Technological Change in the American Newspaper Industry, 1960–1976*

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July 12, 2019

We analyze the diffusion of three technologies across American newspapers between 1960 and 1976: phototypesetting, computerization and offset printing.

JEL №: N32, N72, O33.

* We are indebted to Joseph Ferrie, David Genesove, Benjamin Jones, Joel Mokyr and Matthew Notowidigdo for advice. Seminar participants at Northwestern University offered valuable feedback as well. Priyanka Panjwani provided invaluable research assistance. The Balzan Foundation and the Center for Economic History at Northwestern University provided generous financial support. All mistakes are our own.
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1 Introduction

Technological diffusion is often complex, slow and poorly understood. Technical superiority need not induce adoption on its own: researchers have also highlighted the role of competition (Genesove, 1999), labor costs (Manuelli and Seshadri, 2014), unionization (Tauman and Weiss, 1987) and more.

This paper brings additional empirical evidence to bear on the determinants of technological diffusion and its consequences. We study the adoption of three technological innovations in the American newspaper industry in the 1960s and 1970s: phototypesetters, computers and offset printing. Phototypesetters helped compositors arrange the text for a page through the use of photography. They displaced linecasters, which newspapers had used since the 1880s.[1] Computers augmented compositors' productivity by automating justification and hyphenation.[2] Offset printing substituted photolithography for letterpress. It was the biggest innovation in newspaper printing since the advent of the rotary press in the 1840s. Although it was more expensive than letterpress, it yielded neater copy and had complementarities with phototypesetting (Genesove, 1999).

In this paper, we ask the following questions: what are the determinants of adoption of the three technologies, what is their impact on employment, and what is their impact on newspapers' output? To answer these questions, we combine data on newspapers, their printing technology and their typesetting equipment from *Editor & Publisher*'s *International Year Books* with data on union membership and strike incidence from the yearly accounts of the International Typographical Union (ITU). We use these data to run descriptive regressions in which we control for observable characteristics of newspapers to make inferences about what drove technology adoption.

The newspaper industry has a unique combination of features which makes it useful for a case study on the interaction of technology adoption and organized labor. First, we are able to acquire detailed data on the production equipment of newspapers at a yearly level. Second, since daily newspapers are primarily local monopolies, we have relatively few concerns about the role of competition in technology adoption. Third, whereas other papers have studied the adoption of single technologies, such as tractors or ?, in our context, we are able to study the simultaneous adoption of several technologies with significant complementarities.

[1] Phototypesetting is also known as photocomposition and cold type. Traditional composition is also known as hot metal. See Section 2.

[2] Computers also displaced photocomposition with the development of digital composition at the end of the 20th century. This paper does not analyze this second transition.

These technologies dramatically changed newspapers' labor demand. Not only did skilled linecaster operators became redundant, but newspapers now needed fewer compositors altogether. The International Typographical Union (ITU), which organized typographers in the U.S., recognized the potential for these technologies to render their members obsolete, and sometimes went as far as sanctioning strikes in opposition to the take-up of new technologies. The ITU clearly failed to stop the adoption of these new technologies in the long run, but it is not obvious whether the ITU's negotiating tactics slowed the adoption of the new technologies.

- *Mention Figures 1 and 2 somewhere.*

We find that adoption of offset printing was associated with a ten percent reduction in ITU journeymen employment. Additionally, the adoption of each technology was associated with increased circulation of three to four percent. Unionization is negatively associated with the take up of new technologies, whereas strikes are positively associated with the take up of new technologies, indicating that strikes may been the ITU's weapon of last resort against these disruptive technologies. Finally, we find that chained newspapers are more likely to adopt offset printing than independent ones by six percentage points, but they are no more likely to adopt either photocomposing or computers. Offset presses were large, one-time expenses for newspapers, while photocomposers and computers could be introduced gradually with little initial expense, so this result may reflect newspaper chains' greater ability to finance purchases of expensive offset presses.

Our paper contributes to several literatures. First, our paper provides an empirical example of the dynamics of technology adoption, contributing to a large theoretical literature on technology adoption. One frequent theoretical finding which we confirm is that technological adoption is initially slow, but the majority of a technology's adoption occurs quite rapidly (Gort and Klepper, 1982; Griliches, 1957; Jovanovich and Lach, 1997; Manuelli and Seshadri, 2014). One reason for the initial slow adoption is that technologies improve iteratively, gradually making transitioning more appealing to firms (Manuelli and Seshadri, 2014). Second, our paper contributes to a literature on the interaction of unions and technology adoption. Tauman and Weiss (1987) show that theoretically, unions may support labor-displacing technology, as new technologies may increase firms' productivity, resulting in more jobs for union members. However, most empirical evidence concurs with our paper in showing that unions reduce investment in new technologies (Cardullo, Conti and Sulis, 2015; Odgers and Betts, 1997). Finally, our paper contributes to a literature studying the determinants of newspaper behavior. Genesove (1999) shows that smaller newspapers

