The Effect of Markets for Technology and Vertical Integration on Exit, Entry, and Price: An Empirical Analysis of the Laser Printer Industry

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Abstract

A key question in strategy research on exit relates to the competitive effects of vertical integration. 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 relates to the effect of upstream markets for technology on downstream firm exit rates – i.e., to what extent does a thick upstream market for key technological inputs reduce foreclosure and reduce efficiency benefits of integration? This paper contributes to the literatures associated with these questions.

After developing a series of predictions for the effect of vertical integration patterns and upstream markets for technology on downstream 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. Of all the components within a laser printer, the laser engine is both the most expensive and subject to the most variation in governance. Roughly 25% of laser printer firms make at least some of their engines in-house, and roughly 70% of laser engine producers sell at least some of their engines to other firms. We exploit the variation in governance of engine procurement among printer firms to explore the effects of vertical integration on entry, exit, and pricing dynamics. We explore the effect of vertical integration and prevalence of laser engine suppliers on laser printer firm entry into industry segments (and the industry overall), exit from industry segments (and the industry overall), and pricing dynamics within each segment. We find evidence that increases in the engine supplier base is 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. These results are more consistent with efficiency than with foreclosure. We also find suggestive evidence that vertically integrated firms undertake systemic innovation more rapidly than their non-integrated rivals.

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Introduction

- A key question in strategy research relates to the competitive effects of vertical integration: i.e., competing predictions from foreclosure vs. efficiency theories.
- A related question relates to markets for technology – i.e., to what extent does a thick upstream market for key technological inputs reduce foreclosure and reduce efficiency benefits of integration?
- This paper contributes to the literature associated with these questions.

This paper is most similar to Hortascu & Syverson's (2007) study of the competitive effects of vertical integration in the cement industry. That article exploited detailed data on cement and ready-mixed concrete producers to test whether the competitive effects of vertical integration were consistent with vertical foreclosure theory or with theories of efficiency-driven vertical integration. Their evidence favored 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 among non-integrated firms were driven by efficiency gains rather than by foreclosure. We also look at the effect of vertical integration into a key upstream input on entry, exit, and price in the downstream market. We differ from Hortascu & Syverson (2007) in two ways. First, we have a more complete set of longitudinal data (13 consecutive years, as compared to 5 semi-decennial censuses), which enables us to explore the dynamics of entry, exit, and pricing more precisely. Second, we are able to identify the upstream supplier (when upstream input is purchased). This enables us to gain further insight into pricing dynamics by exploring variation in printer price across printer firms that incorporate the same engine model.

This paper is also similar to Arora & Nandkumar's (2008) study of exit in the information security industry. They find that exit is positively associated with the presence of upstream suppliers, which is consistent with a world in which a thick upstream market (a "market for technology" in their parlance) lowers the fixed cost of downstream entry, thus encouraging entry which, in turn, leads to increased exit as downstream competition ultimately shakes out. They exploit variation both over time (1989-2004) and across product segments within the industry to identify their effects. We differ from Arora & Nandkumar (2008) by exploring entry dynamics directly, by exploiting information on printer prices and on the precise identity of buyer-supplier dyads to test more precisely the mechanisms that lead to exit in downstream markets, by focusing on a setting in which upstream markets appear to affect variable rather than fixed costs downstream, and by also exploring the role of vertically integrated rivals in affecting competitive dynamics.

Finally, this paper is similar to Negro & Sorenson's (2006) study of the competitive effects of vertical integration in the film industry. They find that "vertical integration appears to change the dynamics of competition in two ways: (i) it buffers the vertically integrated firms from environmental dependence, and (ii) it intensifies competition among non-integrated organizations. We differ from Negro & Sorenson (2006) by exploring the role of upstream suppliers in affecting downstream competitive dynamics, and by exploiting our information on the identity of buyer-supplier dyads as well as by exploiting the presence of "tapered" integration in our data to generate more precise tests. De Figueiredo and Silverman (2010) begin to explore the dynamics of vertical integration in an organizational ecology setting.

