The Adoption of Offset Presses in the Daily Newspaper Industry in the United States.

By David Genesove
Hebrew University of Jerusalem

Current Draft: January 10, 2000

ABSTRACT

This paper shows that the move to offset printing from letterpress in the U.S. daily newspaper publishing industry was determined, in part, by the structure of the local market. Although in monopoly markets, low circulation papers were quicker to adopt than high circulation papers, the ranking was reversed within duopoly markets. In such markets, the smaller firm is predicted to adopt four years later than the larger one did. This result is partially consistent with preemption models of adoption. Hazard analysis further shows that in markets in which one firm has exited, the remaining duopolist is less likely to adopt than otherwise, consistent with preemption, and at odds with a declining industry explanation. Further analysis shows that adoption was determined, at least in part, at the firm rather than the newspaper, level, although, on the whole, newspaper chains adopted neither earlier nor later than non-chain newspapers. Ceteris paribus, adoption occurred more quickly in non-industrial states.

Special thanks are due to production managers and executives at the *Boston Globe* for discussions and a tour of the plant. Comments by Adam Jaffe are gratefully appreciated. This paper was funded by the Project on Industrial Technology and Productivity of the National Bureau of Economics Research, with funding from the Alfred P. Sloan foundation.

I. INTRODUCTION

This paper considers the nature of technological adoption by examining the decision to invest in offset presses among newspapers from 1964-1977. In particular, it estimates the effect of the degree of competition on the adoption decision. The results are, in part, consistent with the theoretical literature on preemption. The newspaper industry is useful to study both because its product - the simultaneous provision of news and advertising to consumers on a daily basis - has remained essentially unchanged for many years, and because, in the United States, the markets are local, thus providing variation in market structure.

Until the 1960s, essentially all newspapers were composed by linotype and printed by stereotype and letterpress, both late nineteenth century technologies. The linotype machine cast metal slugs of each line of the newspaper; the slugs were then assembled in a galley, which would be used to create a cardboard impression on a mat. The mat was first curved to fit around a cylinder, then injected with lead and finally fitted around a press cylinder. Each rotation of the latter would impress the text on the newsprint.

In the early 1960s, a pair of new technologies began to diffuse throughout the industry. In photocomposition, the text is composed on a machine that projects the letters, and then photographs them. In offset printing, a plate made from the resulting negative is mounted on a cylinder, which is then immersed in ink. The ink is taken up by the exposed area only; these are transferred to a second, rubber-blanked cylinder which then transfers them to the newsprint (thus offsetting it). Both technologies had been developed outside of the industry, and first deployed in the book and pamphlet publishing industry.

These new technologies promised a number of advantages over the old. Photocomposition reduced the typesetting time initially by some 700 percent, and later, as it itself was improved, by several orders

of magnitude.[1] Its use eliminated the time and labor previously spent on positioning the types and plates for letterpresses, and the proper adjustment of the plates for impression (make-ready).

Offset produced a greater quality image, as one can achieve a much smaller dot, and so greater resolution, with offset than with letterpress (though that advantage has decreased over time, as letterpress has improved). Picture images were especially enhanced (Tripsas, 1996, p. 61); advertisers in particular liked offset printing. Although offset reduced preparation time for picture images (Tripsas, 1996, p. 61), overall it was a more expensive technology to use. The quality improvement was at the cost of more frequent downtime for the presses for cleaning, a three to five percent higher wastage of newsprint and ink costs that are from three to seven times as great (both due to more expensive ink and greater usage).[2] The additional newsprint and ink costs amounted to a ten percent increase in expenditure.

To sum up, photocomposition greatly reduced those costs that were fixed with respect to circulation, and variable with respect to pages; while offset led to higher quality at the expense of an increase in costs that were variable with respect to the product of circulation and the number of pages. Overall, the combined adoption of photocomposition and offset usually implied savings, not including the investment costs.

These two technologies are highly complementary. This was especially true where picture images were involved; letterpress technology required them to be "photoengraved as copper or zinc cuts,

---

[1] In practice, the labor saving in newspaper publishing was not necessarily as great. Employment in the *Boston Globe's* composing room fell from 500 employees in the early 1970s to 140 today. But much of the present day staff is clearly excess labor, and older workers who have guaranteed lifetime contracts.

[2] Editor and Publisher, April 9, 1966, and June 11, 1966.

and then mounted on wooden blocks" (Tripsas, 1996, p. 69), which was a lengthy procedure, whereas with photocomposition and offset, the photographic image could be easily combined with the image of the text, and then exposed on a printing plate. Furthermore, offset printing without photocomposition is very awkward, requiring "a series of elaborate and costly conversion techniques providing an equivalent of a photographic position from metal. Quality suffers as a result since positive type images are susceptible to irregular impressions." (Scott, p. 31). Indeed, offset presses were manufactured solely for use with photocomposition. However, there are substantial savings to photocomposition even without offset printing, and although trade articles in the 1960s often spoke of the two technologies interchangeably, many newspapers, especially the larger ones, initially adopted photocomposition without offset.[3]

Offset printing itself is, in fact, composed of two separate technologies: offset (the interposition of an additional, blanket cylinder) and lithography (the flat plate which uses the chemistry of ink and water to transfer the image). A hybrid system named Dilitho (for "direct lithography") promised to yield the higher quality of offset without the need for new offset presses. Although adopted by a number of the larger newspapers, overall it seems to have been a failure. It was apparently "too messy" a printing method. By 1999, only a couple of newspapers continued to use it. However, most installations of Dilitho, if not all, appear to have occurred after the period of observation, and so that technology will not play a role in the subsequent analysis.

Adoption of offset technology was, and remains, costly. Presses are long-lived investments, and can last from fifteen to

---

[3] See, e.g., Editor and Publisher, November 11, 1960 for an advertisement that explains to the reader how photocomposition can be used with letterpress.

forty years. They take some two years to install, in large part because of the need to install the new presses in a way that will allow the old ones to continue to operate. They are also costly. In 1972, an offset press for a paper with a circulation of 50,000 to 100,000, cost around 1.2 million dollars, or on the order of one-tenth of yearly revenues (Compaine, p. 130). Conversion costs would be another couple of hundred thousands of dollars.