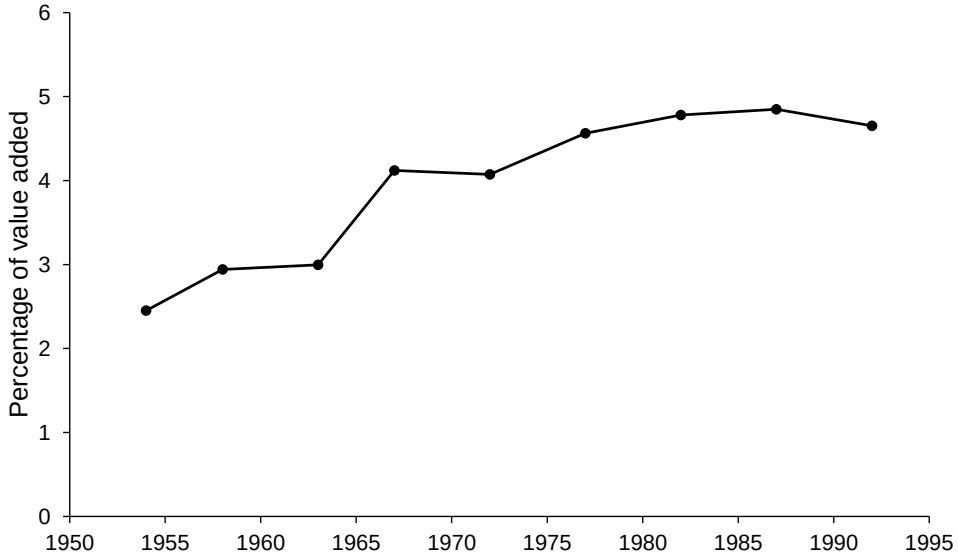

Figure 1: Investment in new machinery in the newspaper industry by year

Source: Economic Census.

were the first to adopt offset printing, a result consistent with our findings. Gentzkow and Shapiro (2010) show that newspapers think strategically about political affiliation when considering entering a new market. Fan (2013) shows that competition-reducing mergers can lead newspapers to provide less journalistic content relative to advertising.

In the rest of the paper, we begin in Section 2 by providing some background information on offset printing, photocomposition, and computers in the context of the newspaper industry. In Section 3, we provide background on the American newspaper industry, the ITU, and the development of the technologies. In Section 4, we describe our data, and in Section 5, we present and discuss our results. Finally, we conclude in the conclusion in Section 6, the concluding section in which we conclude.

2 Production technology

Newspaper production involves two main steps: compositors first prepare pages for printing by arranging headlines, text, pictures and advertisement; pressmen then print the pages and assemble the newspaper.

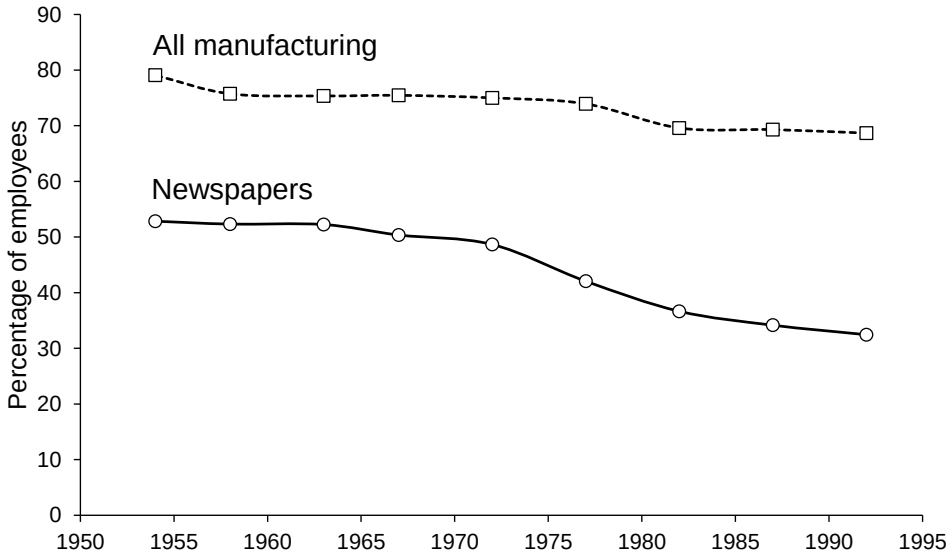

Figure 2: Production personnel by year

Source: Economic Census.

2.1 Composition methods

2.1.1 Manual composition

The compositor first selects *sorts* from a case. A sort is a metal cast of an individual symbol (e.g., a letter or a punctuation sign). They set the page by assembling the sorts into lines of text and arranging them within a frame into a *form*. All sorts in a form stand at the same height. The compositor fills white space with shorter blocks, which secure the sorts without interfering in printing, and tightens the frame. The form is then ready for printing.

