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Contents

Service Industrialization, Employment and Wages in the US Information Economy

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ABSTRACT

The US economy has undergone significant shifts towards services and towards information intensive industries. The latter trend has been driven by advances in information technology. These advances have concurrently led to substantial changes in the production and delivery of services, especially notable in information-intensive sectors. We examine these changes from the perspective of "service industrialization", since they are similar in many ways to the historical industrialization of goods production. We focus on the effect of industrialization on employment and wages, and identify certain important consequences of this direction. One major consequence is the impact on the customer facing services and the "front office" in addition to the effect on service processes in the "back room". An important aggregate result is a decline in white collar jobs in both those categories. A larger effect is at the sector level, with significant disruptions in

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some sectors leading to their substantial restructuring. Such disruptions are likely to occur in other information intensive sectors as well.

Keywords: information economy; service industrialization; US economy; jobs; employment; job and employment trends; information intensive services.

1

Introduction

There appear to be wide-spread popular and professional concerns about jobs, employment, and wages in the US. This is visible in articles in the popular press, in political positions across the spectrum, as well as in the academic and research literature. The concerns relate to job availability and the growing inequality in incomes and wealth. The reasons underlying the concerns include the loss of jobs to other countries, the effects of globalization and trade (including the "China effect"), differential productivity levels, and the threat of technology and automation replacing humans in jobs. To these underlying factors we could add the effects of demographics and changes in the working and dependent populations, global competition, shortcomings in education, technology-enabled restructuring of industry, and the impact of national policies in areas such as immigration and trade.

Our emphasis in this paper is on "service industrialization". This term refers to the recent and ongoing changes in the economy, and in industry sectors, markets, companies, processes and organizations, which have been enabled or created by new information technologies related to computers and telecommunications. These changes are especially concentrated in information intensive service sectors, but are also very apparent in physical services such as retailing and transportation. They are also directly and indirectly affecting many aspects of manufacturing. Our perspective of "industrialization" is based on the traditional view of that term, as applied to manufacturing and products, but expanded to include the impact of modern information technologies, which affect consumer behavior, markets, interactive communications, and social structure.

The paper has three main research objectives

- Study the impact of service industrialization on employment and wages in the US and understand the forces driving them,
- Using national income and labor data until 2017, update our earlier study of the size, structure, and trends in the US Information economy in a way of presenting a macroeconomic context for our analysis of employment and wages, and
- Identify implications of the above for management and public policy.

Our main conclusions regarding employment and wages are that

- Technology driven service industrialization has had and continues to have a substantial impact on the structure of the US economy, with the largest effect being a growth in the GNP, job and wage shares of information intensive industries
- Service industrialization has had a negative impact on jobs through automation, offshoring, outsourcing, large scale disruption, and process changes in processing and delivery. These effects are ameliorated by a growth in physical services such as food services, personal services and health care, so that there are enough jobs and unemployment has been and is likely to remain low.
- A major current effect of service industrialization on jobs is the recent decline of white collar jobs (such as Sales and related, and Office and Administrative Support) in terms of employment share and wage share.

- There have been increases in employment in the occupational categories of Management, Business and Financial Operations, Computer and Mathematical occupations. The wage shares in these occupations have also increased, since these are all high-wage job categories.

- The preceding two effects are increasing income inequality among white collar workers.

- Industry sectors showing declines in employment and wage share due to service industrialization include Retail Trade, Wholesale Trade, and Finance and Insurance.

- While the Arts, Entertainment and Recreation sector is holding up in share, specific subsectors such as music distribution and news publishing have seen severe disruptions, which do not show up in the aggregate sector figures. We believe that these disruptions will soon spread to other content delivery subsectors such as publishing and broadcast entertainment.

- Managers in many, if not all sectors need to pursue service industrialization strategies, or risk being overtaken by new entrants, or left behind as service sectors restructure

- There are significant policy implications from these shifts, arising from the impacts on jobs, and employment shifts, which directly affect wage distribution and inequality of income.