In what follows, I will consider only the adoption of offset printing. This is not a reflection of the relative importance of the two. Photocomposition may well have been the more important of the two. Indeed, while newspapers were relatively early in the adoption of photocomposition,[4] among all printing industries, they were rather late in adoption of offset printing. (Scott, p. 30). Rather, the data for the adoption of offset printing is more readily available than that for photocomposition.[5]

II DETERMINANTS OF ADOPTION OF OFFSET PRINTING

The first U.S. newspaper to move to offset was the *Opelousas Daily World*, a small newspaper in Louisiana, which started printing by offset in 1939 (Featherston, 1977). Perhaps in part because it still relied on the old typesetting technology, and not photocomposition, it had no imitators for the next twelve years. Appreciable adoption of the technology did not begin until the early 1960s. By 1964, the first year that Editor and Publisher International Yearbook lists the "offset" newspapers, about 6 percent of newspapers were using offset. Thereafter, about seventy

---

[4] Photocomposition was first used for telephone directories, and in fact was designed with that use in mind.

[5] See Dertouzos and Quinn for an analysis of the adoption of photocomposition and video display terminal. They use a somewhat different time period (1972-1982 and 1979-1982, respectively), and a much smaller sample of 200 firms. They do not consider the degree of competition in the market.

newspapers a year moved to the new technology. By 1977, the fraction of adopters had increased to two-thirds (See Figure 1). (By 1999, twenty-two years after our sample ends, 93% of daily newspapers were printing by offset, 3% by letterpress, and most of the remainder by the new flexographic method.)

The clearest pattern in adoption is in newspaper size, as measured by circulation. Smaller newspapers adopted much earlier than larger ones, as Figure 2, which shows the median adopter size, by year, indicates. For example, in 1965, the highest circulation paper printing by offset was the *Oklahoma Journal*, with a circulation of about 71,000; the second highest had a circulation of some 40,500. The *New York Times* only announced its move to offset printing in 1977, and did not do so until 1979. The *Boston Globe* only moved to offset twelve years ago (although it had adopted Dilitho before that); and before 1977, the largest offset newspaper was the *St. Louis Dispatch* (circulation 267,000).

The delay in adoption by large newspapers was necessarily driven, at least in part, by the technological limits of the new offset presses, which ran much more slowly than the existing letterpresses. The first newspaper offset press manufactured by Gross, in 1960, the leading offset press manufacturer, had a rated maximum speed of 12,000 papers per hour (Editor and Publisher, April 1960). This is far below the requirements of a large newspaper, with say a circulation of a few hundred thousand, and five hours in which to print them. (The *Boston Globe*, which has a 10:30 p.m. deadline, tries to publish in this time frame today, so that its delivery trucks can leave the plant before dawn.) In principle a large newspaper could have substituted many offset presses for a few letterpresses. However, there are substantial costs that are variable with the number of presses but fixed with the respect to the output of each, principally the wages of the pressmen and the maintenance workers, so that this approach would not have been

profitable. Furthermore, a press run at the maximum speed would produce a much lower quality paper; the actual speeds at which presses were operated at were perhaps as much as forty percent less.[6]

As times passed, more and more newspapers were "eligible" for offset printing. In 1963, Gross was manufacturing a 30,000 paper per hour offset press. In 1970, it offered a press with a maximum speed of 60,000 papers per hour. Still, letterpress was faster. In that same year, Gross offered a letterpress with a speed of 80,000 papers per hour. Aside from the technological limits, offset was relatively more expensive to operate than letterpress, given the higher newspaper wastage rates and ink expenditures.

A natural presumption would be that the larger papers were thwarted in the move to the new technology by powerful unions. Newspapers have since the end of the last century been highly unionized, and management must negotiate with several unions simultaneously. Even today, The *Boston Globe*, for example, has some seventeen unions, of which it must negotiate contracts with twelve. At the time, unions often had substantial jurisdiction over job definition.[7]

The role of unions *may* have been important in the adoption of photocomposition. That technology was a threat to unions since it dramatically decreased the number of workers required, and thus provided a substantial cost saving to management, given the high union wages earned. Indeed, under the old technology "the composing room [was] likely to exceed the cost of any other department"

---

[6] Editor and Publisher, September 8, 1962, p. 54. The 40 percent figure is offered by the Vice-President of a company that sold offset presses. In the early years of the technology, offset plates did not last long, and so could only be used for short press runs. However, this was essentially solved by 1960 (Editor and Publisher, July 1960, p. 12).

[7] Since then, many newspapers, such as the Globe, have won full rights to reassign workers, in return for lifetime job guarantees.

(Davidson and Roy, 1960, p. 787-8.) A related concern to the union was the elimination of both their members' intrinsic skills (i.e., the strength to move massive galleys) and their accumulated ones. Compaine (1980) blames unions for the reluctance of newspapers in major cities to move to "cold-type" before 1976. Photocomposition did precipitate a general strike among newspaper workers in New York in the early 1960s,[8] and one sees in the Typographical Journal, the union magazine of the International Typographical Union, resistance to the new technology during this period.

However this explanation does not necessarily carry over to offset printing. The relevant union there was the International Printing Pressmen and Assistants Union (IPPAU). It was, in general, sympathetic to the new technology, having fought for jurisdiction over it within the AFL-CIO since 1913 (The American Pressmen, February 1960, p. 21) and maintained a center for training in the use of the technology for its members for some time. In contrast to the articles about photocomposition in the Typographical Journal, those in the American Pressmen were quite positive about the new offset technology.

