produce the monopoly quantity

[4] As the marginal cost curve shifts in and the marginal revenue curve stays fixed, the profit maximizing price of the firm drops.

of inputs, and sell ½ of the monopoly quantity to each of D1 and D2. The problem is that, once U sells ½ of the monopoly quantity to D1 at the monopoly price, it would actually prefer to sell a larger amount of inputs, at a slightly lower price, to D2. D2 in turn could then undercut D1 in the product market. (See Rey &Tirole 2007 for the formal model of this.) Thus, if contracts are renegotiable, U cannot commit to refrain from selling a higher quantity to D2 once it has already sold ½ of the monopoly quantity has already occurred to D1. Knowing this, D1 will not buy at the monopoly price and the market will fail.

[INSERT FIGURE 1 ABOUT HERE]

The solution to this problem is for U to acquire D1 (Figure 0, panel 2). U now internalizes all the losses to D1 associated with selling "too much" to D2. In this simple model with no competition in the upstream market, the vertically integrated U-D1 will sell the entire monopoly quantity to its downstream unit, will not sell to D2 at all, and will thus internalize the full monopoly profit.

In the more advanced formulation, which mirrors our empirical setting very nicely, U faces potential competition from U' (Figure 0, panel 3). U' is a higher cost (or otherwise inferior) substitute to U. The non-integrated case is the same as the basic case, except the price set by U may be lower than the monopoly price, because it is constrained by U'. However, in the vertical integration case, after U integrates with D1, U will then have an incentive to sell to D2 at a price of epsilon below the value offered by U' (Figure 0, panel 4). In this way, U keeps U' out of the market, but does not enjoy the monopoly rent because of U'. The better a substitute U' is for U, the lower the price U will charge D2, but in all cases the internal transfer price, p1, will always be lower or equal to the external price for the input, p2. As a result, the vertically integrated U-D1 will be able to charge a lower price than D2 in the product market, and consequently out-compete the non-integrated D2.

The new foreclosure theory thus generates predictions about entry and exit that mirror those of efficiency theory. Vertical integration will lead to increased competitive pressure on non-integrated downstream firms, and ultimately will cause non-integrated firms to exit. Higher input prices will also make it less likely that a given potential entrant will have positive expected profits. Thus, entry downstream will decrease.

However, while both rationales agree on the effect of integration on industry entry and exit rates, they yield conflicting implications for price behavior. The efficiency rationale predicts that vertical integration will lead to lower prices for inputs and for downstream products, while the foreclosure rationale predicts that vertical integration will lead to higher prices. Thus, if vertical foreclosure is the dominant strategy by the integrated player, then we would expect to see rises in price rises, increases in exit, and decreases in entry as vertical integration becomes more prevalent. If vertical integration primarily results in efficiency gains, then we would expect to see decreased prices, increases in exit, and decreases in entry as vertical integration becomes more prevalent. Although we formulate the exit and entry predictions as hypotheses, we formulate the pricing hypotheses as predictions and then empirically test which prediction is actually operating in our data to infer which theoretical model is least likely to be rejected.

**H3a: Vertically integrated rivals increase the exit rate in a downstream industry more than non-integrated rivals.**

**H3b: Vertically integrated rivals decrease the entry rate in a downstream industry more than non-integrated rivals.**

**Foreclosure Prediction 4: Vertical integration will be associated with higher (rising) long-run prices of downstream products.**

**Efficiency Prediction 4: Vertical integration will be associated with lower (declining) long-run prices of downstream products.**

Together, these hypotheses and predictions integrate the literature in economics, innovation, and strategy to yield a more integrated framework of how vertical integration will affect entry, exit, pricing, and overall industry evolution.

## IV. THE LASER PRINTER INDUSTRY

As the U.S. personal computer market expanded in the 1980s, so too did the market for desktop printers. Hewlett-Packard introduced the first desktop laser printer for the retail market in 1984. By the end of 1985, 17 firms had introduced 33 models of printers. At its peak in 1990, the industry had 144 firms, but by 1996 the number of firms had fallen to 97. In contrast, the number of printer models continued to rise even as the number of firms fell, increasing from 297 models in 1990 to more than 600 models in 1996.

A desktop laser printer is made, essentially, of three main components – laser engine, controller card (the electronics), and exterior features such as toner cartridge, feeder tray and plastic outside box. To create a printed page, the paper passes from the feeder tray to the laser engine, where the page is electrically charged. Fine-grain toner of the opposite charge is attracted to the paper, heated, and fused to the page by the fuser assembly of the laser engine. The paper is then ejected to the exterior paper tray. The controller card governs the process and provides the many features that a given laser printer offers.

Of these components, the laser engine is both the most expensive and subject to the most variation in governance. The vast majority of laser printer producers make their own controller cards. Conversely, virtually all laser printer producers purchase exterior features, which are essentially commodity components, on the open market. However, there is substantial variation in production of laser engines, with roughly 20% of laser printer firms making at least some of their engines in-house. From the perspective of the engine manufacturers, roughly 80% of laser engine producers sell at least some of their engines to other firms. Canon is the dominant engine supplier, with 60% market share throughout the sample period (including in-house shipments that comprise a small amount of market share). Figure 1 shows the entry and exit patterns of vertically integrated and vertically disintegrated laser printer firms, while Figure 2 shows these patterns for laser engine firms. We focus on the variation in governance of engine procurement among printer firms to explore the effects of vertical integration on entry, exit, and pricing dynamics.

[INSERT FIGURES 1 and 2 ABOUT HERE]

One feature of the laser printer industry is particularly salient to this study. The key characteristics of a laser printer are speed, measured in pages per minute (PPM), and resolution, measured in dots per inch (DPI). These are the two characteristics most prominently assessed in popular press rankings of printers (e.g., Consumer Reports 2005). Additionally, in a hedonic analysis of laser printers, de Figueiredo and Kyle (2005, 2006) find that speed and resolution are two of the most important characteristics (with memory being third). Figure 3 provides the location in speed-resolution space of each laser printer model introduced in the U.S. between 1984 and 1996. Each circle represents a printer model. A striking feature of this scatterplot is that printers are clustered tightly into distinct groups in this space.[5]

As described in de Figueiredo and Silverman (2007), we pursued three avenues to identify the product classes, or segments, in this industry. First, we used the clustering in Figure 3 and accompanying statistical tests to identify classes where printers of roughly the same DPI and PPM are located together. Second, we consulted trade journals and research reports to determine how experts segmented the industry. Finally, we met with firm managers to determine how they and their customers though about segments and competition. From this we developed the 24 product classes in Figure 3. These are the classes that we use for our empirical estimations below.

[5] The scatterplot understates this clustering because it uses a "jitter" approach, which shows multiple printers that have identical characteristics as being slightly offset from each other. Hence, the printers clustered in class 9 actually have identical speed and resolution – a visualization approach that did not offset would simply show a single dot.

[INSERT FIGURES 3 & 4 ABOUT HERE]

Figure 4 shows the pioneering entries into each product class. We label as “pioneers” all firms that enter in the first year in which a class is populated. Two features stand out from this table. First, in eight of these classes vertically integrated firms enter first, while in four they enter concurrently with non-integrated printer firms. Thus, in nearly half of all entered classes, vertically integrated firms are among the pioneers, although integrated firms comprise less than one-quarter of printer firms. Second, in those classes that are jointly pioneered by an integrated and non-integrated firm, the integrated pioneer is often the source of engines for the non-integrated pioneer. Thus, the integrated firms do not appear to use their engines exclusively to gain a “first mover advantage” in the new class.