This process is labor intensive and time consuming. It was seldom used in the composition of straight matter for newspapers after the invention of the Linotype in the 1880s, but it was still employed for headlines and advertisements. It was later displaced by phototypesetting and digital composition.

2.1.2 Hot-metal composition

The compositor types a row of text on the keyboard of a *linecaster* (e.g., a Linotype), hyphenating as necessary. As they press each key, the linecaster collects the corresponding *matrix*, which contains the character in question in counter relief. Space bands separate words. When the row is ready, the compositor sends it for casting. The linecaster first

adjusts the bands to justify the line before pouring molten metal on the resulting mold.[3] The compositor finally assembles the casts of the different lines into a form for printing.

Mechanical typesetting is more efficient than manual composition on two levels: linecasters are faster at selecting matrices and justification is automatic. A linecaster operator produces as much type as six hand typographers (Grimes, 1985; ITU, 1968). Nevertheless, it remains a skilled job. Compositors must type proficiently and carry heavy metal slugs. They are typically responsible for maintaining the machines as well.

2.1.3 Cold-type composition

The compositor types text on the keyboard of a *phototypesetter* (e.g., a Fotosetter), breaking lines as necessary. As they press each key, the phototypesetter exposes film to light through a matrix with a transparent outline of the corresponding character.[4] The resulting negative yields a column of text after development.[5] To set the page, the compositor collects the type, cuts it and pastes it on a board. They then photograph it and transfer the negative onto a photosensitive plate.[6] The form is now ready for printing.

Cold type offers several advantages over hot metal. First, it is faster. Grimes (1985) estimates that a phototypesetter yielded eighty lines per minute in 1964, while a Linotype set six. This gap widened as phototypesetters improved (Genesove, 1999). Second, it produces neater copy. Third, cold type facilitates the integration of images and text, which is valuable for advertisements. Fourth, phototypesetters can easily adjust the font size by projecting characters through lenses, which eliminates the need for separate equipment. Fifth, phototypesetters and their matrices are smaller, saving room, and are suitable for an office environment. Sixth, they need less maintenance. Seventh, cutting and pasting do not require physical strength.

Cold type demands different skills than hot metal, such as processing negatives and pasting copy. Managers realized early on though that it requires less training and fewer hands in all (Barnhart, 1948; Dertouzos and Quinn, 1985). It would not only cut labor costs, but it held the promise of breaking the grip of the ITU over the composing room.

[3] This description fits the two most popular linecasters for straight matter, the Linotype and the Intertype. The Monotype and the Ludlow differ. The Monotype casts individual letters, which it assembles them into justified lines. The Ludlow casts continuous slugs from manually typeset molds. It is useful for large display type.

[4] Early phototypesetters struck the film with a sort instead. Results were mediocre (Grimes, 1985), so they were never popular.

[5] Early phototypesetters did not justify; therefore, they were most useful for display text. Justification became feasible by integrating a tape reader into the phototypesetter (q.v. Subsection 2.1.4).

[6] The compositor first covers the plate with a photosensitive emulsion. They expose it to light through the negative, which hardens the emulsion. The unexposed emulsion is then stripped away with chemicals.

2.1.4 Teletypesetters and computers

The *teletypesetter* was the only major innovation in newspaper composition between hot metal and cold type (ITU, 1968). It complements either method. The compositor types on the keyboard of the teletypesetter, breaking lines as necessary. As they press each key, the teletypesetter punches a tape. They can then set the text by feeding the perforated tape to an adapted linecaster or phototypesetter. The advantages were threefold. First, this procedure is slightly faster: according to Grimes (1985), a linecaster operator's output increased by fourteen percent. Second, corrections are easier: special equipment is able to merge a correction into a tape with a mistake. Third, it frees compositors from retyping syndicated stories: it suffices to connect a teletypesetter to the wire service instead.

Computers were a similarly complementary technology at first. The compositor prepared *idiot tape*, which did not contain line breaks or hyphenation, and fed it to the computer. The computer returned a second tape with annotations for line breaks and hyphenation. Automatic hyphenation meant a productivity leap (ITU, 1968) as well as a reduction in skill requirements. A linecaster operator set six lines per minute with the aid of a teletypesetter in 1932 (Grimes, 1985). A computer helped him set fourteen by 1960 – the upper bound for a linecaster at the time because of physical limitations. A computerized phototypesetter set five thousand lines per minute in 1978.

Advances in computer memory, video terminals and personal computers allowed further efficiency gains as text became easier to type, reuse and correct. Compositors were eventually freed from retyping journalists' stories. Photocomposition was finally displaced altogether with the advent of digital composition evolved in the late 1980s.

2.2 Printing methods

2.2.1 Letterpress

Traditional letterpress begins with a flat form with characters in high relief. The pressman prints the page by inking the form and pressing it against paper.