Vertical Integration and Upstream Market Thickness: Theory

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.[1]

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.

[INSERT FIGURES 3 & 4ABOUT 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

[1] 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.

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.

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.

<u>Dependent variables</u>

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.

$\underline{\text{EngineDensity}}_{jt}$ 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 EngineDensity 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.

EngineSellerDensity$_{jt}$ 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. EngineCaptiveDensity$_{jt}$ 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 EngineSellerDensity into EngineSellAllDensity and EngineTaperedDensity, 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.

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

MakePrinterDensity$_{jt}$ 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. MakePrinterDensity$^2_{jt}$ is the square of MakePrinterDensity$_t$. BuyPrinterDensity$_{jt}$ is a count of the number of laser printer firms whose printers in class j rely exclusively on purchased laser engines in year t. BuyPrinterDensity$^2_{jt}$ is the square of BuyPrinterDensity$_t$. To further distinguish levels of integration, we also disaggregate MakePrinterDensity into MakeAllPrinterDensity and TaperedPrinterDensity, 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. $\underline{\text{LnTotalEnginesSold(Model)}}_{kijt}$ 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, $\underline{\text{ModelUnitsMissing}}_{kijt}$, 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 $\underline{\text{FirmAge}}_{jt}$, a count of the number of years that firm j has participated in the laser printer industry as of year t.[2] 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 $\underline{\text{NumProducts}}_{jt}$, measured as the number of different printer models that firm j sells in year t, and $\underline{\text{NumClasses}}_{jt}$, 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 scope.[3] 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.

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[2] 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.
[3] In the reported models we use NumClasses. The models using NumProducts are essentially identical.

Results

Please see Tables 1-2 for results of our estimations of entry. Key points:

Table 1:

- Printer density has a positive coefficient and printer density squared has a negative coefficient, indicating that printer firm density first encourages entry and then ultimately discourages it – although the discouragement rarely occurs within the observable range of data.
- Engine density has a negative coefficient, which is surprising. However, when we distinguish between engine firms that sell in the market vs. engine firms that are captive to a downstream printer firm, this effect is entirely due to captive firms. One methodological twist: every captive engine firm also represents a vertically integrated printer firm. So one interpretation is that it is not engine firms per se that discourage entry, but rather vertically integrated printer firms. We look at that in Table 2.

Table 2:

- When we distinguish between integrated and non-integrated printer firms, we find that non-integrated printer firm density encourages entry while integrated printer firm density discourage entry. This is consistent with prior literature on the competitive effects of vertical integration. It is also consistent with our interpretation of engine density coefficients in Table 1 (note that the coefficient for engine density in Table 2 is never significant).

We then turn our attention to exit, with particular interest in different governance forms of suppliers and rivals. Please see Tables 3 and 4 for results of our estimations of exit.

Table 3:

- Engine firm density reduces the likelihood of exit by printer firms. This is most pronounced for engine firms that sell on the market rather than supply an in-house downstream printer division.

- Printer firm density increases the likelihood of exit by printer firms. Although the square term of printer firm density has a negative coefficient, the combined effect remains positive (i.e., increasing a focal firm's exit rate) throughout the observed range of data.

Table 4:

- The above-described competitive effect of printer firm density on exit is most pronounced for vertically integrated printer firms, indicating that vertically integrated rivals generate more intense competition for a focal firm than do non-integrated rivals.

We finally turn our attention to pricing. Figure 5 shows the evolution of price of non-integrated and vertically integrated printer models in select classes. Table 5 presents data on the pricing of printers that rely on a handful of Canon engine models. Table 6 presents statistical analyses.

Figure 5:

The figure appears to indicate that vertically integrated models are priced lower than non-integrated models, on average. Also, after a vertically integrated model enters a class, the average price of non-integrated models falls.

Table 5:

This chart shows the price of all printers that use particular Canon engine models. In classes 10 and 18, Canon prices its printers near 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.

Table 6:

- ClassClock has a negative coefficient, indicating that price in a class erodes over time.
- VIinClass has a negative coefficient, indicating that prices fall in a class after a vertically integrated printer model is introduced.