In the next section, we present a brief review of relevant literature. In the third section we discuss service industrialization and the "services revolution". We then present an update of the major trends in the US economy up to 2017, in the fourth section. As in our past work (Apte *et al.*, 2008 and 2012) we examine the structure of the US economy in terms of the breakdown of GNP and GNP shares along two dimensions: products vs. services, and material intensive vs. information intensive activities. This aggregate view clearly shows the two major trends along those dimensions: a move from products to services and from material to information. We also look at the trends in jobs and employment share, and in shares of the total wage bill. In the fifth section, we identify and discuss the forces including service industrialization that are driving the changes in the economy with an emphasis on the employment and job effects. The sixth section presents a more detailed breakdown of jobs based on SOC (Standard Occupational Classification) codes, and wages by sectors based on NAICS (North American Industrial Classification System) codes. We present the distribution of job shares and wage bill shares along these two dimensions. This gives a clear picture of the sectors and job categories that contribute the most in terms of jobs and wages, which though correlated, are not the same. We present data on how job and wage bill shares have changed over the period from 2002 to 2017. There are clear patterns that emerge, and we relate these to the previous discussion of the factors driving the trends in the economy. We then present other important observations and conclusions regarding service industrialization and demographic changes in the seventh section. In the eighth section, we discuss the implications of the trends discussed earlier for managers and policy makers to address the issues that are being faced at all levels of the economy. Finally, we present our concluding remarks about the potential for future research in the ninth section.

2

Literature Review

This section presents a brief review of the literature that studies employment and wages either in the broad context of the structural changes of the economy and the trend to the dominance of information (or knowledge) services, or in relation to some of the service industrialization processes that have been taking place. For example, there are studies that examine employment patterns along the information versus material (non-information) dichotomy that have been observed and documented. Osberg *et al.* (1989) identify three broad occupational sectors within modern advanced economies like the US and Canada: the goods sector comprising occupations that directly involve the manipulation or transformation of goods; the personal service sector consisting of occupations that involve service to other individuals; and the information sector that involves the production or manipulation of symbolic information. They argue that labor productivity in goods and data production grows steadily over time due to increasing capital intensity of production and the impact of advances in information and communication technologies (ICT). In contrast, labor productivity in the personal services and knowledge sectors does not tend to increase over time, as labor time is the output in personal services occupations and the human creativity essential to knowledge production demonstrates little tendency to increase over time.[1] These differences in productivity growth explain the relative increase in the employment of personal service and knowledge workers. They analyze occupational data between 1960 and 1980 in the US to demonstrate a relative shift in employment towards knowledge-based occupations. Wolff (2006) extends this analysis and finds that information workers (knowledge producers and data processors) increased from 37 percent of the workforce in 1950 to 59 percent in 2000 in the United States. His analysis further shows that the growth of information workers is not attributable to a change in tastes for information-intensive goods and services. According to him, changes in production technology that make it possible to substitute goods and service workers for information workers and differential rates of productivity movements among the industries of the economy are responsible for this growth. Thus, these developments seem to fit the framework of unbalanced growth. Using a slightly different classification scheme, Apte *et al.* (2008 and 2012) also examine employment and wages of information and non-information workers in the product and service sector from 1999 to 2007 in the US and observe a trend toward employment and wage growth for information workers, primarily in the service sectors.

Cortada (1998) includes an eclectic mix of articles that present historical, economic, and sociological perspectives on the rise of the "knowledge workers" – the fastest growing segment of the workforce in the world today. There are some interesting observations made in this volume. First, the emergence of knowledge workers was invariably linked to the advances in technologies. That is, knowledge workers emerged wherever technologies were advanced. Second, the shift to knowledge work began in earnest before World War I and by the end of the 1920s it became a major trend. Third, the ability of a woman to work in professional careers was made possible mainly by the rise of knowledge work rather than through any altruistic change in the

[1] In case of personal services (e.g., childcare workers, security guards), it is the labor time of the worker that the consumer purchases. In that sense, the labor time is an output.

attitude of male managers. Freeman (2002) further discusses various labor market outcomes of ICT extension to economic activity.

