



Exploring the Effects of Digitization on Employment and Wages in the American Printing Industry 2002-2021

Humberto Merritt^{1*}, Juan Carlos Vilchis-Flores¹

¹*Instituto Politécnico Nacional, CIECAS. Lauro Aguirre # 120, Col. Agricultura, C.P. 11360, CDMX, Mexico*

Abstract. Information and Communication Technologies (ICTs) have forced long-established businesses to adapt to innovations. Most changes have emerged from the digitization of products and services. In the United States (U.S.), the printing industry has faced enormous challenges ranging from shifting markets to declining sales. As a result, several jobs have become redundant. We argue that the digitization phenomenon can be ascribed to the Schumpeterian paradigm of creative destruction. This study measures digitization's impact on employment and wages in the U.S. printing industry from 2002 to 2021. We conduct an exploratory statistical analysis to verify whether the printing industry has experienced any impact on employment and wages compared to the American national trend. We draw on the United States Bureau of Labor Statistics Occupational Employment and Wage Statistics (OEWS) Survey to analyze historical employment and wage figures between 2002 and 2021. Empirical evidence suggests that the U.S. printing industry has experienced a substantial reduction in its workforce, with wages also suffering lower rises than the rest of the economy. The importance of this article rests in its contribution to the analysis of the economics of innovation by considering the impact of new technologies on employment in traditional activities, while other works concentrate mainly on new sectors.

Keywords: Digitization; Employment; Printing industry; Schumpeterian paradigm; United States

1. Introduction

Information and Communication Technologies (ICTs) have revolutionized vital sectors in the United States. Over the last 30 years, several well-known firms, including Blockbuster, Borders, Kodak, and Polaroid, have crumbled. In contrast, companies like Google, Apple, Facebook, and Amazon, which were inconceivable in the 1990s, now dominate the techno-economic milieu due to ICTs (Martel, 2018; Parker, Van Alstyne, and Choudary, 2017; Lucas and Goh, 2009).

Digital activities have thus opened up new markets, creating demand for specialized jobs such as web technicians, artificial intelligence programmers, digital designers, software developers, and Big Data analysts (Martel, 2018). Moreover, since the turn of the century, ICTs have accelerated the necessity for greater technical skills for harnessing the so-called knowledge-based economy (Merritt, 2012). Consequently, ICT jobs have grown more quickly than those related to traditional sectors (Mudzar and Chew, 2022; Acemoglu and Restrepo, 2019; OECD, 2017).

*Corresponding author's email: hmerritt@ipn.mx, Tel.: +52-55-57296000; Fax: +52-55-57296300
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This research examines the digitization of the American printing industry. We draw on Schumpeter's approach to understand this process, thus interpreting digitization as a revolutionary technology (Schumpeter, 1943). We, therefore, define digitization as the innovative conversion of tangible goods into electronic formats. In economic terms, digitization is a technological weapon innovative firms harness to increase users' value (Abaidi and Vernet, 2018; McCullough, 2018; OECD, 2017; Yoffie, 1996).

We decided to study the printing industry because it has undergone significant transformation, but in recent years, the need to embrace digital technology has been a key factor in its business model. To some extent, the printing industry is facing a Schumpeterian transformation because in an increasingly technology-driven world, traditional sectors are also involved in the so-called "creative destruction paradigm" (Schumpeter, 1943). As digital technology has evolved, the need for efficiency, flexibility and sustainability has led the printing industry to embrace this technology more broadly (Lucas and Goh, 2009). Digital technology has revolutionized the printing industry's ability to offer highly customized and flexible solutions. In the past, traditional offset printing limited the ability to change designs or adapt to specific customer demands quickly. With digital printing, it is possible to print short runs cost-effectively and easily adjust designs according to customer needs. This saves time and resources and allows for greater customer satisfaction by offering customized products tailored to their preferences.

Moreover, digitization has significantly improved operational efficiency in the printing industry. Digital processes eliminate the need for complex plates and setups associated with offset printing. This reduces makeready time and material waste, improving overall efficiency. In addition, digital printing enables on-demand production, which means there is no need to maintain large print inventories, reducing costs associated with storage and unused surplus.