- VertIntegDummy has a negative coefficient, indicating that printer models that are vertically integrated into the engine have significantly lower prices than non-integrated models.
- Both of the LnTotalEnginesSold variables have negative coefficients. This may imply scale economies in engine production. More important, the vertical integration effect survives inclusion of these variables.

Discussion

Pretty cool, huh?

Conclusion

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Table 1: 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)
PrinterDensity	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)
$\text{PrinterDensity}^2/100$		-0.160 ***		-0.148 ***		-0.196 ***		-0.192 ***
		(0.040)		(0.041)		(0.043)		(0.043)
EngineDensity			-0.093 **	-0.050				
			(0.046)	(0.046)				
EngineSellSomeDensity					-0.059	0.019		
					(0.049)	(0.049)		
EngineSellAllDensity							-0.026	0.038
							(0.056)	(0.054)
EngineTaperedDensity							-0.148 *	-0.037
							(0.090)	(0.089)
EngineCaptiveDensity					-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

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Table 2: 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)
PrinterMakeDensity	-0.143 **	0.031		
	(0.061)	(0.102)		
PrinterMakeDensity^2		-0..029 ***		
		(0.010)		
PrinterMakeAllDensity			-0.132 *	0.049
			(0.071)	(0.112)
PrinterMakeAllDensity^2				-0.033 ***
				(0.012)
PrinterTaperedDensity			-0.182	0.206
			(0.136)	(0.322)
PrinterTaperedDensity^2				-0.324 *
				(0.175)
PrinterBuyDensity	0.054 ***	0.074 ***	0.056 ***	0.072 ***
	(0.016)	(0.025)	(0.018)	(0.028)
PrinterBuyDensity^2		-0.001		-0.001
		(0.007)		(0.001)
Engine Density	-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 3: 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 Density ----		----- Add Engine Density 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 Density	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 Density^2/100		-0.122 *		-0.076		-0.001		-0.000
		(0.070)		(0.073)		(0.085)		(0.084)
Engine Density			-0.141 **	-0.113 *				
			(0.057)	(0.063)				
EngineSellerDensity					-0.145 ***	-0.145 **		
					(0.055)	(0.060)		
EngineSellAllDensity							-0.167 **	-0.167 **
							(0.068)	(0.073)
EngineTaperedDensity							-0.086	-0.086
							(0.120)	(0.121)
EngineCaptiveDensity					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 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 Density -----