The newspaper industry abandoned traditional letterpress for the faster *rotary press* in the 19th century. A rotary press takes a cylindrical form, which the pressman mounts on the *plate cylinder*. A paper reel runs between the plate cylinder and a smooth *impression cylinder*. As it spins, the form first takes ink from a roller before touching the paper and printing the page. The paper is then cut, assembled and folded.

The rotary press requires a cylindrical form with characters in high relief. If the page was composed by hand or hot metal, a stereotyper ensures the conversion. They press a flexible

material against the flat form. The resulting *flong* is a mold with characters in counter relief. They mount the flong on the inside of a drum and pour molten metal on it, producing a cylindrical *stereotype* with characters in high relief for printing. If the page was composed by phototypesetting, the original form is flexible enough in itself for mounting on the plate cylinder. Therefore, it only needs an acid bath, which corrodes the white space around the type and leaves the characters in high relief.

2.2.2 Offset

Offset printing exploits lithography. It requires a smooth form with the image in emulsion. This hardened oily emulsion rejects water and accepts ink. The pressman mounts the form on the plate cylinder, which touches a *blanket cylinder* in rubber. The rubber rejects water and accepts ink. A paper reel runs between the blanket cylinder and the impression cylinder. As the plate spins, a first roller applies water, which the white space accepts and the emulsion rejects, before a second roller applies ink, which the water rejects and the emulsion accepts. The form transfers the ink to the blanket cylinder, which prints the page on the paper in its turn. The paper is then cut, assembled and folded.

If the page was set in cold type, the form is fit for offset printing without further treatment. If it was set by hand or hot metal, it needs conversion. Various techniques exist: for example, the typographer might print a proof by letterpress, photograph it and transfer the negative onto a plate.

As Genesove (1999) notes, an offset press was a hefty investment: it took about two years to install and cost a tenth of the yearly revenues of an average newspaper in 1972. It is also more expensive to operate because of additional downtime, wasted newsprint and pricier ink. However, it benefits from complementarities with cold type: the two technologies are jointly cheaper than other production methods (Genesove, 1999). Furthermore, photolithography produces neater copy, which is especially valuable for advertisement.

3 Historical background

This section provides some historical context for the various elements at play in the newspaper industry's technological transition from hot-metal typesetting and letterpress printing to computerized phototypesetting and offset printing.

3.1 Newspaper industry

The American newspaper industry comprises hundreds of daily and weekly newspapers. This paper only analyzes daily newspapers.

Most of the initial adoption of offset printing, phototypesetting and computers occurred between 1960 and 1980. The number of newspapers remained fairly constant in the United States during this period. For instance, there were 1736 daily newspapers in 1968 and 1746 in 1976 (the two years in our empirical analysis). The majority were local monopolies. In 1968, 70 percent of them were the only newspaper in their city; in 1976, 75 percent. These figures overstate the extent of competition in fact, since they exclude towns with multiple editions of a single newspaper (for instance, a morning and an evening edition). Moreover, many newspapers shared printing operations in otherwise competitive markets.

Besides technological change, the newspaper industry underwent a second major transition in the postwar period from independent family firms to ownership by newspaper chains (i.e. corporations with more than one newspaper in their portfolio). Chain ownership rose from 14 percent of all newspapers in 1950 to 58.6 percent in 1980. There were two important differences between chain-owned and independent newspapers. First, chains were likely to enjoy greater access to finance, which may have helped them purchase costly new technologies. Second, they were better able to meet a growing demand for national advertising than independent newspapers, since it was logistically easier for advertisers to negotiate with a single corporation than several independent newspapers.

3.2 International Typographical Union

American printers organized as early as 1794 in New York City (Saposs, 1918). They first mulled plans to federate their local unions into a national organization in December 1850. The National Typographical Union was finally established in Indianapolis on May 3, 1852. Member locals remained largely autonomous, but they paid dues to and received support from the national union. It became the International Typographical Union upon the admission of Canadian workers in 1869. It was a founding member of the American Federation of Labor in 1886 and of the Congress of Industrial Organizations in 1935.

The ITU originally encompassed photoengravers, pressmen and stereotypers, but they organized separate unions at the turn of the nineteenth century century, reducing it to compositors and mailers by 1902. It maintained jurisdiction over linecasters in spite of a challenge from the International Association of Machinists in the late nineteenth century. It also preserved jurisdiction over the composing room during the transition to cold type in