III COMPETITION AND TECHNOLOGICAL ADOPTION

Our main interest in this paper is on the effect of competition on the speed of technological adoption. One would expect the first firm in a duopoly to adopt to do so at an *earlier* date than a similarly sized single-newspaper monopolist. First, compared to a monopolist with the same circulation, a duopolist has a greater

---

[8]Dertouzos and Quinn (1985) report that "[i]n 1964, the *New York Times* and the *Daily News* purchased the latest generation of computer equipment, an IBM Model 1620, only to encounter stiff opposition from the powerful ITU Local Number 6. Both units sat idle in basements until long after they had become technologically obsolete."

stand-alone incentive (Katz and Shapiro, 1987). This is the payoff from adoption when the rival firm can not also innovate. Whereas both the monopolist and the duopolist benefit from the increased willingness to pay of their existing customers, the duopolist will also be able to steal away some customers from its rival. Second, a duopolist has a *preemption incentive* to innovate before its rival does. This incentive arises out of the loss in flow profits (principally, market share) from prior adoption by the rival. Fudenberg and Tirole (1985) have shown that the preemption incentive leads to earlier adoption than under monopoly situations.[9]

In contrast, the second firm to adopt in the market is likely to do so *later* than a similarly sized monopolist. In the simplified models of Fudenberg and Tirole (1986) and Tirole (1992), where because of Bertrand competition the gain to adopting second is zero, the second firm in fact never adopts. In the more general model of Riordan (1992), where duopoly profits when both firms have adopted are potentially positive, the second firm adopts late because the increase in flow profits as a second adopter is less than the increase obtained as a first adopter. That is an assumption of the model, but it would seem appropriate for the newspaper market, if consumers' reading habits are habitual, i.e., there are switching costs. The improvement in quality inherent in offset may be sufficient to offset these switching costs, so that the first adopter draws readers away from the other firm - but these costs might still be large enough to deter these readers (and new readers) from returning to the other firm when it, too, adopts.

One can also ask which firm is likely to adopt first. Clearly, the smaller firm has a stronger stand alone incentive. Because of its

---

[9] Fudenberg and Tirole (1985) also find a "late adoption" equilibrium, but this is only possible when response is immediate, an inappropriate assumption for an environment in which installation of the new technology takes two years.

smaller circulation level, its adoption costs are lower. Furthermore, as it starts from a smaller market share, it has a greater opportunity to increase it through adoption.[10] However, the larger firm probably has the stronger preemption incentive. The logic is similar to that of Gilbert and Newberry (1982), who show that the gain to a monopolist of winning a patent race is greater than the gain to an entrant whose win of that race would destroy the monopoly. So long as industry profits are greater when the larger firm is the only adopter than when the smaller firm is the only adopter, the former will have the greater preemption incentive.[11]

Thus, the possibility arises that the preemption incentive will be greater for the larger firm, and sufficiently greater than it predominates the stand alone incentive, so that the large firm will adopt first.

Although the empirical literature on the relationship between *innovation* and market structure is quite large, the literature on the relationship between *adoption* and market structure is small. Joskow and Rose count as a virtue that the electric utilities they are examining are regulated monopolists, so that strategic considerations can be abstracted from. In examining the diffusion of oxygen burning furnaces, Oster works within the single market of steel with no attempt to define geographic or product sub-markets that might exhibit variation in structure. Stoneman and Karshensas attempt to measure these effects by the stock of previous adopters. However,

---

[10] This is a generalization of Arrow's (1962) replacement effect.

[11] Vickers (1986) provides a Cournot example in which the small (i.e., high cost) firm has the greater preemption incentive to adopt a cost-reducing technology. However, in that model, adoption is always to the frontier technology, so that marginal cost for the adopter is the same regardless of its position before adoption. An analogous assumption in the present case would have offset not only increasing the physical quality of the paper, but also eliminating any other disadvantage of the small paper that gave it a smaller market share to begin with.

although they are ostensibly interested in testing models of adoption under oligopoly, their defined markets include, on average, about a hundred firms. Of course, the vast literature on adoption of new hybrids and technology in agriculture (e.g., Grilliches, 1957) concerns a competitive market.

One exception to this general pattern of neglect is the research on the installation of Automated Teller Machines (ATMs). Hannan and McDowell (1984, 1987) include among their regressors the three firm concentration ratio at the county or SMSA level. Their various regressions indicate that adding a fourth, equal-sized firm to a three-firm market would increase adoption time by twenty to sixty percent. They also show that prior adoption increases the hazard rate of adoption among the surviving non-adopters by about a third. The first result is generally consistent with my findings, while the second is not. However, given the network characteristic of ATMs may make this case an inappropriate one for generalization. Working with a subset of the same data, Saloner and Shepard also find that adoption is faster in more concentrated markets (measured, in their work by a state-wide Herfindahl Index), but attribute that to the greater internalization of network effects in such markets.

IV. DATA

The primary data for this project are derived from the yearbook of *Editor and Publisher*, an industry trade weekly. It publishes a yearly listing of newspapers, that details circulation, advertising price, circulation price and mechanical specification. I use 1960 values for the independent variables. Offset status for the years 1964-1977 are taken from yearly listings of newspapers that adopted the technology that Editor and Publisher published for those years. Offset status for later years are available from the mechanical specifications given for each newspaper, but they are more time consuming to transcribe and input, and are not used in this draft.

Later years also introduce the complication of the adoption of the Dilitho process will enter, although that could be handled within a competing hazard framework.

Pressmen status is taken from listings of the newspaper chapels of the International Pressmen and Pressmen's Assistants Union (IPPAU) in The American Pressman, the union's official journal.

In cases where two newspapers are owned by the same firm, I assume that they are printed on the same press. The assumption is necessary since in certain years, Editor and Publisher seem to list only one of the two papers, and in other years, they list both. In the mechanical specifications, only one description of presses and other equipment is given for both newspapers. This suggests that both newspapers are, indeed, printed on the same press. Occasionally, however two types of presses are listed, and it is impossible to know whether presses are dedicated to particular newspapers or not.