	(9)	(10)	(11)	(12)
Time piece 1	-6.429 *** (0.591)	-6.437 *** (0.727)	-6.431 *** (0.592)	-6.361 *** (0.711)
Time piece 2	-3.816 *** (0.356)	-3.816 *** (0.464)	-3.819 *** (0.352)	-3.732 *** (0.456)
PrinterMakeDensity	0.266*** (0.089)	0.174 (0.239)		
PrinterMakeDensity^2/100		0.722 * (1.926)		
PrinterMakeAllDensity			0.264 *** (0.100)	0.062 (0.286)
PrinterMakeAllDensity^2/100				0.021 (0.026)
PrinterTaperedDensity			0.274 * (0.170)	0.127 (0.420)
PrinterTaperedDensity^2/100				0.067 (0.166)
PrinterBuyDensity	0.054 * (0.025)	0.080 (0.064)	0.053 * (0.028)	0.105 (0.078)
PrinterBuyDensity^2/100		-0.074 (0.156)		-0.001 (0.002)
Engine Density	-0.201 *** (0.064)	-0.190 ** (0.078)	-0.199 *** (0.077)	-0.201 ** (0.088)
Firm Age	0.043 (0.049)	0.040 (0.050)	0.043 (0.049)	0.040 (0.050)
Firm Scope	-0.105 * (0.065)	-0.106 * (0.062)	-0.104 * (0.062)	-0.108 * (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 (1495)	
LBP-LX	1	1990	1545 (1545)	1249-1595 (1395)	1495-3299 (2382)
LBP-LX	1	1991	1545 (1545)	1249-1595 (1380)	1199-3299 (2201)
LBP-LX	1	1992	1249-1595 (1496)	1249-1595 (1380)	949-3299 (1970)
LBP-LX	1	1993	1249-1595 (1496)	999-1595 (1281)	949-2599 (1661)
LBP-LX	1	1994	1249-1595 (1496)	999-1595 (1158)	699-2599 (1724)
LBP-LX	1	1995	1249-1595 (1463)	999-1595 (1158)	699-2599 (1665)
LBP-LX	1	1996	1249-1595 (1463)	999-1595 (1158)	699-2599 (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 *** (23.00)	-360.21 *** (27.39)	-351.13 *** (27.57)	-671233 *** (218.93)	-650.35 *** (208.33)	-552.11 *** (185.77)	-621.98 *** (180.43)	-614.18 *** (178.53)
Class density (firms)		-6.79 (9.11)	-0..84 (9.35)	-1.07 (9.36)	-3.25 (9.28)	4.37 (9.23)	16.54 * (9.25)	17.13 * (9.25)
VI model in class			-995.50 *** (367.51)	-801.98 ** (390.47)	-651.83 * (388.89)	-458.63 (378.01)	-663.31 * (371.56)	-607.24 * (372.38)
VI clock				322.65 (218.98)	318.17 (208.47)	203.69 (185.49)	218.97 (179.84)	208.21 (177.93)
VI dummy					-924.49 *** (335.28)	-1276.09 *** (335.08)	-1048.39 *** (329.24)	-1127.43 *** (322.29)
VI dummy * VI clock					4.85 (47.21)	51.09 (47.16)	33.76 (46.40)	43.17 (46.71)
Ln total engines sold (mfr)						-79.28 *** (13.44)		-24.97 * (14.90)
Ln total engine sold (model)							-124.72 *** (12.54)	-114.21 *** (14.03)
Model info missing						640.66 *** (129.35)	-152.54 (152.99)	-93.89 (156.86)
Constant	6232.70 *** (555.37)	6255.04 *** (567.80)	6972.33 *** (620.03)	7171.79 *** (645.35)	7262.51 *** (583.05)	7697.69 *** (528.01)	8026.76 *** (507.10)	8177.15 *** (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