TABLE 1: STATE OF THE INDUSTRY, 1960–1976

	Sample	Unit	1960	1968	1976
Technology adoption					
Hot-metal typesetter	Printing plants	Percentage	100.0	92.1	31.7
Phototypesetter	Printing plants	Percentage	1.6	28.5	86.9
Computer	Printing plants	Percentage		17.8	60.0
Offset	Printing plants	Percentage		22.9	70.5
Newspaper characteristics					
Circulation	Printing plants	Mean	30,656	35,006	34,117
Pages per edition	Printing plants	Mean	26	32	42
Chain membership	Printing plants	Percentage	26.5	43.4	57.2
Unionization	Printing plants	Percentage	50.5	49.3	47.1
Strike incidence	Printing plants	Percentage		13.7	11.7
Union characteristics					
Receipts per journeyman	Union locals	Mean[a]	951	1,461	1,156
Journeymen	Union locals	Mean	129	145	149
Apprentices	Union locals	Mean	9	8	5
Defense expenses per journeyman	Striking locals	Mean[a]	2,395	3,112	1,673

[a] Inflated by the PCE index to 2019 dollars.
Sources: Editor & Publisher's *International Year Books*, ITU's *Annual Proceedings*.

the 1960s despite plausible claims from the Amalgamated Lithographers of America, the Commercial Telegraphers' Union and the International Photo-Engravers' Union.

The ITU was early to recognize the threat of computerized phototypesetting (ITU, 1968). In an attempt to help members adapt, it inaugurated its first training center in 1955. It eventually dissolved in 1986, as computerized phototypesetting and offset reduced employment in the printing industry. The National Typographical Union was the oldest trade union in the country at the time. Most mailers went on to join the International Brotherhood of Teamsters, while remaining compositors joined the Communications Workers of America.

3.3 Labor conflict

Strikes have long been a bargaining tactic in the newspaper industry.

- *Give a few examples from 19th century, especially strikes not by typographical workers*

For typographical workers, striking was a particularly credible tactic. Newspapers depended on typographical workers to compose a newspapers, and because of the significant skill involved in operating a linecaster, it was difficult to find replacements with short notice. Additionally, because the ITU maintained jurisdiction over linecasters, newspapers had difficulty training non-union typographers. Because of its strong bargaining position, the ITU was able to extract significant, costly concessions from newspapers.

- *Forced reuse of advertising copy*
- *Requirement that 8 workers do an ink cleaning job that requires only 3 people*

However, some newspaper owners recognized the ability for phototypesetting technology to give them the upper hand in their negotiations with the ITU.

- *Summarize p. 43 discussion of Chicago newspapers' response to ITU Local 16 strike in opposition to Taft-Hartley Act*
- *The ITU founded Unitypo Inc in 1946. It managed the union's defense fund.*

3.4 Technological development

3.4.1 Offset printing

Offset printing is predicated on lithography, a printing process in which inked and non-inked surfaces are on the same plane, and the plane is treated to repel ink outside of the inked area. In letterpress printing, on the other hand, the inked surfaced is raised above the non-inked surface. Alois Senefelder invented lithography in 1796 and it became a popular small-scale printing method in the 19th century.

Lithography was one of the necessary developments for the invention of offset printing. In offset printing, the transference of ink from the printing surface to print is mediated by some intermediate surface. By using an intermediate surface, the printing plate has a much longer life than with direct lithographic pressing, because there is no direct contact with the printing plate and the printing surface. Additionally, offset printing produces a higher quality image compared to direct lithographic pressing.

While offset printing originated in the late 19th century, it was only adapted for use in the newspaper industry in the early 1950s. Until that time, all offset presses were *sheet fed* rather than *web fed*. A sheet-fed offset press prints on pre-cut sheets, whereas a web-fed offset press prints on a continuous paper reel, which is cut and folded after printing. A sheet-fed press suffices for small jobs, but the higher printing speed of web offset becomes necessary for larger printing needs.

Before the advent of the web offset press, a newspaper only had the potential option of printing using a rotary letterpress, which uses the older, inferior letterpress printing technology with a continuous roll of paper. In the late 1940s, the owner of a small Texas newspaper chain, Staley McBrayer, developed interest in developing a web offset press. He approached a manufacturing firm to assist them in developing the press, and one of the

firm's engineers, James Grant Ghormley Jr., developed the press along with a colleague, Clyde T. Kitchens (Rosenberg, 2002).

3.4.2 Cold type

Ottmar Mergenthaler developed the first linecaster in the 1880s. He called it the Linotype. He established the Mergenthaler Linotype Company in 1886. Its main competitors were the Lanston Monotype Corporation, founded in 1887, and the Intertype Company, founded in 1914. Linecasters allowed composers to work much more productively by using a keyboard-style input to cast lines of type, and then individually arrange the metal lines into a page of composed type.

In offset printing, the printing plate is created by having a camera expose the image of a composed page to photosensitive metal. In order for a linecaster to be used with an offset printer, one must set the page by using a linecaster to arrange lines of text, print a single page, take an image of that page and expose the image to photosensitive metal to create an offset printing plate.

Two French engineers, Louis Moyroud and Rene Higonnet, observed this process in a French printing facility, and found it counter-intuitive. Instead of using a linecaster to compose and the print a page, they reasoned that one could work more efficiently and create a higher quality image by exposing characters to film, developing the film into a composed page, and exposing the image of the composed page to photosensitive metal. This alternative process creates a higher-quality image, and skips the cumbersome step of using a linecaster (Hevesi, 2010).