In addition, adopting digital technology has contributed to cost reductions in the printing industry. Digital printing eliminates costly investments in offset printing equipment and reduces costs associated with design and configuration adjustments. Moreover, the ability to print smaller quantities reduces storage and waste costs, making printing more affordable for small and medium-sized businesses. This democratizes access to high-quality printing services previously reserved for larger companies.

Concerning the effect of external factors, it should be noted that digital technology has also driven sustainable initiatives in the printing industry. Traditional offset printing often involves chemical processes and uses large amounts of water. In contrast, digital printing is cleaner and more sustainable, with less waste and less environmental impact. The ability to print on demand also reduces the need to store large quantities of printed material, avoiding overproduction and contributing to environmental sustainability.

In this context, we argue that the adoption of digital technology in the printing industry is encouraged by gains in flexibility and personalization, increased operational efficiency, cost reduction, environmental sustainability, and the ability to integrate with emerging technologies. This digital transformation benefits printing companies by improving their competitiveness and providing customers with customized and sustainable solutions. The convergence of digital technology with the printing industry is a strategic step towards a more efficient, sustainable and customer-centric future.

We analyze the sectoral performance of the long-established U.S. printing sector over the last twenty years (2002-2021), a period during which this traditional industry faced challenges due to the Schumpeterian winds transforming its business. Hence, this paper has two exploratory aims. The first objective is to identify patterns that might explain the downward trend in the American printing industry from 2002 to 2021. The second is to

determine the extent of the impact. To this end, the study presents a brief literature review. The study develops a model to provide insight into the changing sectoral pattern of industrial employment across the U.S. and the printing sector in the four-digit NAICS category 3231. Finally, empirical results will be presented, and conclusions will be drawn.

2. Literature review

The digital economy was born out of the works of Nicholas Negroponte and David Yoffie, who trailblaze the concept. The former famously claimed that interactive multimedia would draw on the personal computer to offer multiple entertainment and information services, thus replacing the outmoded T.V. set. Negroponte anticipated that Americans would spend more hours on the Internet than watching television (Negroponte, 1995). His forecast fatally evolved into a dismal result for T.V. broadcasters.

On the other hand, Yoffie considered digitization a revolutionary innovation that would rewrite the world economy. He described several market opportunities that would arrive by the turn of the 21st century. He presaged the merging of telecommunications, broadcasting, and computing into a new technology that would spur new ventures in video-on-demand, interactive television, and online services to deliver novel digital content (Yoffie, 1996). In hindsight, they forecasted the current digital world as a revolutionary paradigm with destructive effects on many long-established economic sectors, as Schumpeter (1943) would have argued.

Digitization refers to the analog-to-electronic transformation of tangible documents and printed media. To a large extent, information technologies spur productivity when digitized data steps in to automate processes, thus enhancing entry. Typical uses include analog music encoding, photograph scanning, and transforming paper reports into portable file documents (PDF). In essence, digitization involves encoding real-world content into a digital format. The continuous advancement of Information and Communication Technologies (ICTs) has brought about significant transformations in various traditional industries. Notably impacted are the publishing industry and paper and printing manufacturing. Digitalization introduces new avenues for companies to generate added value for their business (Berawi *et al.*, 2020).

Digitization has produced many benefits, however. To begin with, firms can encourage users to shift from printed invoices and paper bills by offering immediate cost savings and lower prices. Suppliers can also switch to digitally delivering all relevant information. And governments can digitize their services by transferring face-to-face interactions to online-only processes, such as requesting tax records, licenses, and permits (OECD, 2017).

We argue that ongoing technical change plays a vital role in enhancing firms' value chains. Following Parker, Van Alstyne, and Choudary (2017), we distinguish three forms of digitization and their outcomes. Vertical convergence induces changes along the value chain, e.g. for video delivery. Horizontal convergence cuts across existing platforms, such as cable, TV, and wireless communications, and platform convergence, which is currently serving as a universal platform on the mobile Internet.