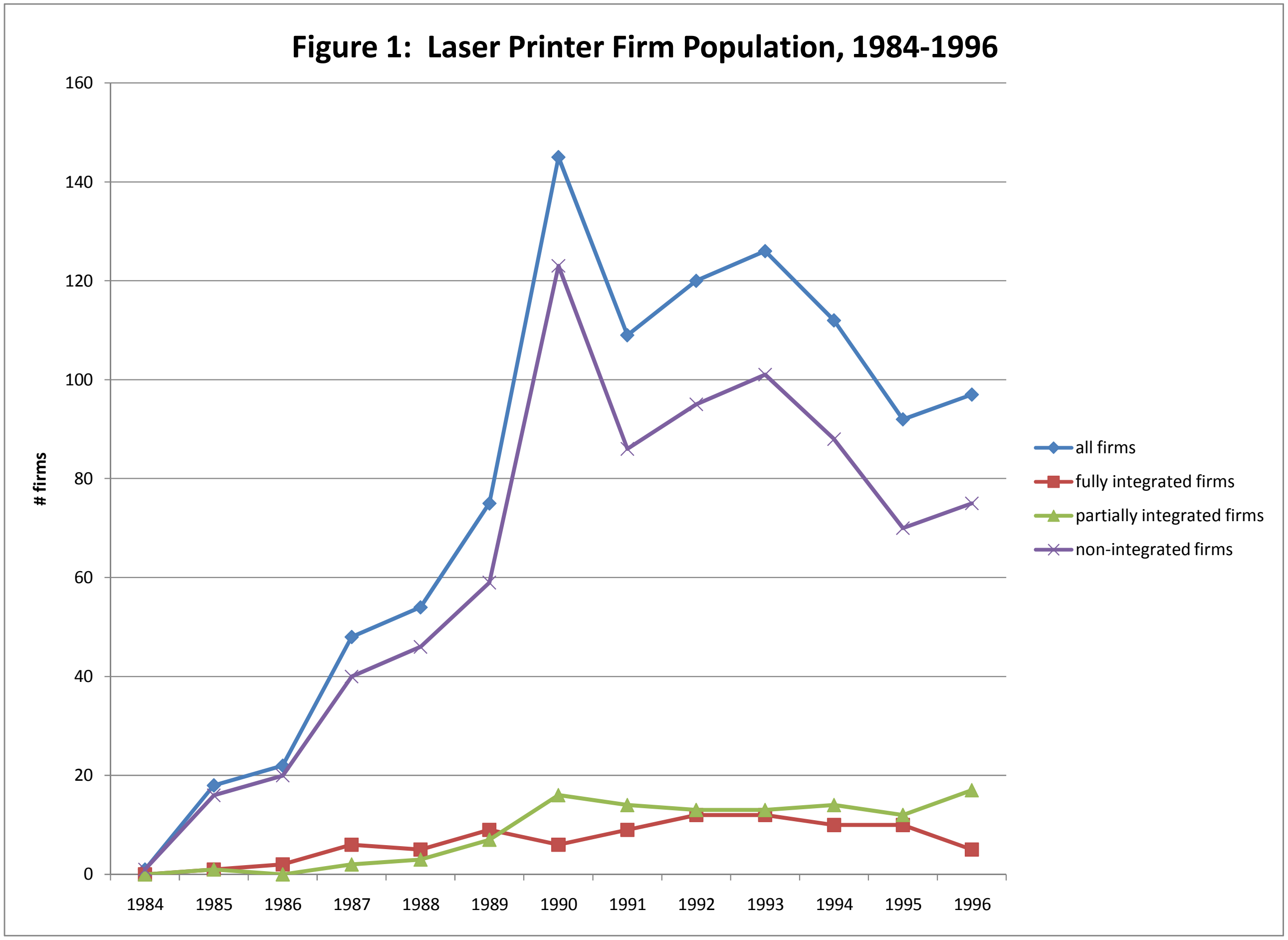


Figure 1: Laser Printer Firm Population, 1984-1996
firms
160
140
120
100
80
60
40
20
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
all firms
fully integrated firms
partially integrated firms
non-integrated firms