A. EMPIRICAL ANALYSIS

We compiled life histories of each product and firm in the desktop laser printer industry, from its inception in 1984 through 1996. Our primary data source was Dataquest’s annual *SpecCheck* report on page printers, which is the single most comprehensive public database on these printers. *SpecCheck* provides information on a variety of printer characteristics including printer manufacturer, engine manufacturer, printer model, engine model, speed in PPM, resolution in DPI, initial ship date, number of units shipped in the year, and other features. To fill in missing data from early years in the industry, we supplemented this data source with information from *PC Magazine* and *PC World*. In addition, we obtained further quantity data from a separate, non-public Dataquest market research database and from a private consulting firm that had engaged in a long-term study of the laser printer industry. We believe that the resulting dataset is the most comprehensive available for the laser printer and laser engine industries. Over the 13-year period, we record 3,836 printer-year observations that aggregate up to 1,882 firm-class-year observations.

Dependent variables

To test our hypotheses, we analyze entry into and exit from product classes, both at the firm and the class level. We also analyze the effect of vertical integration and the thickness of the market for engines on price within a class. Consequently, we construct three dependent variables to support these analyses.

$\underline{\text{EntryCount}}_{jt}$ is a count of the number of printer firms that enter class j in year t. A printer firm i enters class j when it introduces its first product into that class. Subsequent introductions of additional products into that class by an incumbent firm are not considered entries.

$\underline{\text{Exit}}_{ijt}$ is a categorical variable set equal to 1 if printer firm i exits class j in year t, and 0 otherwise. Printer firm i exits class j when it ceases to ship all products in the class. If firm i withdraws one or more products, but continues to sell at least one other product in the industry, then it does not exit the industry. In our data there are no instances of a firm exiting a class in one year and then re-entering that class in a subsequent year.

$\underline{\text{Price}}_{kijt}$ is measured as the price charged for printer k produced by firm i in class j in year t. We report models using the list price because the list price data are substantially more complete than the street price data. Price is a continuous variable.

Given the different structures of these dependent variables, we use different model specifications for each. To test class-level predictions about entry, we estimate negative binomial models. To test firm-level predictions about exit, we estimate piecewise hazard rate models of the probability that a firm exits a given class. Finally, to test predictions about price, we estimate ordinary least squares (OLS) models with class random effects.

Independent variables

We employ a variety of independent variables that measure the degree of competition in the focal class, the number of classes in which the focal firm participates, presence of upstream engine firms serving the focal class, and several clocks that measure elapsed time from a relevant event. Descriptive statistics can be found in Table 1.

EngineFirms$_{jt}$ is a count of the number of laser engine firms serving class j in year t. An engine firm e serves class j if at least one printer model in that class has an engine from firm e. Note that EngineFirms includes independent laser engine firms that sell all of their products on the open market, vertically integrated firms that are entirely captive producers, and partially integrated firms that both sell on the market and sell to a downstream division.

EngineSellerFirms$_{jt}$ is a count of the number of laser engine firms that sell *at least some* of their engines through the market in class j in year t. EngineCaptiveFirms$_{jt}$ is a count of the number of laser engine firms whose engine production is entirely captive to a downstream laser printer division in class j in year t. To further distinguish levels of integration, we disaggregate EngineSellerFirms into EngineSellAllFirms and EngineTaperedFirms, which are counts of the number of laser engine firms that sell only on the open market and that both use in-house and sell on the open market, respectively.

PrinterFirms$_{jt}$ is a count of the number of laser printer firms operating in class j as of year t. PrinterFirms$^2_t$ is the square of PrinterFirms$_t$.

MakePrinterFirms$_{jt}$ is a count of the number of laser printer firms whose printers in class j use *at least some* of their own laser engines in year t. MakePrinterFirms$^2_{jt}$ is the square of MakePrinterFirms$_t$. BuyPrinterFirms$_{jt}$ is a count of the number of laser printer firms whose printers in class j rely exclusively on purchased laser engines in year t. BuyPrinterFirms$^2_{jt}$ is the square of BuyPrinterFirms$_t$. To further distinguish levels of integration, we also disaggregate MakePrinterFirms into MakeAllPrinterFirms and TaperedPrinterFirms, which are counts of the number of laser printer firms that use only in-house engines and that use both in-house and purchased engines in class j, respectively.

VIinClass$_{jt}$ is a categorical variable equal to 1 if class j has at least one vertically integrated printer model in year t, and 0 otherwise.

VIClock$_{jt}$ is the number of years since the first vertically integrated model entered class j, set equal to t - year of first vertically integrated models' entry + 1.

VertIntegDum$_{kijt}$ is a categorical variable equal to 1 if product k by firm i in class j at time t uses an in-house engine, and 0 otherwise.

Economies of scale in engine production should affect the price of engines and, consequently, the price of printers. We include two measures to proxy for engine production volume. For each printer model k by firm i in class j in year t, we identify the engine model and manufacturer used. LnTotalEnginesSold(Mfr)$_{kijt}$ is measured as the natural log of the total number of engines shipped by that engine manufacturer in all classes and for all engine models in year t. LnTotalEnginesSold(Model)$_{kijt}$ is measured as the natural log of that engine model's shipments in all classes, in units, in year t. We lack information on units for roughly 20% of the observations (according to Dataquest, these are printers that shipped only small unit volumes in a given year); for these observations we set LnTotalEnginesSold(Model) equal to 0 and create a categorical variable, ModelUnitsMissing$_{kijt}$, which is equal to 1 for these observations and 0 otherwise.

We also include several control variables in our estimation. A firm's age is often found to have an effect on its survival chances. We therefore include FirmAge$_{jt}$, a count of the number of years that firm j has participated in the laser printer industry as of year t.[6] A firm's size is also frequently found to have an effect on its survival chances. We do not have a direct measure of size other than firm sales, which is a problematic measure because it may conflate other key aspects of the firm's performance with its size (i.e., more successful firms have higher sales and also are not likely to exit). Instead, we construct the proxies NumProducts$_{jt}$, measured as the number of different printer models that firm j sells in year t, and NumClasses$_{jt}$, measured as the number of different product classes in which firm j competes (see de Figueiredo and Kyle 2006 for a detailed description of the product classes). Klepper and Thompson (2006) demonstrate that under a wide set of conditions, firms that participate in a wider range of classes will be less likely to exit an industry. We include NumProducts$_{jt}$ and NumClasses$_{jt}$ as proxies for firm size or

[6] We replicate all models adding FirmAge$^2$. FirmAge$^2$ is never significant, and its inclusion does not significantly change the coefficients of any other variables in the model.

scope.[7] Finally, price, entry, or exit may vary systematically with the age of a product class. We include $\underline{\text{ClassClock}}_{jt}$, the age of class j at time t, set equal to t - year that class j had its first entrant + 1.

## V. RESULTS

We first estimate the effect of upstream engine firm competition on the exit rate for downstream laser printer firms. We use piecewise hazard-rate estimation. Results appear in Table 1. Models 1 and 2 provide baseline estimations. The coefficient on PrinterFirms in Model 1 is positive and significant, indicating that a focal firm in a printer class is more likely to exit as it faces an increased number of rivals in that class. Model 2 introduces $\text{PrinterFirms}^2$. Although this variable has a negative coefficient, the combined effect of PrinterFirms and $\text{PrinterFirms}^2$ is positive throughout the observed range of data. Thus, an increase in the number of rivals in a class will increase a focal firm's likelihood of exit, but this competitive effect becomes attenuated as the number of rivals increases. This is consistent with Bresnahan & Reiss (1991), who find that the effect of the marginal rival tapers off fairly quickly as the number of rivals in a market increases.