Moyroud and Higgonet's solution was the phototypesetter: a machine that allows its operator to expose individual characters to film. Higgonet filed for the patent in 1945 and acquired it in 1949. While earlier inventors had also acquired patents working towards the use of photography in composition, Moyroud and Higgonet were the first to develop a commercially viable phototypesetter (Romano, 2014).

4 Data

4.1 Industry year books

We obtain newspaper data from *Editor & Publisher*'s *International Year Books*. First issued in 1921, the yearbooks cover the near universe of American daily newspapers as well as various other publications across the world. They contain detailed self-reported information

about newspapers' operations, including location, circulation, ownership structure and mechanical equipment.

Gentzkow and Shapiro (2014) had previously digitized each newspaper's location and circulation. We augment their panel with four indicators for ownership by chain, offset printing, phototypesetting and computerization. The *Year Books* directly state each newspaper's printing technology (letterpress or offset). They also specify their parent company, which allows us to identify whether they were part of a chain. Each entry further includes a list of mechanical equipment. This list has sections (e.g., "composing") and subsections (e.g., "cold type" withing "composing"). Our phototypesetting indicator is one if the newspaper declared any equipment under "cold type" or "photocomposer". Our computerization indicator is one if it declared any computer or video terminal. To limit measurement error, we do not use the model or the number of machines in each category. We measure each variable in 1960, 1968 and 1976.

Editorially independent newspapers often shared printing operations to reduce production costs. The *Year Books* might only have a complete mechanical section for one newspaper in the joint operation and report nothing for the remainder or they might alternatively print identical entries for every one of them. The latter allows us to identify newspapers with shared operations. We accordingly treat all newspapers in a town as a single unit if their mechanical sections are identical in one *Year Book* or more. Therefore, our unit of observation is a printing plant instead of a newspaper. Note that some joint operations might only have started in the middle of the sample period, but we treat them as a single unit in all three years.[7]

4.2 Union accounts

We obtain labor data from the annual accounts of the ITU. Officers prepared the reports at the end of each fiscal year in June and published them as a supplement to the union's *Typographical Journal* before presenting them at its annual convention in August.

The ITU published the following information for each local: receipts by source, defense benefits by source, amount in treasury and membership by seniority. We construct four variables for our analysis: receipts per journeyman, an indicator of strike incidence, the number of journeyman and the number of apprentices. We measure each variable in 1958, 1966 and 1974.[8] We only use data from typographers' locals.

[7] In aggregating newspapers, we use the maximum value of each variable of interest across all newspapers in question.

[8] Note that there is a two-year difference between our samples: newspapers in 1960 are matched with locals

We use receipts per journeyman as a proxy for wages, given that the ITU charged members a share of their annual income in dues. This share did not vary across locals or years in our period. As for strike incidence, our indicator is one if the local received monies from the union's national defense fund in any of the preceding eight years. We do not exploit the dollar value of defense benefits because the resulting estimates would probably be sensitive to outliers and locals could partially finance their own strike expenses.

A local federated all unionized newspapers in a town.[9] Because we do not have finer data, we do not know which newspapers in a town were actually unionized or how many union members worked at each unionized newspaper. Following Genesove (1999), we assume therefore that all newspapers in a town with a local were unionized and we merge the data from each local with all newspapers in the town in question. We are able to match 673 out of 706 locals in the data. We ignore decertification elections in measuring unionization because our sample does not allow us to distinguish extinct locals from missing data.

There were several other important unions in the newspaper industry. We focus our analysis on the ITU for four reasons. First, it was large. About half of all newspapers operated in towns with an ITU local. For comparison, a mere tenth operated in towns with a local of the International Pressmen and Pressmen's Assistants Union (Genesove, 1999). Second, it had a long tradition of militancy (unlike the American Newspaper Guild, for instance). Third, it was particularly vulnerable to the disemployment effects of computerization, phototypesetting and offset printing. Fourth, it collected consistent data at the local level throughout the sample period.

5 Empirical analysis

This section conducts an empirical analysis of technological change in the newspaper industry between 1960 and 1976. We first consider the determinants of the diffusion of offset presses, phototypesetters and computers (Subsection 5.1). We then evaluate their impact on ITU locals (Subsection 5.2) and output (Subsection 5.3).

Given the pace of innovation in this period, early and late adoption are likely to differ (Dertouzos and Quinn, 1985; Genesove, 1999). Therefore, we estimate each specification on separate cross sections (1968 and 1976). Each specification includes the lag of the outcome in question as a control; hence, our coefficients capture the effect of regressors on changes in outcomes across years. We use linear regression throughout for convenience

in 1958 and so forth.