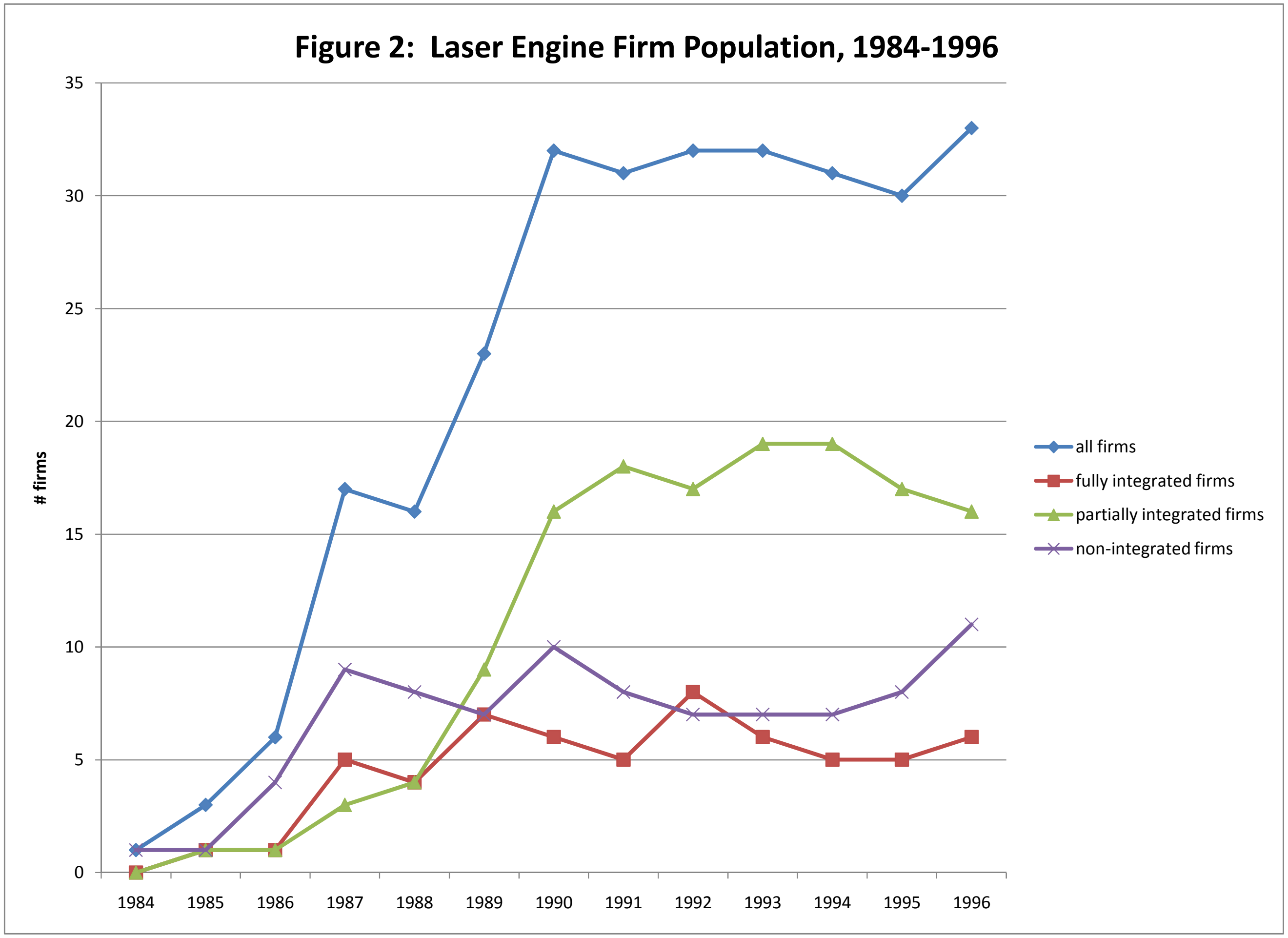
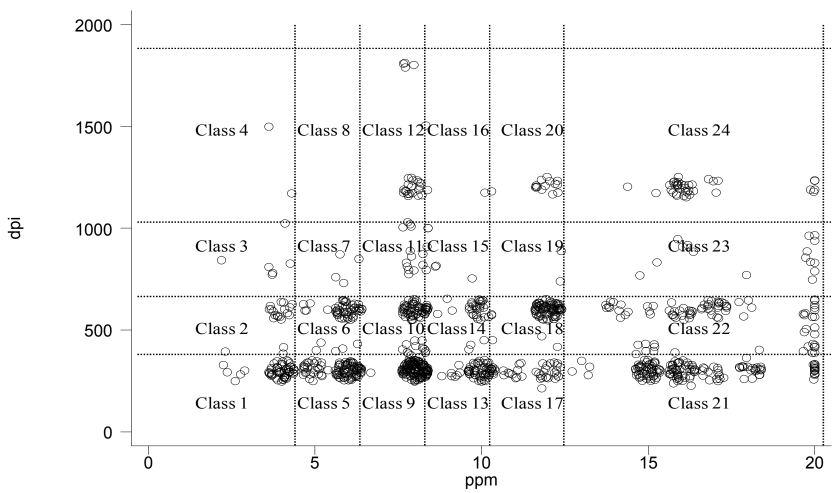


Figure 2: Laser Engine Firm Population, 1984-1996
firms
35
30
25
20
15
10
5
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
all firms
fully integrated firms
partially integrated firms
non-integrated firms