One must also decide how to measure circulation where two newspapers in a given market are published by the same firm. The appropriate measure depends on the manner in which high circulation thwarted adoption. Recall that offset required more expensive ink and entailed higher wastage of newsprint, thus increasing variable costs. Obviously, if this was the dominant impediment to adoption for high circulation firms, than the appropriate measure would be the sum of the two newspapers' circulation.

Another reason that large newspapers were late to adopt was the slowness of the offset presses. Here the appropriate measure depends upon the degree of rivalry (in the private/public good sense) in printing the two newspapers. Were the two newspapers printed on different presses, clearly one would want to measure circulation as each newspaper's circulation. Were they printed on the same press (which I am assuming, and seems usually to be the case), one might still want to use this measure, if, say, the printing of an evening

paper does not increase the cost of printing a higher circulation morning paper. But to the extent that there is a substantial required down-time for presses, as for maintenance, using the sum of the circulation of both newspapers would be appropriate. I will presents results primarily under the specification of the sum of the circulation, but will also show how they change when individual circulation numbers are used instead.

Table 1 lists the number of observations for each market structure. The vast majority is single newspaper markets. There are 124 duopolists, representing 62 markets, and 193 two-newspaper monopolists, representing the same number of markets. I use one observation for each two-newspaper monopoly market, since the value of the dependant variable is identical for both newspapers in such markets.

Table 2 presents summary statistics for the remaining variables. Average log circulation corresponds to a circulation level of about 11,000; at about 9,500, the median circulation level is somewhat less, and observations range from a circulation of 400 to almost half a million. Some 40% of newspapers belong to a chain, the largest of which had (in 1960) eighteen newspapers. Only 4 percent of newspapers were in markets with newspaper locals of the IPPAU.

V. ESTIMATION

Because not all newspapers adopt offset during the 1964-1977 period (or ever - the *Chicago Tribune*, for example, has never done so), and others close down, or merge, before ever adopting, some method for handling the censoring must be used. I assume a latent variable indicating adoption year in the absence of these censoring events, and assume that the error term, representing the difference between this latent variable and its expected variable conditional on a set of independent variables, follows a normal distribution. This leads to the log-likelihood function:

$$(1- L_i - R_i)f(y_i-bx_i/s)/s + L_i\ln F(y_i-bx_i/s) + R_i\ln[1-F(y_i-bx_i/s)]$$

where y_i is the date of adoption or censoring of observation i, x_i is the vector of independent determinants, b is a conformable vector, s is the standard deviation of the uncensored error term, f is the standard normal p.d.f., F is the standard normal c.d.f, L_i is a dummy variable equal to one if the newspaper had adopted by 1964 (as no pre-1964 information on offset use is available, and R_i is a dummy variable equal to one if (a) y is right censored, or (b) the newspaper merged with a rival that had already adopted offset or (c) ceased to publish before adoption.[12] In the case where papers merge before either had adopted offset, both observations were considered as having adopted in the year that the merged firm did adopt.

Table 3 shows the results. Column (1) includes the basic market structure variables, and log circulation (measured as the log of the sum of circulations for two-newspaper monopolists). As to be expected, high circulation papers are shown to adopt later: a paper with a circulation of 100,000 will adopt some six years later (ln10 times 2.5) than a paper with a circulation of 10,000, and a million circulation paper will adopt another six years after that. Holding circulation constant, a single-newspaper monopoly is shown to adopt earliest. Two-newspaper monopolies adopt a year later, although the difference is insignificant. In contrast, a duopolist adopts almost three years later than a single-newspaper monopolist. At almost six years, the standard error of the equation is large, if one recalls that two-thirds of all newspapers moved to offset printing in slightly more than twice that time.

---

[12] In principle, the log-likelihood specification should allow for correlation between two duopolists in the same market. The log-likelihood function will be thus amended in future drafts.

To check the sensitivity of the results to the definition of the circulation variable in two-newspaper markets, column (2) uses the alternative specification of the average of the two newspapers' log-circulation. The major effect is an increase in the coefficient on two-newspaper Monopoly status - hardly a surprising result, given that the new specification decreases a variable with a positive coefficient only in the two-newspaper Monopoly case. Now, the two-newspaper monopolist is predicted to adopt almost three years later than a single-firm monopolist, and the difference is significant. No conclusions can be drawn without some evidence on the degree to which presses are dedicated to specific newspapers, although my sense is that the specification in the first column is to be preferred. Nonetheless, this column is useful as it shows the robustness of the remaining estimates to the specification choice. As it is always the case that only the coefficient on the two-newspaper monopolist dummy is effected by the specification change, I will only report results using the first specification from here on in.

Of course, markets with either a duopoly or two-newspaper monopoly are otherwise different from those with a single-newspaper monopoly; the former are typically bigger. I capture the size of the market by the log of the total circulation of the market. This proxy is appropriate so long as circulation price does not fall too much with the introduction of a second firm and demand is not too elastic with respect to that price. The first condition has been shown to be true in related, but as yet unpublished, research, and the second seems reasonable. (Measures of county population and income are immune from this endogeneity problem, but I have been not been able to obtain those data in electronic form for 1960 yet; I have used the 1969 data and the results are very similar to those using the log of total circulation, although matching difficulties reduce the size of the sample substantially.)

With the inclusion of the log of total circulation in column (3), the coefficient on duopoly falls to less than two additional years, and is insignificant from zero. The coefficient on two-newspaper monopoly is unchanged from column (1). However the coefficient on log total circulation itself is insignificant.

Column (4) substitutes a finer measure of competition, DUOHHI=DUO*(1-HHI)*2, where DUO is the duopoly dummy, and HHI is the Herfindahl index, using the share of each newspaper's circulation. This variable ranges from zero, for a non-duopoly or a duopoly with a negligible second firm, to one, for a symmetric duopoly. The results are quite similar to the other columns.