In Models 3 and 4 we introduce our first key variable of interest, EngineFirms. The coefficient on EngineFirms is negative and significant; an increase in the number of engine firms serving a class reduces a focal printer firm's likelihood of exit. This is consistent with H1b. In Models 5-8 we decompose EngineFirms into those that sell at least engines on the market and those that use all engines in-house. These models indicate that the beneficial effect of upstream engine firms is attributable to the presence of non-integrated engine firms; the coefficient on EngineSellAllFirms is negative and significant, while the coefficients on EngineTaperedFirms and EngineCaptiveFirms are not significant. Consistent with H2, the relationship between exit

[7] In the reported models we use NumClasses. The models using NumProducts are essentially identical.

rate and upstream competition indeed is stronger for suppliers that sell on the open market than for captive suppliers.

We next estimate the effect of upstream engine firm competition on the entry rate for downstream laser printer firms. Following prior practice, we use negative binomial estimation. Results appear in Table 2. Again, the key variables of interest are EngineFirms, EngineSellerFirms, etc. The coefficient on EngineFirms is negative and significant in Model 3; an increase in the number of engine firms serving a class is associated with a reduction in the rate of entry into that class. (It is not significant in Model 4.) This is inconsistent with H1a, which predicted the opposite effect. Models 5-8 give us a bit of insight into this surprising result. Notably, the negative effect of upstream engine firms on downstream printer-firm entry is driven by the presence of vertically integrated engine firms – that is, the coefficient on EngineCaptiveFirms is consistently negative while the coefficient on other forms of engine firms is not. One interpretation is that it is not engine firms *per se* that discourage printer-firm entry, but rather vertically integrated printer firms (which add to the number of captive seller firms by virtue of having an upstream supplier division).

We thus turn our attention to the effect of integrated vs. non-integrated rivals on downstream entry and exit. Since Table 2 revealed a puzzle regarding entry, we begin here by exploring entry. We estimate the effect of printer firms' integration patterns on the entry of new printer firms into a class. Table 3 presents the results of our negative binomial estimations. In Models 1 and 2 we decompose printer firms into PrinterMakeFirms, who make at least some of the engines that they use, and PrinterBuy Firms, who buy all of their engines on the market. The coefficient on PrinterMakeFirms is negative and significant in Model 1; in Model 2, which introduced square terms, this coefficient falls to insignificance but the coefficient on $\text{PrinterMakeFirms}^2$ is negative and significant. Thus, across both models, an increase in the number of integrated printer firms in a class is associated with less entry into that class. In contrast, the PrinterBuyFirms has a positive and significant coefficient (of much smaller magnitude), indicating that increases in the presence of non-integrated firms in a class may actually encourage entry into the class. This pattern is replicated in Models 3 and 4, which further decompose printer-firm integration levels. Thus, we find that integrated printer firms discourage printer-firm entry, while non-integrated firms (if anything) may encourage entry. This rank-ordering of effects is consistent with H3a.

We estimate the effect of printer firms' integration patterns on the likelihood that a focal firm will exit a class. Table 4 presents the results of our hazard-rate estimation. In Model 1, the coefficient on PrinterMakeFirms is positive and significant, as is the coefficient on PrinterBuyFirms. A $\chi^2$ test for equality across the coefficients indicates that the coefficient on PrinterMakeFirms is significantly larger than that on PrinterBuyFirms. Thus, consistent with H3b, an increase in the number of vertically integrated printer firms in a class has a significantly greater increase on the exit rate of a focal firm than an increase in the number of non-integrated printer firms. This pattern of coefficients is echoed in Models 2-4.

The above results indicate that vertically integrated rivals generate greater competitive pressure for a focal firm than do non-integrated rivals. As noted in Section III, this is consistent with both the efficiency rationale and foreclosure rationale of vertical integration. We now turn our attention to the relationship between integration and pricing, which is the one dimension along which these rationales clearly differ. Figure 5 shows the evolution of the price of printer models produced by vertically integrated and non-integrated firms in four representative product classes. Visual inspection of these charts yields two impressions. First, within a given class, printers produced by integrated firms appear to be priced lower than printers produced by non-integrated firms. In virtually all years, the mean price of vertically integrated printers is lower than the mean price of non-integrated printers. Second, when the first vertically integrated printer is introduced into a class populated by non-integrated printers, the price of non-integrated printers appears to fall (for example, in Class 2). These patterns appear to be consistent with an efficiency rationale, whereby integrated firms impose competitive pressure on rivals by pricing more aggressively and pushing price downward.

Table 5 presents prices for all printers (in a handful of classes) that use one of two particular Canon engine models. In classes 10 and 18, Canon prices its printers hear the bottom end of HP's price range. Non-HP purchasers of Canon engines have prices that are much higher than those of HP or Canon. The price of Canon relative to HP is a bit different in class 1, but the non-HP purchases continue to sell printers at a much higher price. These patterns again appear to be consistent with an efficiency rationale, where Canon's forward integration leads it to have lower prices than rivals and sparks continued price reductions in the relevant classes.

Finally, we examine this statistically. Table 6 presents results from our estimation of printer price as a function of the presence of vertically integrated printers in a class. Models 1 and 2 provide baseline estimations. The coefficient on Class Clock is -371.16 and is significant, indicating that the price of the average printer in a class declines by $371 per year. The coefficient on PrinterFirms is not significant. In Models 3-9 we introduce variables that reflect the degree to which a class has vertically integrated printers. Since the coefficients are largely stable across these models, we interpret the fully specified model, Model 9.

VI Model in Class has a negative, significant coefficient. The average printer price in a given class is $607 lower if there is at least one vertically integrated printer for sale in that class. The coefficient on VI dummy is also negative and significant. A vertically integrated printer in a given class is priced $1,127 lower than the average printer in that class, even after taking into account the general decline of $607 in average price due to the presence of a vertically integrated printer in the class. These effects are economically significant. Given an average printer price of $8,177 (i.e., the coefficient on the constant term), the entry of a vertically integrated printer leads to a decrease of 7.5% in the average price, and vertically integrated printer will be sold for a price that is 15% below this price. These effects persist after controlling for scale economies in engine production, as measured by Ln Total Engines Sold. The statistical evidence is consistent with the efficiency prediction for vertical integration, and inconsistent with the foreclosure prediction.

## VI. CONCLUSION

In this paper, we added to a nascent research stream within the industry-evolution and vertical-integration literatures that addresses the following questions: How does the structure of upstream input markets affect the evolution of downstream product-market competition? How is this affected by vertical integration that spans these markets? We constructed a model of (downstream) industry entry, exit, and price in the presence of an upstream market that affects marginal costs in the focal industry. We predicted that increased competition in the upstream market would lead to increased entry and decreased exit downstream, but that this effect would be moderated by patterns of vertical integration between the markets. We further predicted that that vertically integrated rivals in the downstream industry would generate more intense competitive pressure than non-integrated rivals. We tested our predictions through a study of 23 segments within the desktop laser printer industry (and its upstream relative, the laser engine industry). We found support for most predictions. Of particular interest, we were able to run an empirical "horse-race" between the two dominant rationales for vertical integration, efficiency and vertical foreclosure. We found that vertical integration in an industry segment is associated with significant reductions in price, consistent with the efficiency rationale, rather than with the significant increases in price predicted by foreclosure models. This paper thus contributes to our understanding of vertical integration and markets for technology in the evolution of industries.