Figure 3: Product Distribution and Classes



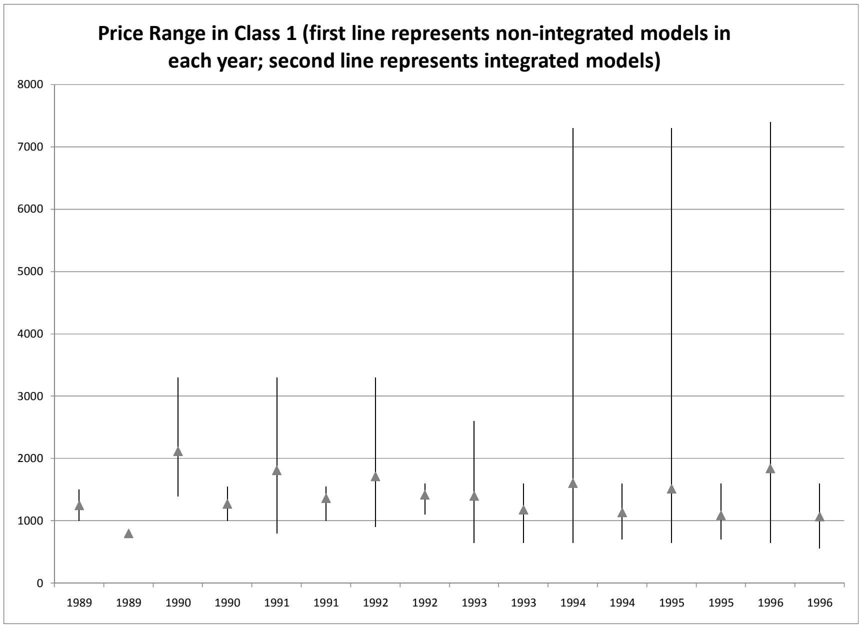
Note: Each small circle represents a printer.

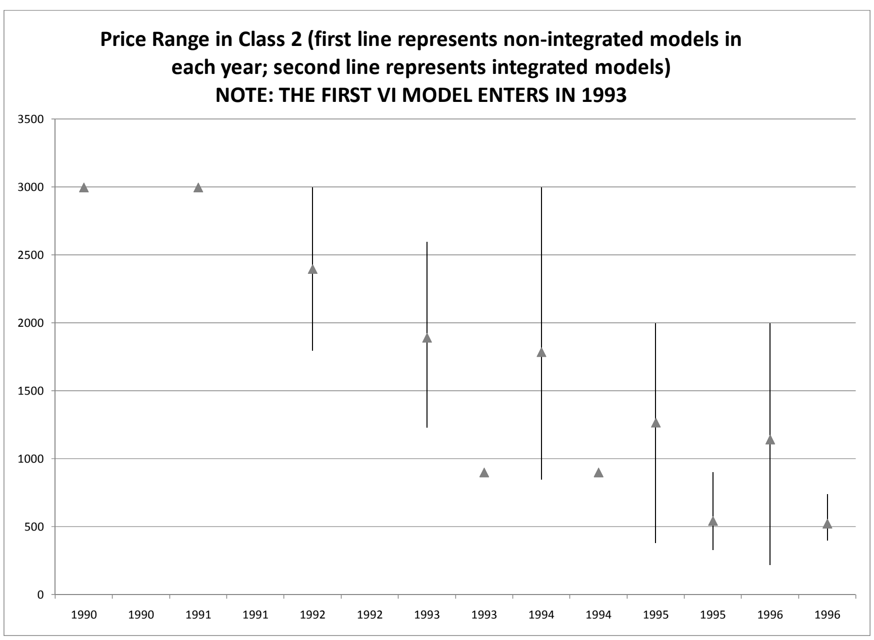
Figure 4: Pioneering firms in each class (printer firm/engine maker)