3. Methods

The research follows a time-series analysis approach that draws on the yearly statistics collected by the U.S. Bureau of Labor Statistics (BLS). This database relies on the periodic survey, Occupational Employment and Wage Statistics (OEWS), which is freely available at <https://www.bls.gov/oes/tables.htm>.

We collected data for the last twenty-year employment and wage statistics (2002-2021) from the American sector named “printing and related support activities (NAICS 3231)”. We selected this industry because it produces and relies primarily on tangible goods, epitomizing the pre-internet economy.

Although the OEWS database reports sectoral economic information for the U.S. industry based on the North American Industry Classification System (NAICS), a preliminary methodological note is worth presenting.

The time series from the OEWS website provides industry data since 1988, but we restrict our analysis to the 2002-2021 period because of methodological issues. First, digitization’s effects on jobs and wages can safely be attributable to the rapid diffusion of ICTs during those years. Second, the selected time series data are relatively homogeneous. Yet, one limitation of our approach is that it is based on aggregate data. Thus, we do not measure how specific jobs were affected by the ongoing digitization process. However, we argue that aggregate industrial employment data still helps explain the downward trend in the examined sector.

On the other hand, the printing industry is a clear example of a pre-digital manufacturing sector. This industry has faced shrinking sales of traditional print stuff as digital versions supplant physical items. Its troubles began when publishers and advertisers, its main customers, started an accelerated transition to the digital world in 2002. Also, online advertising platforms have lured many long-time printing customers because they are cheap and provide practical tracking tools for measuring investment returns. Moreover, advertisers’ expenditures have also declined on other printed products like magazines and newspapers. So, when advertising spending shrinks, newspapers and magazines drop page output and seek to consolidate operations, further shrinking the industry’s supply. Additional threats are appearing from social concerns regarding the long-term sustainability of paper production.

It is worth noting that printing is an activity mainly focused on producing printed matter. Thus, printing firms typically make tangible stuff such as newspapers, business cards, labels, books, business forms, stationery, etc. Additional activities comprise supporting processes such as plate-making services, data imaging, and bookbinding. So, this sector embraces business units handling paper stuff to make printed material. Therefore, the current wave of digitization has affected the essence of the industry, forcing it to quickly adopt impinged upon. In any case, and as [Berawi \(2021\)](#) emphasizes, companies must embrace innovation to survive and remain competitive.

According to the NAICS Association, as of 2022, there were 53,874 commercial establishments registered in the four subsectors, distributed as follows. Commercial Printing (NAICS 323111): 43,605 Commercial Screen Printing (NAICS 323113): 8,257. Books Printing (NAICS 323117): 362, and Support Activities for Printing (NAICS 323120): 1,670 (<https://www.naics.com/naics-code-description/?code=3231>).

Regarding the impact of industrial innovation, the printing industry has historically been a study case for labor sociologists, who have been interested in analyzing working conditions in the industry. Yet, digitization first affected printing manufacturing as early as the mid-1980s. The digitization process encouraged the capital consolidation that newspaper production finally achieved during the 1990s when the first electronic tools to deliver digitally printed material appeared ([Vogel, 2011](#)).

4. Results and Discussion

We seek to assess digitization’s impact on printing through different means. One is by examining the change of job creation (or destruction) registered in the available datasets.

We chose this approach to gauge the macroeconomic results on wages and employment due to digitization, limiting our analysis to 2002-2021 to keep the OEWS data set consistent.

4.1. Descriptive Data

Table 1 reports total employment and annual wages for the printing industry and the entire U.S. industrial sector from 2002 to 2021. Job analysis indicates that the printing industry (NAICS 3231) employed more people in 2002 than in 2021. The sector also experienced the impact of the 2008-2009 financial crisis, leading to a 10.4% reduction in the workforce from 2009 to 2010. But, from 2010 onwards, the industry has experienced a constant contraction. The OEWS reports that the U.S. manufacturing sector increased its wages from 2002 onwards, albeit at different rates, with printing below the U.S. mean wage.