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**Table 1: Effect of (upstream) engine firm population on *exit* rate for (downstream) laser printer firms, at class level**

[standard errors in parentheses; *** = p < 0.01; ** = p < 0.05; * = p < 0.10; + = p < 0.12]

| | ------ Baseline ------- | | ---- Add Engine Firms ---- | | ----- Add Engine Firms with Governance ----- | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Time piece 1 | -6.312 *** | -6.784 *** | -6.393 *** | -6.676 *** | -6.520 *** | -6.521 *** | -6.492 *** | -6.494 *** |
| | (0.572) | (0.709) | (0.583) | (0.710) | (0.606) | (0.684) | (0.597) | (0.675) |
| Time piece 2 | -3.628 *** | -4.110 *** | -3.680 *** | -3.973 *** | -3.897 *** | -3.899 *** | -3.877 *** | -3.878 *** |
| | (0.327) | (0.464) | (0.341) | (0.467) | (0.368) | (0.452) | (0.363) | (0.559) |
| Printer Firms | 0.020 ** | 0.081 ** | 0.074 *** | 0.101 *** | 0.065 *** | 0.066 + | 0.060 ** | 0.060 |
| | (0.008) | (0.036) | (0.024) | (0.036) | (0.023) | (0.041) | (0.025) | (0.043) |
| Printer Firms$^2$/100 | | -0.122 * | | -0.076 | | -0.001 | | -0.000 |
| | | (0.070) | | (0.073) | | (0.085) | | (0.084) |
| Engine Firms | | | -0.141 ** | -0.113 * | | | | |
| | | | (0.057) | (0.063) | | | | |
| EngineSellerFirms | | | | | -0.145 *** | -0.145 ** | | |
| | | | | | (0.055) | (0.060) | | |
| EngineSellAllFirms | | | | | | | -0.167 ** | -0.167 ** |
| | | | | | | | (0.068) | (0.073) |
| EngineTaperedFirms | | | | | | | -0.086 | -0.086 |
| | | | | | | | (0.120) | (0.121) |
| EngineCaptiveFirms | | | | | 0.049 | 0.049 | 0.057 | 0.057 |
| | | | | | (0.103) | (0.106) | (0.103) | (0.107) |
| Firm Age | 0.042 | 0.278 | 0.057 | 0.046 | 0.051 | 0.051 | 0.050 | 0.050 |
| | (0.049) | (0.051) | (0.049) | (0.051) | (0.049) | (0.051) | (0.049) | (0.051) |
| Firm Scope | -0.121 ** | -0.114 * | -0.115 * | -0.111 * | -0.111 * | -0.111 * | -0.110 * | -0.110 * |
| | (0.061) | (0.062) | (0.062) | (0.063) | (0.062) | (0.062) | (0.061) | (0.062) |
| Wald chi-square | 976.08 *** | 956.16 *** | 965.77 *** | 955.23 *** | 947.24 *** | 947.67 *** | 947.41 *** | 947.79 *** |
| Log-pseudolikelihood | -158.45 | -156.77 | -156.00 | -155.42 | -153.45 | -153.45 | -153.32 | -153.32 |
| N | 1992 | 1992 | 1992 | 1992 | 1992 | 1992 | 1992 | 1992 |
| # subjects | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| # failures | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 |

**Table 2: Effect of (upstream) engine firm population on *entry* rate for (downstream) laser printer firms, at class level**

[standard errors in parentheses; *** = p < 0.01; ** = p < 0.05; * = P < 0.10]

| | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) |
|---|---|---|---|---|---|---|---|---|
| PrinterFirms | 0.016 ** | 0.076 *** | 0.048 *** | 0.089 *** | 0.044 ** | 0.096 *** | 0.051 *** | 0.100 *** |
| | (0.006) | (0.016) | (0.017) | (0.020) | (0.017) | (0.020) | (0.018) | (0.020) |
| $PrinterFirms^2/100$ | | -0.160 *** | | -0.148 *** | | -0.196 *** | | -0.192 *** |
| | | (0.040) | | (0.041) | | (0.043) | | (0.043) |
| EngineFirms | | | -0.093 ** | -0.050 | | | | |
| | | | (0.046) | (0.046) | | | | |
| EngineSellSomeFirms | | | | | -0.059 | 0.019 | | |
| | | | | | (0.049) | (0.049) | | |
| EngineSellAllFirms | | | | | | | -0.026 | 0.038 |
| | | | | | | | (0.056) | (0.054) |
| EngineTaperedFirms | | | | | | | -0.148 * | -0.037 |
| | | | | | | | (0.090) | (0.089) |
| EngineCaptiveFirms | | | | | -0.180 *** | -0.196 *** | -0.191 *** | -0.202 *** |
| | | | | | (0.064) | (0.062) | (0.064) | (0.062) |
| Constant | 0.786 *** | 0.513 *** | 0.839 *** | 0.561 *** | 0.879 *** | 0.979 *** | 0.849 *** | 0.534 *** |
| | (0.102) | (0.119) | (0.103) | (0.127) | (0.104) | (0.149) | (0.107) | (0.123) |
| N | 202 | 202 | 202 | 202 | 202 | 202 | 202 | 202 |
| Log-likelihood | -427.27 | -419.65 | -355.85 | -419.07 | -423.40 | -413.34 | -422.71 | -413.06 |
| PseudoR2 | .0080 | .0257 | .0076 | .0270 | .0170 | .0404 | .0186 | .0410 |

.

**Table 3: Effect of rival printer firm governance on entry rate for laser printer firms, at class level**
[standard errors in parentheses; *** = p < 0.01; ** = p < 0.05; * = P < 0.10]

| | (21) | (22) | (23) | (24) |
|---|---|---|---|---|
| PrinterMakeFirms | -0.143 ** | 0.031 | | |
| | (0.061) | (0.102) | | |
| $PrinterMakeFirms^2$ | | -0..029 *** | | |
| | | (0.010) | | |
| PrinterMakeAllFirms | | | -0.132 * | 0.049 |
| | | | (0.071) | (0.112) |
| $PrinterMakeAllFirms^2$ | | | | -0.033 *** |
| | | | | (0.012) |
| PrinterTaperedFirms | | | -0.182 | 0.206 |
| | | | (0.136) | (0.322) |
| $PrinterTaperedFirms^2$ | | | | -0.324 * |
| | | | | (0.175) |
| PrinterBuyFirms | 0.054 *** | 0.074 *** | 0.056 *** | 0.072 *** |
| | (0.016) | (0.025) | (0.018) | (0.028) |
| $PrinterBuyFirms^2$ | | -0.001 | | -0.001 |
| | | (0.007) | | (0.001) |
| Engine Firms | -0.000 | 0.069 | -0.008 | 0.062 |
| | (0.053) | (0.053) | (0.058) | (0.057) |
| Constant | 0.849 *** | 0.486 *** | 0.852 *** | 0.496 *** |
| | (0.100) | (0.121) | (0.101) | (0.120) |
| N | 202 | 202 | 202 | 202 |
| Log-likelihood | -420.04 | -408.53 | -419.99 | -407.43 |
| PseudoR2 | .0248 | .0515 | .0249 | .0541 |