To explore further the nature of the adoption lag in duopoly markets relative to single newspaper markets, column (5) introduces a dummy variable for the smaller firm in a duopoly. Thus the smaller duopoly firm is estimated to adopt later than a single-newspaper monopolist by the sum of the coefficient on that variable and the coefficient on duopoly status. The result is quite dramatic. The smaller firm in a duopoly is estimated to adopt some 5 years later than a similarly sized monopoly firm, while the larger firm is estimated to adopt at the same time as its single-newspaper monopoly counterpart. These results are not effected by the inclusion of log -total circulation in column (6)

In fact, these numbers predict that the smaller firm will, on average, adopt *later* than the larger firm, given that the difference in log circulation is, on average, .8, and the coefficient on the log circulation is 2.5.[13] The raw numbers are in support of this contention. Figure 3 shows the Kaplan-Meier estimate of the survival

[13] I have also considered whether the degree of competition as measured by whether the two duopolists are competing head to head (that is, both are morning or both are evening newspapers) matters, by separately categorizing duopoly markets accordingly. It does not.

curves (the percentage of newspapers who have yet to adopt by a given date, given they have not exited the industry) for duopolists. That of the smaller firm almost always exceeds that of the larger firm. Likewise, a censored regression estimation restricted to the set of duopoly markets predicts that the smaller firm will adopt four years later.[14]

Clearly, then, technological or demand considerations are not the sole determinant of adoption. Market structure also plays a role. How do these results compare to the theoretical predictions of preemption? Neither the large nor the small firm are predicted to adopt earlier than their monopolist counterpart, although the standard error on Duopoly in Column (6) is sufficiently great that a lead of nine months over adoption by a single-newspaper monopolist can not be rejected at the five percent level. That the small firm adopts, on average, later is consistent with a strong preemption incentive on the part of the larger firm.

An alternative explanation is that the continuation of a second newspaper in any market was in doubt throughout this period. The 1960s and 1970s saw a decline in the number of duopolies. A single-newspaper monopolist could be relatively assured of continuation in the market. But a duopolist would have been afraid that it might have to exit the market (the number of duopoly markets was halved over our time period), and that would especially be true of the

---

[14]The censored regression is
Y= 49.6 + 5.4Small Duopolist+ 2.8ln(Circulation)
(7.5) (2.1) (0.71)
(N=124, log-likelihood=-142.6). The average and median difference between the predicted adoption time of the small firm and the large firm is 3.4 and 4.1, respectively. Furthermore, in only 4 of the 62 duopoly markets is the small duopolist predicted to adopt earlier.

smaller of the two firms.[15] There is a resale market for presses, but it is far from perfect. (The *Boston Globe* sold some of its presses to the *Boston Herald* when it moved to offset, and junked others).

The preemption and declining industry explanations can be distinguished by considering how the exit of one of the two duopolists effects the adoption decision of the remaining firm. To check that, the model was re-estimated by Cox's partial likelihood method, assuming a proportional hazards model with time varying covariates. The results are presented in Table 4. Column (1) repeats the analysis of the preceding table in a hazard framework (all variables are measured at their 1960 values). These results are qualitatively the same as those presented earlier. For example, higher circulation is shown to lead to a lower hazard rate of adoption, equivalent to a higher expected time to adoption. Also, the small duopolist has an adoption hazard that is only .24 (= .6 X .4) that of a single newspaper, which implies, under a constant hazard assumption, an expected lag of four years.

In column (2), an additional variable, "Former Duopoly" is added. This takes the value one for a market that had two independent newspapers in 1960, but presently has only one newspaper due to the (non-merger) exit of one of the firms.[16] The estimate indicates that a duopolist that has yet to adopt is *less likely* to adopt if its rival has exited, but the coefficient is insignificant.

---

[15]Related work shows that whereas in 1972 the one-firm and two-firm entry-threshholds (Bresnahan and Reiss, 1991) were population levels of 63,000 and 997,000, respectively, in 1982 they were 70,000 and 1,797,000, respectively. Here n-firm entry-threshholds are calculated as the population level at which the probability of there being n or more firms (calculated from kernel regressions) is one-half.

[16]Others are no more than two observations in which merger by exit has occurred, per year, and so no corresponding variable was defined.

The effect becomes marginally significant (at the 13 percent level) when "Prior Adoption", a dummy variable that takes the value one if their has been a prior adoption in the market, is included in Column (3). (Clearly this variable can only take the value one in the case of a duopoly.) This is inconsistent with the declining industry explanation: once the rival is gone, the remaining firm, more certain of its continued survival, should be more willing to undertake costly investment. It is consistent with a preemption explanation: with the exit of the rival, the preemption incentive is eliminated, and adoption is slower.

"Prior Adoption" itself predicts a smaller hazard of adoption, and is highly significant. This is consistent with preemption stories - the loser in the adoption race adopts later than it would otherwise.

VI. OTHER RESULTS

Table 5 considers other determinants of adoption. Column (1) adds a dummy variable for whether or not a chapel of the IPPAU existed in the market. The coefficient has an insignificant negative sign.[17]

The next couple of columns investigate the effects of membership in a newspaper chain. There are a few reasons why one might suspect this to be relevant. Larger firms might be more or less eager to adopt new technology: more, if they are greater resources to do so, less if they are more bureaucratically hidebound or there are problems in coordination. The associated technology of photocomposition also allowed composition to be physically separated from printing (because of the elimination of the huge metal galleys)

[17]Compare Dertouzos and Quinn who find that unions have an insignificant effect on adoption of photocomposition and video display terminals.

which allowed the printing of several newspapers composed elsewhere in one plant. However, this may have been more relevant for commonly owned weekly newspapers, than daily ones.

Column (2) adds a dummy variable for membership in a chain, defined as a group of newspapers serving at least two markets and owned by the same firm. It has an insignificant effect. Column (3) adds the number of newspapers in the chain. The variable is insignifcant on its own, and jointly insignificant with the Chain dummy (p-value = .19). Column (4) uses a set of chain dummies, with the omitted dummy corresponding to those newspapers that are not members of a chain. This allows us to test the weaker hypothesis that the chain to which a newspaper belongs matters in some undefined manner. The log-ratio test statistic for the exclusion of all 117 chain dummies is 198 with 116 degrees of variables, and so highly significant. Thus either there are unobserved determinants that are shared by commonly owned newspapers, or, more likely, the adoption decision was taken at the firm level - with no greater or less inclination towards adoption by chains, large or small.