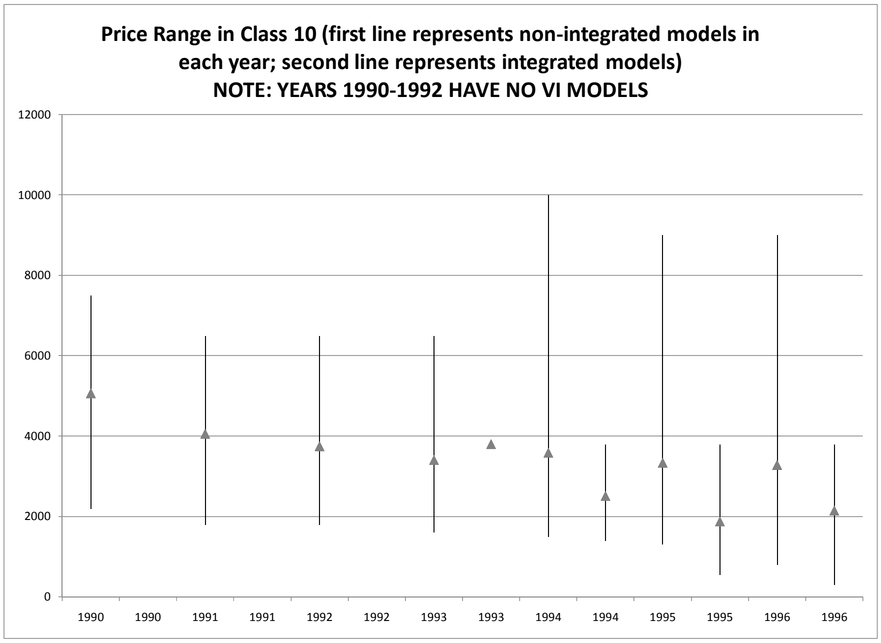
Blue: class was pioneered by non-integrated firm [classes 2, 3, 4, 9, 10, 12, 16, 17, 20, 24]
Pink: class was pioneered by vertically integrated firm [classes 6, 7, 11, 13, 14, 15, 19, 22, 23]
Orange: class was pioneered by non-integrated firm and vertically integrated firm [classes 1,5, 18, 21]

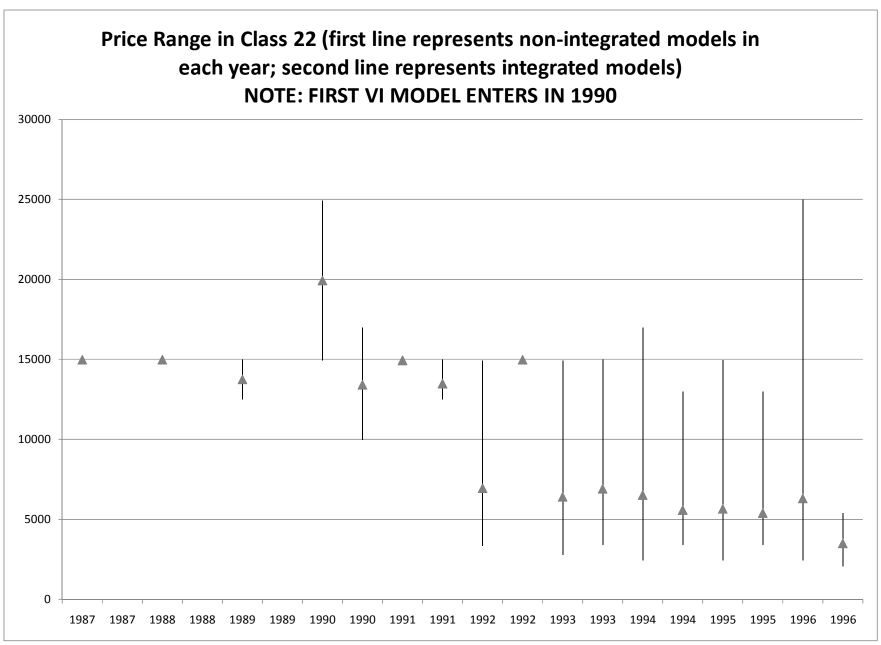
Class 4: 1993 XLI/Canon	Class 8: N/A	Class 12: 1990 Printware/Toshiba	Class 16: 1995 Genicom/IBM-Lexmark	Class 20: 1991 Printware/Fujitsu	Class 24: 1994 IBM/IBM Xante/Canon Calcomp/Canon
Class 3: 1991 Lasermaster/Canon	Class 7: 1995 OKI/OKI	Class 11: 1988 Printware/Printware	Class 15: 1996 Alps America/Alps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