**Table 4: Effect of rival printer firm governance on *exit* rate for laser printer firms, at class level**

[standard errors in parentheses; *** = p < 0.01; ** = p < 0.05; * = p < 0.10]

| | ----- Add Governance Form to Printer Firms ----- | | | |
|---|---|---|---|---|
| | (9) | (10) | (11) | (12) |
| Time piece 1 | -6.429 *** | -6.437 *** | -6.431 *** | -6.361 *** |
| | (0.591) | (0.727) | (0.592) | (0.711) |
| Time piece 2 | -3.816 *** | -3.816 *** | -3.819 *** | -3.732 *** |
| | (0.356) | (0.464) | (0.352) | (0.456) |
| PrinterMakeFirms | 0.266*** | 0.174 | | |
| | (0.089) | (0.239) | | |
| $PrinterMakeFirms^2/100$ | | 0.722 * | | |
| | | (1.926) | | |
| PrinterMakeAllFirms | | | 0.264 *** | 0.062 |
| | | | (0.100) | (0.286) |
| $PrinterMakeAllFirms^2/100$ | | | | 0.021 |
| | | | | (0.026) |
| PrinterTaperedFirms | | | 0.274 * | 0.127 |
| | | | (0.170) | (0.420) |
| $PrinterTaperedFirms^2/100$ | | | | 0.067 |
| | | | | (0.166) |
| PrinterBuyFirms | 0.054 * | 0.080 | 0.053 * | 0.105 |
| | (0.025) | (0.064) | (0.028) | (0.078) |
| $PrinterBuyFirms^2/100$ | | -0.074 | | -0.001 |
| | | (0.156) | | (0.002) |
| Engine Firms | -0.201 *** | -0.190 ** | -0.199 *** | -0.201 ** |
| | (0.064) | (0.078) | (0.077) | (0.088) |
| Firm Age | 0.043 | 0.040 | 0.043 | 0.040 |
| | (0.049) | (0.050) | (0.049) | (0.050) |
| Firm Scope | -0.105 * | -0.106 * | -0.104 * | -0.108 * |
| | (0.065) | (0.062) | (0.062) | (0.062) |
| Wald chi-square | 947.38 *** | 952.34 *** | 947.29 *** | 955.45 *** |
| Log-pseudolikelihood | -153.58 | -153.43 | -153.58 | -155.05 |
| N | 1992 | 1992 | 1992 | 1992 |
| # subjects | 400 | 400 | 400 | 400 |
| # failures | 69 | 69 | 69 | 69 |

**Table 5: Prices for printers using select Canon engine models in select classes (figures in parentheses are average prices)**

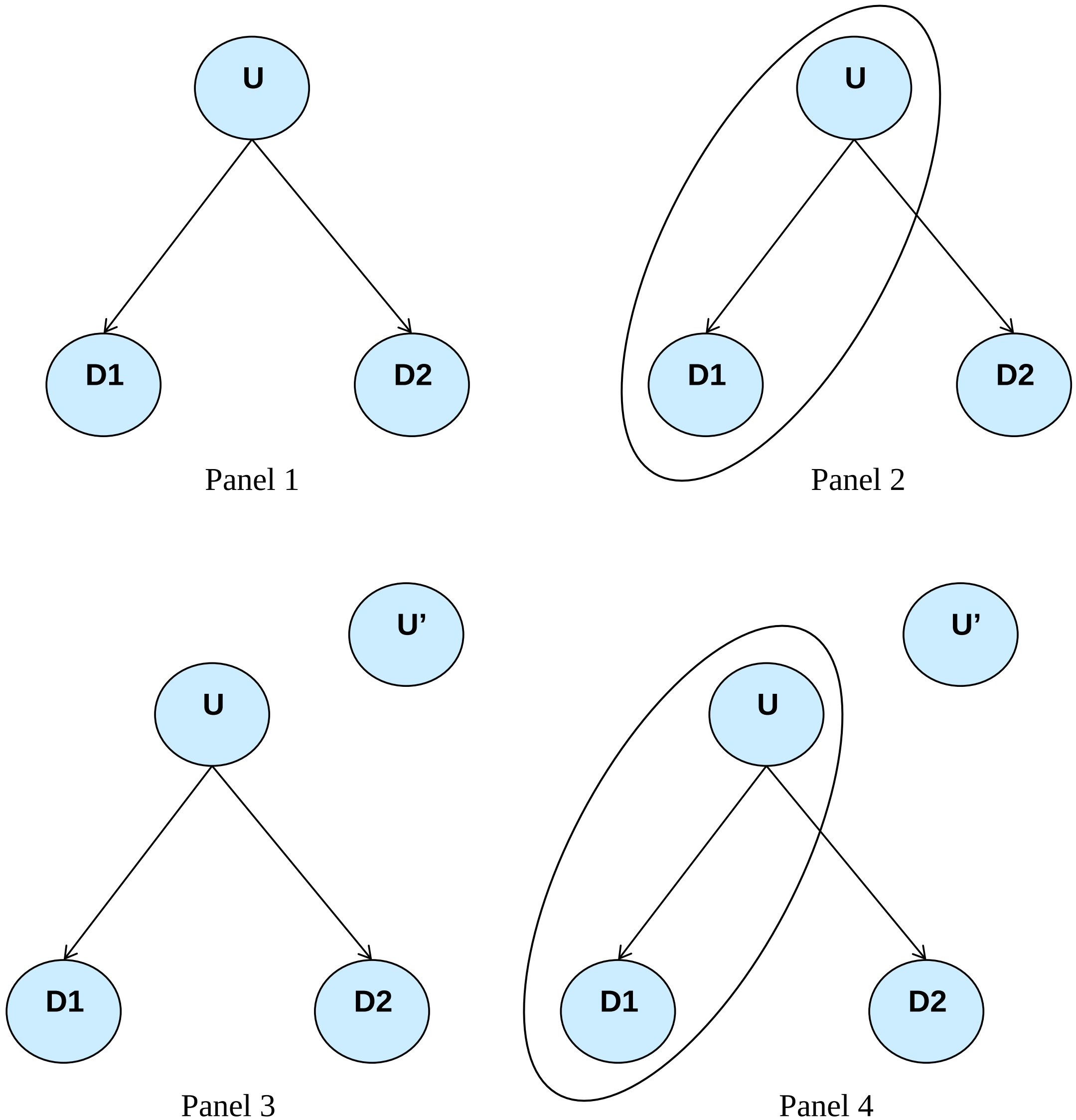
| Engine model | Class | Year | Price of Canon printers ($) | Price of HP printers ($) | Price of other printers ($) |
|---|---|---|---|---|---|
| LBP-LX | 1 | 1989 | | 1495<br>(1495) | |
| LBP-LX | 1 | 1990 | 1545<br>(1545) | 1249-1595<br>(1395) | 1495-3299<br>(2382) |
| LBP-LX | 1 | 1991 | 1545<br>(1545) | 1249-1595<br>(1380) | 1199-3299<br>(2201) |
| LBP-LX | 1 | 1992 | 1249-1595<br>(1496) | 1249-1595<br>(1380) | 949-3299<br>(1970) |
| LBP-LX | 1 | 1993 | 1249-1595<br>(1496) | 999-1595<br>(1281) | 949-2599<br>(1661) |
| LBP-LX | 1 | 1994 | 1249-1595<br>(1496) | 999-1595<br>(1158) | 699-2599<br>(1724) |
| LBP-LX | 1 | 1995 | 1249-1595<br>(1463) | 999-1595<br>(1158) | 699-2599<br>(1665) |
| LBP-LX | 1 | 1996 | 1249-1595<br>(1463) | 999-1595<br>(1158) | 699-2599<br>(1665) |
| | | | | | |
| LBP-EX | 10 | 1993 | | 2199-2999 | 3995 |
| LBP-EX | 10 | 1994 | 1839 | 1839-2479 | 2199-3995 |
| LBP-EX | 10 | 1995 | 1839 | 1839-2479 | 1599-3995 |
| LBP-EX | 10 | 1996 | 1839 | 1839-2479 | 1599-3995 |
| | | | | | |
| LBP-EX | 18 | 1994 | 1699 | 1839-2479 | 1649-4295 |
| LBP-EX | 18 | 1995 | 1699 | 1839-2479 | 1649-4295 |
| LBP-EX | 18 | 1996 | 1699 | 1305-2479 | 1649-4295 |

Note: Canon printers are typically priced at or below HP's printers that use the same Canon engine, and other printer firms' printers that use the same Canon engine are priced much higher
--higher non-engine production costs?
--Canon's market price is higher than its transfer price?
--fringe printer firms produce printers of higher quality or greater product differentiation?