One would also like to know whether there are technological spillovers in adoption. Henderson, Jaffe and Trajtenberg (1993) have shown that patents tend to cite other patents whose originators reside in the same area. Geographical spillovers in adoption should be revealed by geographical clustering of initial adopters. The newspaper industry is an ideal one to examine this issue as the adopting industry is widely dispersed (more or less in proportion to population) and complementary inputs are not location specific. The knowledge spillover in this case would probably not have been the availability of offset - that would have been clear to anyone even

occasionally reading the trade press - but the opportunity to see offset work in practice.[18]

Estimating spatial correlation in the presence of censored variables is a difficult task. As a first approximation, I simply add state dummies to the basic specification in Column (5). These are significant at the six percent level, with log-likelihood ratio test of 66, with 50 degrees of freedom. The estimated coefficients are shown in Table 6. There is a tendency for newspapers in non-industrial states, such as Alaska, Georgia, Oklahoma, South Dakota, Alabama, Kansas, Vermont and Mississippi to adopt offset earlier than one would otherwise predict, although Ohio is also an early adopter.

Spatial diffusion is still a possible explanation. One would expect adoption to begin in those states where newspapers have a greater incentive to adopt on their own, and these states (including Ohio) are characterized by small newspapers. To model this process, I allow the latent adoption time to depend not only on the market structure and other determinants discussed above, but also on the mean latent adoption time of other newspapers in the state. Thus

$$y^*_i = X_i b + c\mathbf{y}_i^* + e_i = X_i b + c(\mathbf{X}_i b) + \{c\mathbf{e}_i + e_i\}$$

where a bold script indicates a mean taken over all observations in i's state, other than i itself. The parameter c measures the effects of spillovers. The results of this estimation are presented in

[18] One way that technology diffuses through an industry is through plant visits by managers of other, even competing, firms. The *Boston Globe* executives to whom I spoke had just returned from a visit to the *Washington Post*, to see the new technology being installed there. They also claimed to have exchanged technical information with the *Boston Herald*, and to have provided, and have been provided with, technical assistance in emergency systems to the competing firm.

column (7) of Table 5. It is clear that there is little evidence that spillovers, if they exist, operate in that fashion.

Finally, Column (6) includes both sets of dummy variables. The basic findings on the market structure variables and circulation are unaffected by their inclusion. Now the chain dummies are insignificant (p-value = .19) and the state dummies only marginally so (p-value = .11).

VII. CONCLUSION

The work described in this paper is very preliminary. Future work will extend that discussed here in a number of ways.

First, the specification followed in this paper measures chain membership and circulation at their 1960 values. But the 1960s and 1970s saw a rise in chains. Although circulation remained relatively constant, it would have fluctuated for individual newspapers. Hazard estimation with time-dependent covariates can handle this temporal variation. This approach has its own limitations, as it assumes that all events subsequent to 1960 are not determined by future offset adoption. The other major disadvantage with the hazard approach is the much greater data requirements.

The linear specification is inappropriate because certain firms could not have adopted the technology before a given data. Thus, in the language of hazard functions, certain newspapers are not in the "risk set" in a given year. Of course, that reasoning follows a technological push, rather than pull, perspective. But given that the technology and its refinements originated outside of the industry (the press manufacturers), and were first applied in yet another (commercial printing), that seems a not unreasonable working assumption.[19]

---

[19]Scott, 1987, p. 30.

Second, it would be interesting to see whether other technological adoptions follow the same pattern as that uncovered here. Photocomposition is the obvious candidate, although finding adequate measures for its adoption has so far proved elusive. The complementarity between the two technologies can perhaps be captured in a hazard analysis by including an indicator of past adoption of the other technology in the hazard specification.

Third, I have begun to link the database created for this paper to the Census Bureau's Longitudinal Research Database (LRD), specifically, establishments classified under SIC Code 2711-11. This will allow me to use financial status, as measured by current and past profit flows (Total Value of Shipments minus Costs), and technical efficiency, as measured by newspaper costs/(circulation times the number of pages), as independent determinants of adoption. This will allow me to address an additional explanation for the market structure results, that investment is constrained by cash flow and that duopolists (especially smaller ones) were less profitable than monopolists were. The LRD also provides indirect measures of offset adoption through reports of the types of inks and plates used by the establishments.

REFERENCE

Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Inventions" in **The Rate of Return of Inventive Activity**, ed. by R. Nelson, Princeton University Press, 1962.

Bresnahan, Timothy and Peter Reiss, "Entry and Competition in Concentrated Markets", **Journal of Political Economy 99** (1991) 977-1009.

Compaine, Benjamin M. **The Newspaper Industry in the 1980s: An Assessment of Economics and Technology.** Knowledge Industry Publications, Inc., White Plains, N.Y. 1980.

Davidson, Sidney and Robert H. Roy, "A Case Study in Newspaper Operations" in **Operations Research and Systems Engineering**, ed. by Charles Flagle, William H. Huggins, and Robert H. Roy (Baltimore: The John Hopkins Press, 1960.)

Dertouzos, James N. and Timothy H. Quinn, "Bargaining Responses to the Technology Revolution: The Case of the Newspaper Industry", unpublished monograph prepared for the U.S. Department of Labor, Rand Corporation, January 1985.

Featerhston, James S. "Making Offset History in Opelousas", Journalism Quarterly, Summer 1977, 368-371.

Fudenberg, Drew and Jean Tirole, "Preemption and Rent Equilization in the adoption of New Technology**", Review of Economic Studies: 52** (1985) 383-401.

Fudenberg, Drew and Jean Tirole, **Dynamic Models of Oligopoly**, Harwood Academic Publishers, New York, 1986.