Table 1 Total employment and wages in the printing and U.S. sectors, 2002-2021 (thousands)

Year	Employment Printing	Var. (%)	Wages Printing	Var. (%)	Employment National	Var. (%)	Wages National	Var. (%)
2002	697.8		35.1		127,506.4		17.5	
2003	688.5	-1.33	35.5	1.17	127,551.5	0.04	17.8	1.97
2004	666.5	-3.20	35.8	0.76	128,127.4	0.45	18.2	2.46
2005	652.4	-2.12	36.6	2.32	130,307.9	1.70	18.6	2.07
2006	638.1	-2.18	37.5	2.54	132,605.0	1.76	19.2	3.05
2007	628.9	-1.44	38.5	2.53	134,354.4	1.32	19.9	3.82
2008	608.0	-3.32	39.7	3.17	135,185.3	0.62	20.5	3.12
2009	552.2	-9.19	40.5	1.99	130,647.6	-3.36	21.1	2.56
2010	494.8	-10.39	40.9	1.16	127,097.2	-2.72	21.6	2.34
2011	479.0	-3.20	41.5	1.25	128,278.6	0.93	22.0	2.00
2012	465.2	-2.88	41.7	0.53	130,287.7	1.57	22.0	0.05
2013	456.5	-1.87	42.2	1.32	132,588.8	1.77	22.3	1.45
2014	455.9	-0.14	42.5	0.62	135,128.3	1.92	22.7	1.70
2015	452.1	-0.83	43.0	1.27	137,896.7	2.05	23.2	2.29
2016	451.5	-0.13	43.8	1.77	140,400.0	1.82	23.9	2.71
2017	444.3	-1.59	44.2	0.91	142,549.3	1.53	24.3	2.01
2018	434.8	-2.14	45.4	2.65	144,733.3	1.53	25.0	2.63
2019	429.7	-1.17	46.1	1.74	146,875.5	1.48	25.7	2.96
2020	391.8	-8.82	47.6	3.06	139,099.6	-5.29	27.1	5.25
2021	368.1	-6.06	48.9	2.90	140,886.3	1.28	28.0	3.47
Total Var	-329.7	-47.3	13.9	39.5	13,379.9	10.5	10.5	60.4

Table 1 confirms that printing (NAICS 3231) has reduced its workforce by 329,700 jobs, a 47.3 percent contraction from 2002 to 2021. These figures strongly contrast with the national U.S. labor market, which created 13,379,890 jobs in the same period. In contrast, all U.S. sectors (including printing) tended to pay higher wages (in current thousand U.S. \$) in 2021 compared to 2002. More detailed comparisons are worthy of discussion, though. Statistical analysis shows that printing exhibited a detrimental performance during the 19 years, when workers enjoyed a total salary increase of 13,860 dollars between 2002 and 2021: a mere 1.68 % increase per annum. As a result, the salary gap between the printing sector and the rest of the U.S. economy is markedly growing.

This downward trend in the printing industry is crucial to our research. The effect of digitization on printing performance is inconclusive because workers' dismissal must be contrasted with payments. Therefore, we need to examine aggregated data to detect these trends.

4.2. Empirical Model

In this section, we shall perform statistical tests to verify whether digitization has affected traditional printing outlets, forcing them to shrink their workforce. So far, we have shown that the printing industry faced a drastic transformation between 2002 and 2021. It scrapped over three hundred thousand jobs while salaries grew below the national average. Although we argue that digitization is behind this condition, we can only assess its macroeconomic effects. Yet, the general tendency seems to confirm the negative digitization effect concerning the employment variable. To support our approach, we should inspect the interrelation of the employment variable with the national trend. Bivariate Pearson correlations between printing and U.S. national employment between 2002 and 2021 show a negative correlation value of -0.66, which is significant at the 0.01 level (2-tailed).

In contrast, bivariate Pearson correlations between wages in printing and the total U.S. between 2002 and 2021 exhibit a strong positive correlation of 0.99. Although this pattern demonstrates the shrinking effect of digitization on employment, further study is worth performing. Therefore, we must conduct a trend analysis of jobs from 2002 to 2021.

Several studies have examined which factors influence U.S. industrial employment. The most frequently cited are recessionary trends, international trade gaps, de-industrialization, offshoring, technological change, and recently, the COVID-19 pandemic (OECD, 2020; Acemoglu and Restrepo, 2019; Fort, Pierce, and Schott, 2018).