**Table 6: Class-level XTREG Estimation of price of printers based on printer model characteristics , incl. vertical integration**
[standard errors in parentheses; *** = p < 0.01; ** = p < 0.05; * = P < 0.10]

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (7) |
|---|---|---|---|---|---|---|---|---|
| Class clock | -371.16 ***<br>(23.00) | -360.21 ***<br>(27.39) | -351.13 ***<br>(27.57) | -671233 ***<br>(218.93) | -650.35 ***<br>(208.33) | -552.11 ***<br>(185.77) | -621.98 ***<br>(180.43) | -614.18 ***<br>(178.53) |
| # firms in class | | -6.79<br>(9.11) | -0..84<br>(9.35) | -1.07<br>(9.36) | -3.25<br>(9.28) | 4.37<br>(9.23) | 16.54 *<br>(9.25) | 17.13 *<br>(9.25) |
| VI model in class | | | -995.50 ***<br>(367.51) | -801.98 **<br>(390.47) | -651.83 *<br>(388.89) | -458.63<br>(378.01) | -663.31 *<br>(371.56) | -607.24 *<br>(372.38) |
| VI clock | | | | 322.65<br>(218.98) | 318.17<br>(208.47) | 203.69<br>(185.49) | 218.97<br>(179.84) | 208.21<br>(177.93) |
| VI dummy | | | | | -924.49 ***<br>(335.28) | -1276.09 ***<br>(335.08) | -1048.39 ***<br>(329.24) | -1127.43 ***<br>(322.29) |
| VI dummy * VI clock | | | | | 4.85<br>(47.21) | 51.09<br>(47.16) | 33.76<br>(46.40) | 43.17<br>(46.71) |
| Ln total engines sold (mfr) | | | | | | -79.28 ***<br>(13.44) | | -24.97 *<br>(14.90) |
| Ln total engine sold (model) | | | | | | | -124.72 ***<br>(12.54) | -114.21 ***<br>(14.03) |
| Model info missing | | | | | | 640.66 ***<br>(129.35) | -152.54<br>(152.99) | -93.89<br>(156.86) |
| Constant | 6232.70 ***<br>(555.37) | 6255.04 ***<br>(567.80) | 6972.33 ***<br>(620.03) | 7171.79 ***<br>(645.35) | 7262.51 ***<br>(583.05) | 7697.69 ***<br>(528.01) | 8026.76 ***<br>(507.10) | 8177.15 ***<br>(509.85) |
| # observations | 3210 | 3210 | 3210 | 3210 | 3210 | 3210 | 3210 | 3210 |
| # groups | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| Random effects | class | class | class | class | class | class | class | class |
| Wald chi-square | 260.43 | 261.15 | 268.89 | 271.37 | 326.33 | 391.95 | 462.79 | 465.66 |
| R-square (overall) | .04 | .03 | .03 | .04 | .06 | .11 | .13 | .14 |

**FIGURE 0: VERTICAL FORECLOSURE**



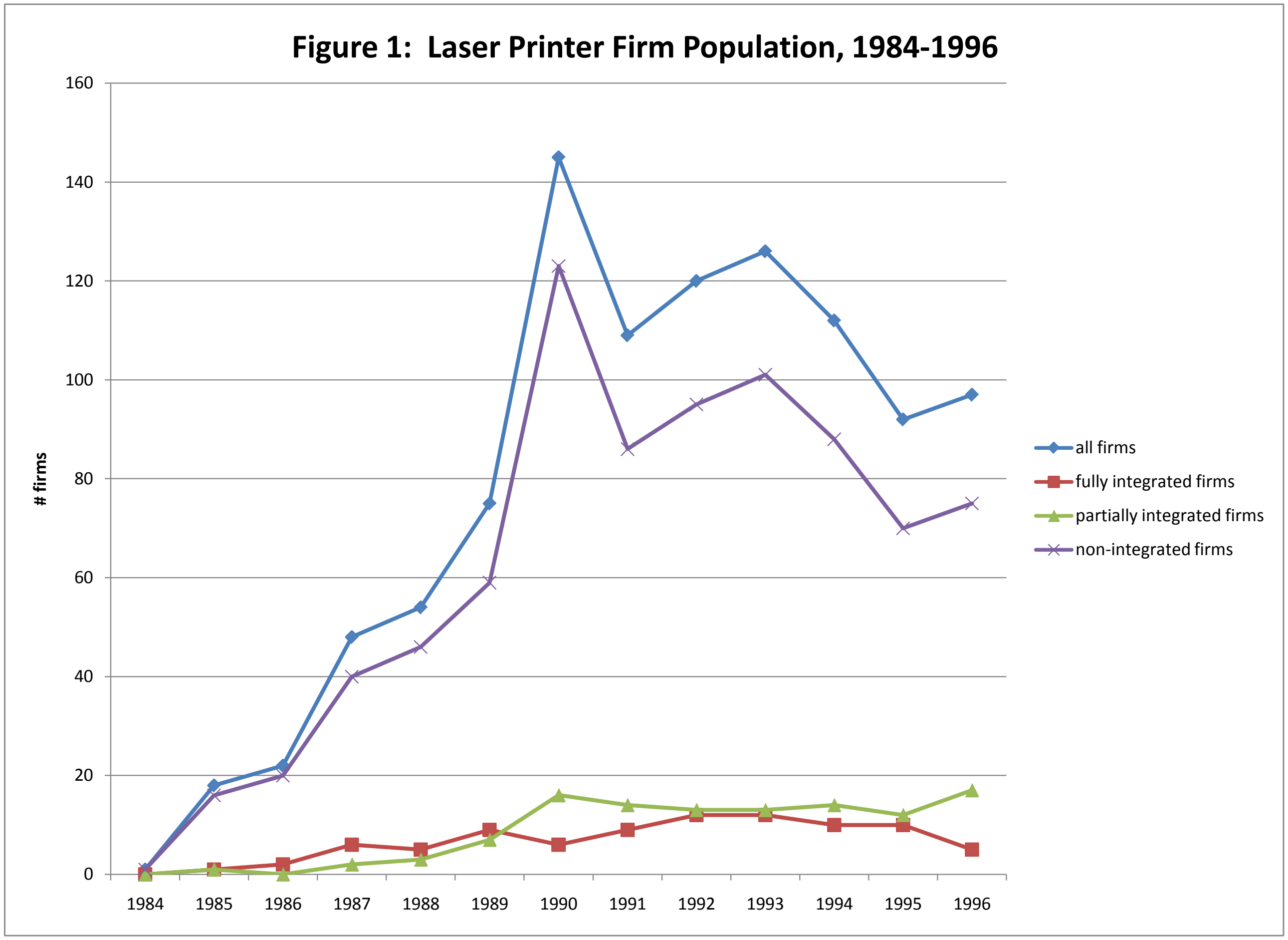


Figure 1: Laser Printer Firm Population, 1984-1996
# firms
160
140
120
100
80
60
40
20
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
all firms
fully integrated firms
partially integrated firms
non-integrated firms