Gilbert, Richard and David Newberry, "Preemptive Patenting and the Persistence of Monopoly", **American Economic Review 72** (1982) 514-526.

Grilliches, Zvi, "Hybrid Corn" An Exploration in the Economics of Technological Change", **Econometrica 25** (1957) 501-522.

Hannan, T.H. and J.M. McDowell, "The Determinants of Technology Adoption: The Case of the Banking Firm", **RAND Journal of Economics**, **15** (1984) 328-335.

____ and ___, "Rival Precedence and the Dynamics of Technology Adoption: An Empirical Analysis", **Economica**, **54** (1987) 155-171.

Henderson, R.,7 A. Jaffe and M. Trajtenberg. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations". **Quarterly Journal of Economics**, 1993.

Karshenas, M. and P. Stoneman, "Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model", **RAND Journal of Economics**, **24** (1993) 479-502.

Katz, Michael L. and Carl Shapiro, "R&D Rivaly with Licensing or Imitation", **American Economic Review 77** (1987) 402-420.

Mooney, J. Printers in Appalachia: **The International Printing Pressmen and Assistants' Union of North America, 1907-1967**, 1993.

Oster, S. "The Diffusion of Innovation among Steel Firms: The Basic Oxygen Furnace," **Bell Journal of Economics**, **13** (1982) 45-56.

Reingenam, J. "On the Diffusion of New Technology: A Game Theoretic Approach", **Review of Economic Studies**, 48 (1981) 395-405.

Saloner, G. and A. Shepard, "Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines", **The RAND Journal of Economics**, **26** (1995) 479-501.

Riordan, Michael. "Regulation and Preemptive Technology Adoption", **RAND Journal of Economics**, Autumn 1992, 334-349.

Rose, N. and P. Joskow, "The Diffusion of New Technologies: Evidence from the Electric Utility Industry**", RAND Journal of Economics, 21** (1980) 354-374.

Scott, Daniel T. **Technology and Union Survival: A Study of the Printing Industry**. Preager 1987, New York.

Tirole, Jean. **The Theory of Industrial Organization**, MIT Press, Cambridge MA, 1994.

Tripsas, Mary. **Surviving Radical Change: An Empirical Study of the Typesetter Industry**, Ph.D. Thesis, MIT Sloan School of Management, Cambridge, MA, 1996.

Vickers, John, "The Evolution of Market Structure when there is a Sequence of Innovations" **Journal of Industrial Economics 35** (1986), 1-12.

The American Pressmen, selected issues.

Editor and Publisher, selected issues.

Editor and Publisher International Yearbook, 1960-1977.

Facts about the Globe.

The Typographical Journal, selected issues.

Table 1
Number of Observations by Market Structure

Market Structure	Number of Observations
Single Newspaper Monopoly	1232
Duopolists	124
Two Newspaper Monopoly	193
TOTAL	1549

Table 2
Summary of Other Variables

Variable	Mean	Minimum	Maximum
Adoption Year	73	64	77
Ln (Circulation)	9.3	6.0	13.1
Ln (Circulation) 2	9.4	6.0	13.6
Ln (Total Circulation)	9.5	6.0	14.2
Chain	0.4	0	1
Chain Size	2.6	1	18
IPPAU	0.37	0	1

Table 3

	(1)	(2)	(3)	(4)	(5)	(6)
Duopoly	2.7	2.8	1.7		0.9	1.3
	(0.8)	(0.7)	(1.3)		(0.9)	(1.1)
HHI of Duopoly				3.0		
				(0.9)		
Small Duopolist					4.7	5.3
					(1.5)	(1.7)
2-Newspaper Monopoly	1.0	2.8	1.0	1.0	1.0	1.0
	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)
Ln(Circulation) - Sum	2.5		1.2	2.5	2.5	3.4
	(0.2)		(1.4)	(0.2)	(0.2)	(1.1)
Ln(Circulation) - Mean		2.5				
		(0.2)				
Ln(Total Circulation)			1.2			-0.9
			(1.4)			(1.0)
Constant	50.3	50.5	50.2	49.9	50.0	50.0
	(1.6)	(1.6)	(1.6)	(1.5)	(1.6)	(1.6)
Equation standard error	5.7	5.7	5.7	5.7	5.7	5.7
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Log-likelihood	-3354	-3356	-3353	-3354	-3345	-3348

Number of observations is 1549, of which 87 are left censored at year (19)64, 898 are uncensored, and 564 are right censored at year 19(77). Ln (Circulation) for 2-Newspaper Monopoly firms is measured as the log of the sum of the circulation of the two newspapers in rows "Ln(Circulation) - Sum", and as the mean of the log circulation for both newspapers in row "Ln(Circulation) - Mean".

Table 4

	(1)	(2)	(3)
Duopoly	-0.4	-0.4	-0.1
	(0.2)	(0.2)	(0.2)
	[0.6]	[0.7]	[0.9]
Small Duopolist	-0.8	-0.8	-0.8
	(0.4)	(0.4)	(0.4)
	[0.4]	[0.5]	[0.4]
2-Newspaper Monopoly	-0.2	-0.2	-0.16
	(0.1)	(0.1)	(0.12)
	[0.8]	[0.8]	[0.9]
Ln(Circulation) - Sum	-0.6	-0.6	-0.7
	(0.03)	(0.03)	(0.03)
	[0.5]	[0.5]	[0.5]
Former Duopoly		-0.8	-1.1
		(0.7)	(0.7)
		[0.4]	[0.3]
Prior Adoption in Market			-1.1
			(0.4)
			[0.3]
Log-likelihood	-8555	-8554	-8548

Number of observations is 1549, of which 87 are left censored at year (19)64, 898 are uncensored, and 564 are right censored at year 19(77). Values in square brackets are coefficients are in exponential form. Ln (Circulation) for 2-Newspaper Monopoly firms is the log of the sum of the circulation of both newspapers.