We test if digitization has contracted the printing industry, forcing it to dismiss workers. What interests us is whether the employment increase (decrease) rate differs from zero. So, we carried out a trend analysis of the two available time series: national U.S. and printing. There are two opposing views. One view is that U.S. total employment increased from 2002 to 2021, along with the industry examined. The alternative view is that only national employment grew, whereas the other decreased. In the first case, all of the regression coefficients must be positive. All coefficients must be negative except for the U.S. total in the second case, as shown in Equation 1.

The test will employ the following regression:

$$E_i = a + bT \tag{1}$$

where E_i denotes employment in sector i , and T is a time trend over the 19 years. What interests us is the sign of the coefficient b . A negative sign will suggest that employment (in either sector) trended downwards. Tables 2 and 3 report the results.

Table 2 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
U.S. National	0.826	0.682	0.664	3.568 E6	0.642
Printing	0.963	0.927	0.923	29,739.48	0.307

Predictors: (Constant), trend (n = 19). Dependent Variable: Employment

Table 3 Coefficients

Model		B	Std. Error	t	Sig.
U.S. National	Constant	1.256 E8	165,7704.36	75.76	0.000
	Trend	859,361.7	138,382.49	6.21	0.000
Printing	Constant	705,309.05	13,814.93	51.05	0.000
	Trend	-17,381.9	1,153.25	-15.07	0.000

As regression results show, the second view stands since the printing industry exhibits a downward trend. The b coefficient for printing is negative and significant. While national

employment grew to almost 860,000 jobs per year, the printing sector expelled hundreds of workers yearly. Yet, due to the time-dependent nature of the dataset, the Durbin Watson (D.W.) statistic values point to positive autocorrelation. Although these values are of concern, our intention is only to test for the sign of the trend. A more robust autocorrelation analysis would ask for a larger dataset, however.

Overall, regression analysis confirms a contrasting effect. Whereas global employment was diminishing, wages were rising. We think that skill composition may explain this condition. We believe that traditional printing was facing stricter business conditions derived from widespread digitization and thus being forced to adopt more advanced production practices, which, in turn, increasingly depended on more complex activities and processes. Then, the industry would try to overcome the trend by substituting unskilled workers with more qualified staff. This interpretation is nevertheless limited because a more informed examination is required. For example, controlling for external economic effects is necessary to separate the innovation effect (i.e., digitization) from other contemporary forces. Unfortunately, the research carried out in this work could not get more disaggregated data to test for this condition. Yet, it would be a promising beginning if more detailed information were available.

5. Conclusions

This research explores the disruptive impact of digitization within the Schumpeterian paradigm of rapidly evolving industrial innovations. We argue that businesses producing real, paper-based stuff have undergone the blow of digital versions of their traditional products. Even though we could only analyze the macroeconomic effects, we could infer that the swift deterioration of market conditions induced employment and salary changes due to digitization. We must acknowledge, however, that the Schumpeterian paradigm is a theoretical concept that can only partially explain the distress caused by the digitization of traditional industries. Therefore, our analysis faces the limitation of this conceptual approach. The policy implications of our empirical findings are that traditional sectors must rapidly adapt to innovation by introducing products and services based on high-value-added technologies. The transition must also consider upgrading workers' skills. One plausible route is improving in-site training practices and ICT education since digitization is constantly evolving and progressing. In this regard, future studies must consider the implications of rapidly changing technologies such as robotics and artificial intelligence on industrial structure and labor conditions. Finally, we think digitization is far from being accomplished because continual discoveries guarantee a constant flux of innovations for the foreseeable future. As a result, many more sectors can face unpredictable changes similar to those experienced by paper-based industries. We claim that the so-called "creative destruction paradigm," proposed several years ago by Joseph Schumpeter, is still valid for firms relying on antiquated processes and techniques. Unfortunately, they cannot assume that previous responses would work well under the newer conditions. So, it seems safer to think that digitization must force traditional companies to offer competitive new services and products, thus reaffirming Schumpeter's conviction that innovative entrepreneurs spur profitable ventures.

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