[9] Chicago and New York had locals for specific ethnicities (e.g., Local 247 organized Swedish typographers in Chicago). We merge these locals before matching them to newspapers.

and comparability.[10]

5.1 Technology adoption

Table 2 correlates technology adoption and newspaper characteristics. The first two columns consider offset printing; the next two, photocomposition; the last two, computerization.

Higher circulation is negatively associated with offset equipment and positively associated with phototypesetters and computers. The coefficients are modest in magnitude: for example, an increase in circulation of ten percentage points reduced the adoption of offset printing by two percentage points in 1976. The signs are consistent with Dertouzos and Quinn (1985) and Genesove (1999). Large newspapers had two reasons to postpone the transition to offset printing: it was slower than letterpress, which did not suit their tighter production schedules, and they faced higher fixed costs. On the other hand, composition needs are independent of circulation, so computerized phototypesetting was relatively cheaper for large operations.

Chain ownership raised the adoption of offset printing by six percentage points in 1976. This effect is plausible: chains might have been better able to fund the acquisition of expensive new presses through external and internal financing. Note, however, that we find no effect in 1968. Chains were perhaps reluctant to experiment with an immature technology. We also estimate a marginally significant reduction in the diffusion of cold type in 1976, whose source is unclear.

Unionization shows a significant negative correlation with offset printing in both years and with photocomposition in 1968. The coefficient ranges from seven to ten percentage points. Since unions limited potential savings through layoffs, wage cuts, etc., they may well have deterred investment (Cardullo, Conti and Sulis, 2015; Odgers and Betts, 1997). By contrast, strikes seem to have hastened the transition to phototypesetters and computers. One explanation is reverse causality: typographers may have struck against planned purchases of new equipment. Alternatively, newspapers may have adopted computerized photocomposition in an effort to tame combative locals (Barnhart, 1948). We find a negative association between strike incidence and the presence of computers in 1976, but it is only marginally significant.

[10] Although Genesove (1999) shows that competition affected the diffusion of offset printing in the 1960s and 1970s, we did not find a significant impact on the cross section. We exclude it from our regressions in the interest of parsimony. Our results are robust to this choice.

TABLE 2: DETERMINANTS OF TECHNOLOGY ADOPTION

	Offset		Phototypesetters		Computers	
	1968	1976	1968	1976	1968	1976
Circulation (log, lag)	–0.096***	–0.215***	0.033*	0.048***	0.123***	0.164***
	(0.012)	(0.015)	(0.017)	(0.012)	(0.015)	(0.015)
Chain	–0.000	0.056**	0.015	–0.036*	0.000	0.012
	(0.025)	(0.022)	(0.028)	(0.020)	(0.022)	(0.027)
Unionization	–0.066**	–0.090***	–0.099***	–0.021	0.027	–0.018
	(0.030)	(0.030)	(0.033)	(0.026)	(0.027)	(0.035)
Strike incidence	0.028	0.035	0.133***	–0.045	0.108**	–0.070*
	(0.031)	(0.043)	(0.045)	(0.034)	(0.045)	(0.038)
Offset (lag)		×		×		×
Phototypesetter (lag)		×		×		×
Computers (lag)		×		×		×
BEA region	×	×	×	×	×	×
Adjusted R^2	0.096	0.423	0.021	0.036	0.205	0.192
Mean outcome	0.218	0.669	0.282	0.867	0.194	0.609
Observations	1112	1127	1090	1132	1090	1132
Parameters	12	15	12	15	12	15

Notes: Robust standard errors in parentheses.
Legend: Stars denote significance: *, at the 10 percent level; **, 5 percent; ***, 1 percent.

5.2 Employment and wages

Productivity gains were an important advantage of computerized phototypesetting and offset printing. Therefore, we should ideally test their effect on employment and wages. Unlike Dertouzos and Quinn (1985), however, we do not have payroll data at the newspaper level, so we use data from ITU locals instead. We estimate the impact of technology adoption on receipts per journeyman, the number of journeymen and the number of apprentices. Receipts serve as a proxy for wages, as the union levied a fixed rate on members' salaries. Table 3 shows our results. Note that we are likely to underestimate the consequences of technological change to the extent that the ITU protected members from pay cuts and layoffs (Dertouzos and Quinn, 1985). Furthermore, the sample is smaller, so we lose precision.

Offset printing is associated with a reduction in the number of journeymen by around ten percent. We find no significant correlation with receipts or apprenticeship. This result is curious: offset photolithography was a printing technology, so it is not clear to us how it affected employment in composition (Genesove, 1999). Typographers may have played a role in the press room, since the ITU offered training in offset printing and discussed it at length (ITU, 1968). Newspapers might also have laid staff off after investing in an offset press because of budget constraints (Genesove, 1999).