Table 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Duopoly	0.8	0.9	1.1	0.1	1.0	0.6	0.7
	(1.0)	(0.9)	(0.9)	(0.9)	(0.9)	(0.9)	(0.9)
Small Duopolist	4.7	4.7	4.4	4.7	4.3	4.7	4.7
	(1.5)	(1.5)	(1.5)	(1.4)	(1.4)	(1.4)	(1.5)
2-Newspaper Monopoly	1.0	1.0	1.1	0.6	1.0	0.9	0.7
	(0.6)	(0.6)	(0.6)	(0.6)	(0.7)	(0.6)	(0.6)
Ln(Circulation)	2.5	2.5	2.5	2.5	2.7	2.5	2.6
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
c - Mean State Attributes							0.09
							(0.14)
IPPAU	0.6						
	(1.3)						
Chain Newspaper		0.5	1.0				
		(0.4)	(0.5)				
Chain Size			-0.1				
			(0.7)				
Constant	50.2	50.2	50.2				51.5
	(1.6)	(1.6)	(1.6)				(1.6)
Chain Dummies	NO	NO	NO .19	YES	NO	YES	NO
State Dummies	NO	NO	NO	NO	YES	YES	NO
equation standard error	5.7	5.7	5.7	5.3	5.5	5.1	5.7
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Log-likelihood	-3349	-3348	-3348	-3248	-3312	-3210	-3305

Number of observations is 1549, of which 87 are left censored at year (19)64, 898 are uncensored, and 564 are right censored at year (19)77. Ln (Circulation) is defined as in Table for Columns (1)-(5), and in Table for Columns (6)-(

Table 6

State	Coefficient
Alabama	----
Alaska	-2.3
Arizona	3.4
Arkansas	1.6
California	4.7
Colorado	3.0
Connecticut	1.2
Delaware	40.0
District of Columbia	0.8
Florida	2.6
Georgia	-2.7
Hawaii	2.6
Idaho	5.1
Illinois	3.4
Indiana	3.0
Iowa	3.5
Kansas	0.2
Kentucky	2.4
Louisiana	7.0
Maine	3.6
Maryland	4.4
Massachusetts	6.5
Michigan	2.8
Minnesota	1.9
Mississippi	1.1
Missouri	1.6
Montana	2.9
Nebraska	3.9
Nevada	5.4
New Hampshire	6.1
New Jersey	4.0
New Mexico	2.8
New York	1.6
North Carolina	3.1
North Dakota	5.1
Ohio	1.5
Oklahoma	-0.3
Oregon	5.2
Pennsylvania	8.1
Rhode Island	1.6
South Carolina	2.5
South Dakota	-0.2
Tennessee	33.3
Texas	2.5
Utah	4.7
Vermont	0.5
Virginia	3.1
Washington	2.7
West Virginia	3.7
Wisconsin	3.5
Wyoming	5.0

Alabama is the omitted dummy variable.

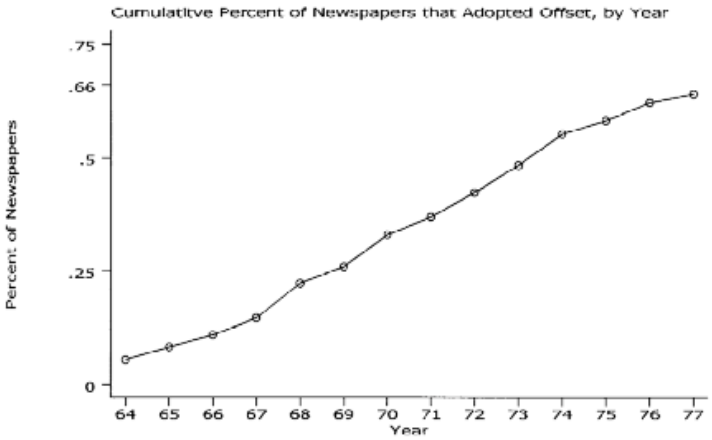

Figure 1

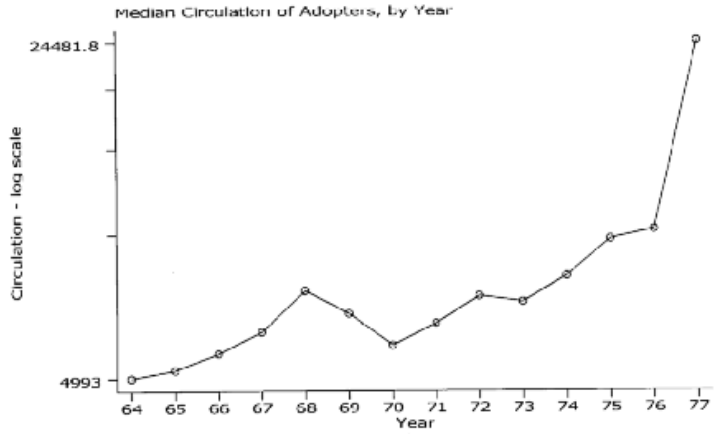

Figure 2

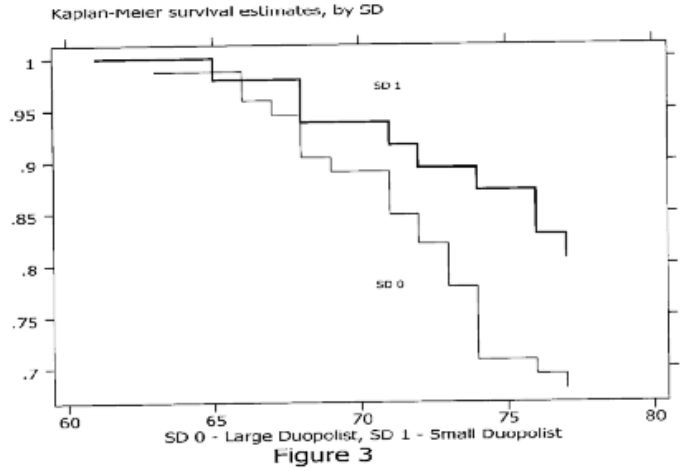

Figure 3