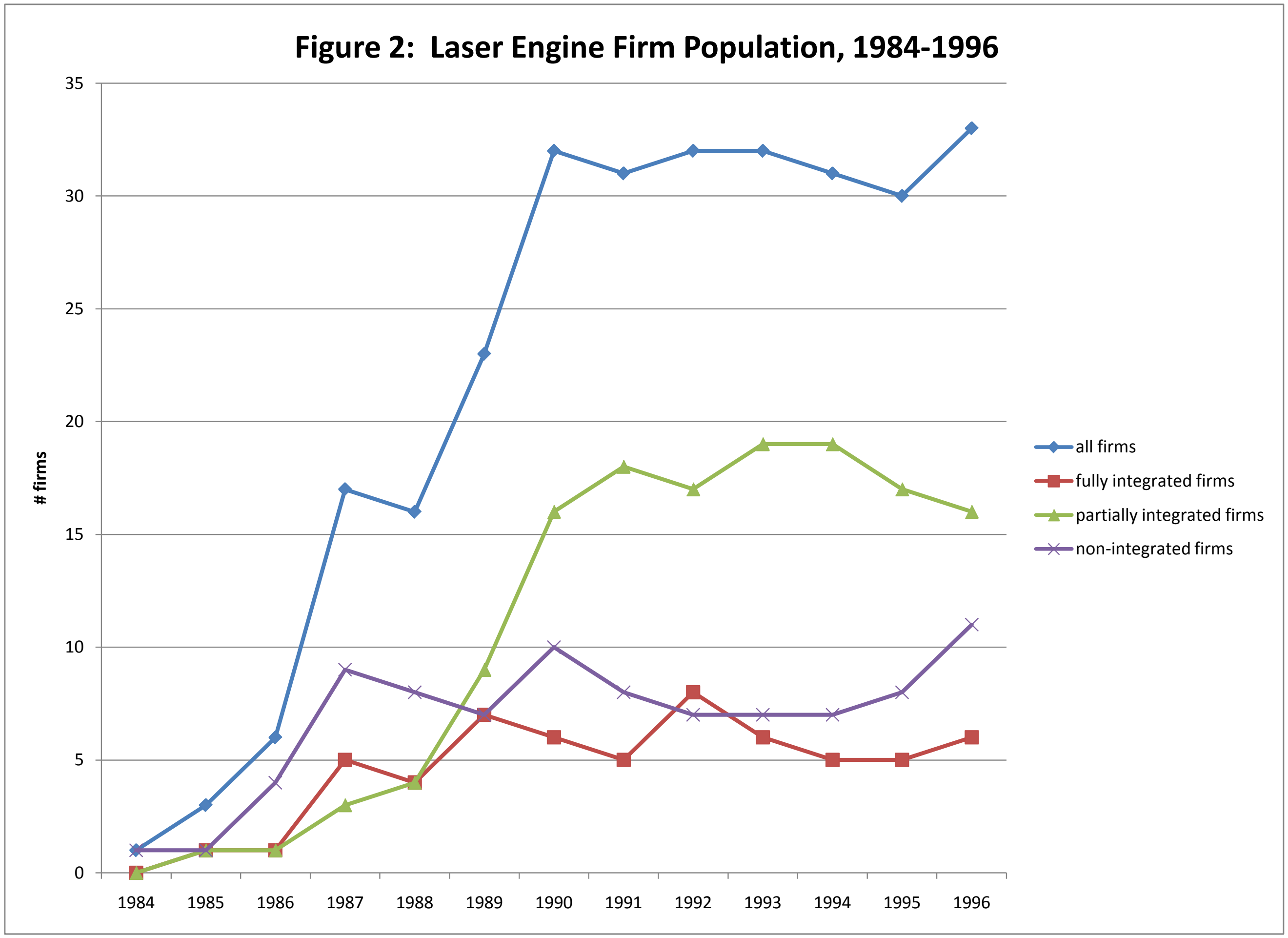
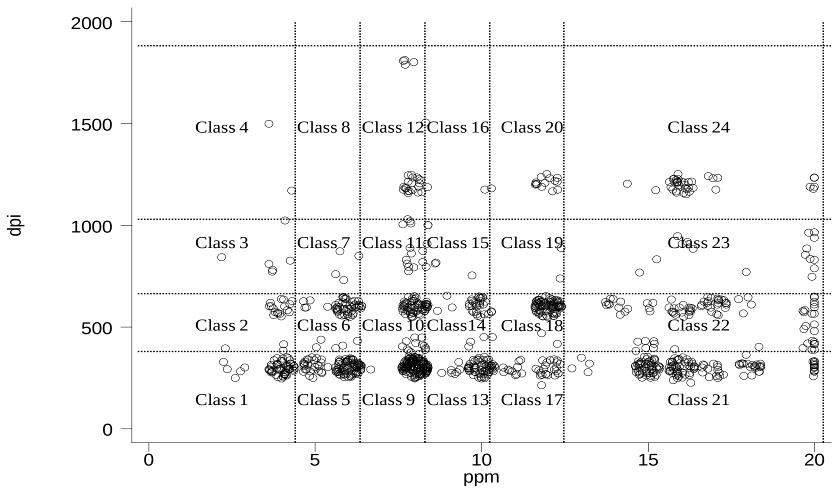


Figure 2: Laser Engine Firm Population, 1984-1996
# firms
35
30
25
20
15
10
5
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
all firms
fully integrated firms
partially integrated firms
non-integrated firms

Figure 3: Product Distribution and Classes



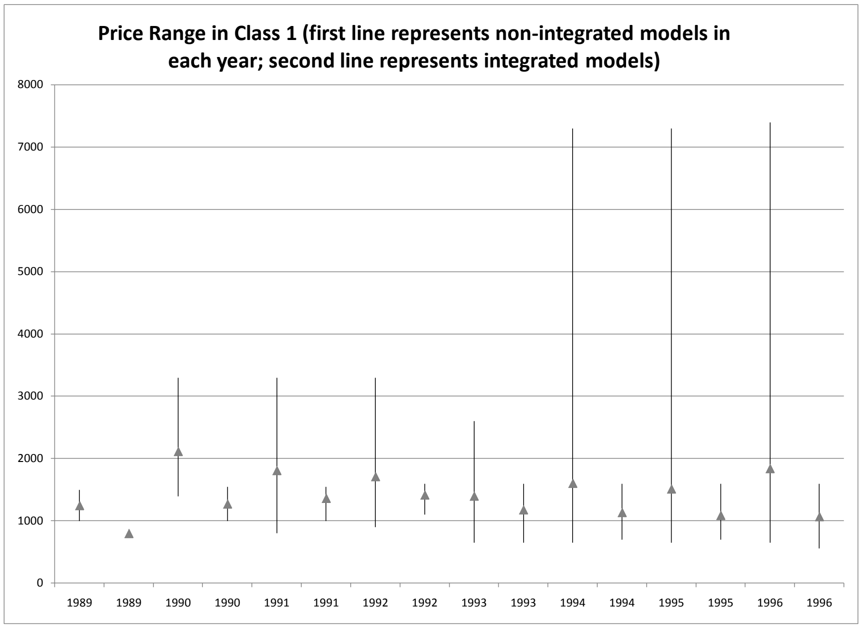

Note: Each small circle represents a printer.