Alternatively, these coefficients could reflect measurement error. Newspapers did not

TABLE 3: DETERMINANTS OF UNION RECEIPTS AND EMPLOYMENT

	Receipts (log)[a]		Journeymen (log)		Apprentices	
	1968	1976	1968	1976	1968	1976
Offset	–0.028	–0.041	–0.105*	–0.100**	–0.541	0.824
	(0.034)	(0.045)	(0.055)	(0.046)	(0.790)	(0.642)
Phototypesetters	–0.028	0.038	–0.016	0.054	1.083	0.912
	(0.026)	(0.049)	(0.036)	(0.076)	(0.914)	(0.774)
Computers	0.013	–0.089**	0.030	–0.104**	–0.164	–1.041**
	(0.018)	(0.037)	(0.028)	(0.047)	(0.835)	(0.465)
Circulation (log, lag)	0.016	–0.039	0.007	0.052*	0.983	–0.562
	(0.014)	(0.025)	(0.027)	(0.031)	(0.682)	(1.208)
Chain	–0.017	–0.042	–0.067**	–0.013	–0.670	–0.660
	(0.017)	(0.032)	(0.029)	(0.036)	(0.719)	(0.757)
Strike incidence	–0.079***	–0.036	–0.045	–0.056	–0.463	0.064
	(0.027)	(0.060)	(0.049)	(0.066)	(0.740)	(0.635)
Receipts (log, lag)[a]	×	×	×	×	×	×
Journeymen (log, lag)	×	×	×	×	×	×
Apprentices (lag)	×	×	×	×	×	×
BEA region	×	×	×	×	×	×
Adjusted R^2	0.362	0.332	0.957	0.933	0.980	0.867
Mean outcome	5.488	5.583	4.124	4.084	15.221	8.049
Observations	493	491	493	491	493	491
Parameters	17	17	17	17	17	17

[a] Per journeyman.
Notes: The sample consists of unionized plants. Robust standard errors in parentheses.
Legend: Stars denote significance: *, at the 10 percent level; **, 5 percent; ***, 1 percent.

combine offset printing with letterpress. As a consequence, this was a simple binary question in the survey of *Editor & Publisher*. By contrast, newspapers could not only mix cold type and hot metal, but they also would frequently misreport their typesetting equipment. If other regressors are noisy, our indicator for offset printing might be acting as a proxy for the transition toward phototypesetting, especially given the complementarities between the two technologies (Genesove, 1999).

Computers are associated with lower receipts, fewer journeymen and fewer apprentices. These correlations only become apparent in 1976, as computers reached three in every five newspapers. The coefficients are sizable: e.g., computerization reduced the number of journeymen by ten percent. On the other hand, we find no effect from phototypesetters.

5.3 Circulation and pages per issue

Table 4 explores the impact of technology adoption on output. We consider two measures: average circulation and the average number of pages per issue.

TABLE 4: DETERMINANTS OF CIRCULATION AND LENGTH

	Circulation (log)		Pages (log)	
	1968	1976	1968	1976
Offset	0.010	0.037**	0.021	0.001
	(0.016)	(0.015)	(0.026)	(0.022)
Phototypesetters	–0.017	0.031*	0.023	0.037
	(0.014)	(0.016)	(0.022)	(0.028)
Computers	0.019	0.041***	–0.008	0.020
	(0.014)	(0.014)	(0.023)	(0.018)
Circulation (log, lag)	0.997***	0.935***	0.033***	0.023**
	(0.007)	(0.011)	(0.010)	(0.010)
Chain	–0.026**	–0.002	0.048***	0.050***
	(0.011)	(0.012)	(0.018)	(0.016)
Unionization	0.007	0.006	0.010	–0.036*
	(0.013)	(0.016)	(0.019)	(0.020)
Strike incidence	–0.001	0.040*	–0.016	0.049**
	(0.018)	(0.024)	(0.029)	(0.022)
Lagged outcome	*supra*	*supra*	×	×
BEA region	×	×	×	×
Adjusted R^2	0.978	0.968	0.365	0.341
Mean outcome	9.600	9.683	3.425	3.671
Observations	1084	1188	1085	1188
Parameters	15	15	16	16

Notes: Robust standard errors in parentheses.
Legend: Stars denote significance: *, at the 10 percent level; **, 5 percent; ***, 1 percent.

While we find no evidence that either technology affected circulation in 1968, significant correlations appear by 1976. The coefficients range from three to four percent. It makes sense that technological diffusion should only affect production with a lag. Since the new equipment was still expensive and unproven, its initial usage was often limited. For instance, a newspaper might initially experiment with a phototypesetter for headlines and advertisements. As phototypesetters' usefulness became clearer, compositors learned to operate them and better models became available, the newspaper replaced its remaining linecasters with phototypesetters for text matter as well. Cold type and computerization might then have induced price cuts as newspapers took advantage of lower labor costs to boost readership. On the other hand, the impact of offset printing was equivocal a priori. It was more expensive than letterpress. It produced neater copy though, which might have attracted custom. It might also have allowed newspapers to charge higher prices for advertisers, enabling further price cuts for readers.

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