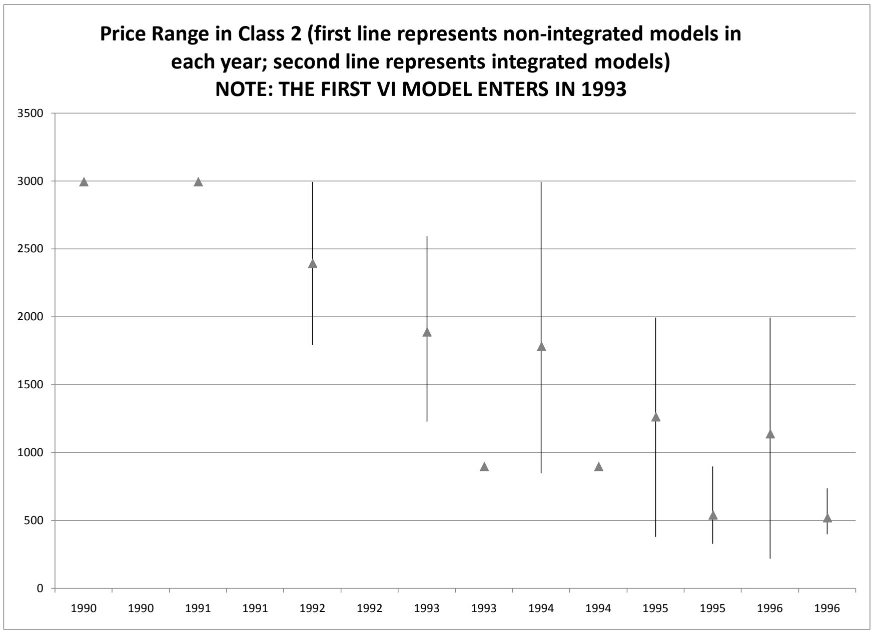
**Figure 4: Pioneering firms in each class (printer firm/engine maker)**

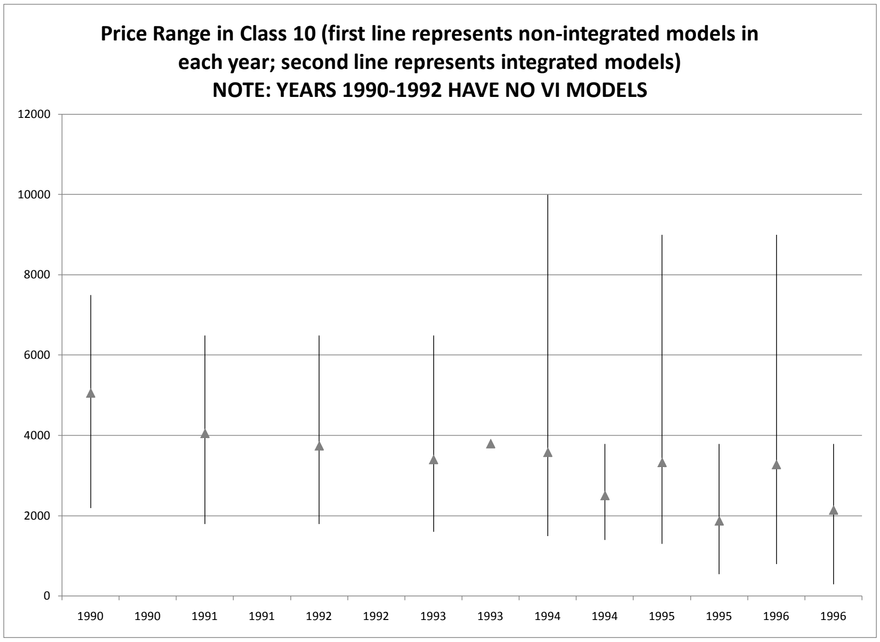
Blue: class was pioneered by non-integrated firm [classes 2, 3, 4, 9, 10, 12, 16, 17, 20, 24]
Pink: class was pioneered by vertically integrated firm [classes 6, 7, 11, 13, 14, 15, 19, 22, 23]
Orange: class was pioneered by non-integrated firm and vertically integrated firm [classes 1,5, 18, 21]

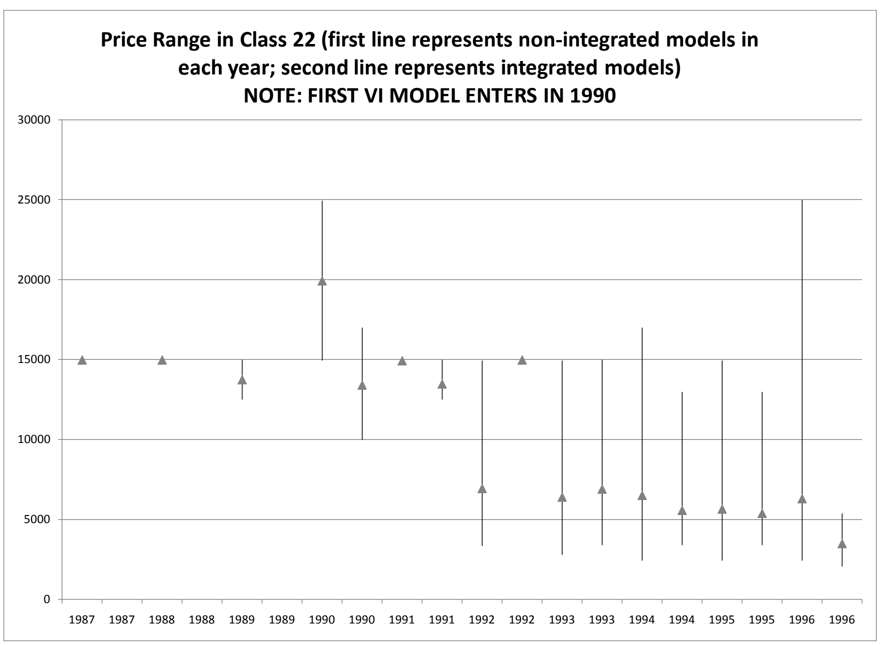
| | | | | | |
|---|---|---|---|---|---|
| Class 4: 1993<br>XLI/Canon | Class 8:<br>N/A | Class 12: 1990<br>Printware/Toshiba | Class 16: 1995<br>Genicom/IBM-Lexmark | Class 20: 1991<br>Printware/Fujitsu | Class 24: 1994<br>IBM/IBM<br>Xante/Canon<br>Calcomp/Canon |
| Class 3: 1991<br>Lasermaster/Canon | Class 7: 1995<br>OKI/OKI | Class 11: 1988<br>Printware/Printware | Class 15: 1996<br>Alps America/Alps America | Class 19: 1992<br>Fujitsu/Fujitsu | Class 23: 1991<br>Graphic Enterprise/ Graphic Enterprise |
| Class 2: 1990<br>Newgen/Canon | Class 6: 1987<br>Varityper/Varityper | Class 10: 1990<br>Newgen/Canon<br>Lasersmith/-999 | Class 14: 1988<br>Varityper/Varityper | Class 18: 1989<br>Fujitsu/Fujitsu<br>Nissho/-999 | Class 22: 1987<br>Varityper/Varityper |
| Class 1: 1989<br>OKI/OKI<br>HP/Canon<br>GCC/OKI | Class 5: 1987<br>NEC/NEC<br>Fortis/Casio<br>OKI/Ricoh<br>Epson/Ricoh | Class 9: 1984<br>HP/Canon | Class 13: 1986<br>Xerox/Fuji-Xerox | Class 17: 1986<br>XPoint/Toshiba | Class 21: 1986<br>Ricoh/Ricoh<br>Acom/Ricoh<br>TI/Ricoh |

**Figure 5: Prices of integrated and non-integrated printers, by class-year, selected classes**




Price Range in Class 10 (first line represents non-integrated models in each year; second line represents integrated models)
NOTE: YEARS 1990-1992 HAVE NO VI MODELS
12000
10000
8000
6000
4000
2000
0
1990 1990 1991 1991 1992 1992 1993 1993 1994 1994 1995 1995 1996 1996


Price Range in Class 22 (first line represents non-integrated models in each year; second line represents integrated models)
NOTE: FIRST VI MODEL ENTERS IN 1990
30000
25000
20000
15000
10000
5000
0
1987 1987 1988 1988 1989 1989 1990 1990 1991 1991 1992 1992 1993 1993 1994 1994 1995 1995 1996 1996