There has been a plethora of speculations and research-based predictions about the effects of artificial intelligence (AI) in particular and ICT in general on jobs in the United States (Brynjolfsson and McAfee, 2014; Ford, 2015). The predictions of job loss range from 45–57% (Chui *et al.*, 2015; Frey and Osborne, 2017; World Bank, 2016) to little or no effect at all (Autor, 2014, 2015). While the technology pessimists seem to focus narrowly on AI, the optimists tend to acknowledge and take cognizance of wide-ranging ICT-induced and enabled changes in examining the impacts of ICT on employment and wages. They do not deny that automation will prove disruptive in the short run. However, alluding to historical episodes of rapid technological change that created more jobs than they had destroyed, they argue that a resilient, adaptable economy would again overcome the threat of technological unemployment. Technology-induced income growth would raise demand for labor in sectors that produce non-automatable goods and for workers that perform manual-intensive tasks; higher productivity would stimulate investment throughout the economy in cooperating capital inputs; and while automation would render some jobs obsolete, it would complement many others, especially jobs that place a premium on creativity, flexibility, and abstract reasoning.

The recent literature has overwhelmingly noted the polarization of the US labor market, a phenomenon of rising employment of high and low skilled jobs together with a decline in middle skill jobs. This polarization has also led to rising wage inequality. Researchers have proposed several theoretical models to explain these empirical observations. One such model that has been widely used (Autor *et al.*, 1998, 2008; Carneiro and Lee, 2009; Katz and Murphy, 1992), referred to as the canonical model, operationalizes the supply and demand for skills by assuming two distinct skill groups (high and low skill) that perform two different and imperfectly substitutable tasks or produce two imperfectly substitutable goods. It assumes that technology takes a factor-augmenting form and, by complementing either high or low skill workers, it can generate skill biased demand shifts. Although this framework helps explain the increase in demand for and wages of high-skilled workers due to skill-biased technological progress, i.e., advances in computer technology or broadly, ICT, it does not adequately explain job polarization. Nor does it explain significant declines in real wages of low skill workers, new technologies directly substituting capital for labor in tasks previously performed by moderately skilled workers, and technology-enabled offshoring that allows foreign labor to substitute for domestic workers specific tasks.

These failures have led researchers (Acemoglu and Autor, 2011) to propose an alternative task-based framework that incorporates interactions among worker skills, job tasks, evolving technologies, and shifting trading opportunities. They assume that there are three types of skills—low, medium, and high—and each worker is endowed with one of these types of skills. Workers have different comparative advantages. Given the prices of different tasks and the wages for different types of skills in the market, firms and workers choose the optimal allocation of skills to tasks. In this framework, technological change can alter both the productivity of different types of workers in all tasks and also in specific tasks, thus changing their comparative advantages. In general, this model treats skills (embodied in labor), technologies (embodied in capital), and trade or offshoring as offering competing inputs for accomplishing various tasks. Thus, which input (labor, capital, or foreign inputs supplied via trade) is applied in equilibrium to accomplish which tasks depends in a rich but intuitive manner on cost and comparative advantage. This model is referred to as the Ricardian model of the labor market and presents a richer understanding of the current trends in the US labor market.

Extending this task-based framework further, Acemoglu and Restrepo (2018) have recently proposed a model in which technological progress proceeds on two fronts: automation and the creation of new more complex tasks that only human labor can perform. A representative agent invests in AI capital that serves as a perfect substitute for labor in a subset of potentially automatable tasks. In this model, endogenous directed technological change drives the economy onto a balanced growth path with automation and the creation of complex, new AI-immune tasks advance at the same rate, provided labor supply is increasing in the ratio of the wage to capital income. Ceteris paribus, advances in automation then reduce the demand for labor relative to capital if the elasticity of substitution between tasks that produce the final good is close to the elasticity of substitution between task-specific intermediate inputs and labor services. The short- and medium-run impact on absolute labor demand is unclear, but in the long run, after the capital stock fully adjusts, the real wage increases and labor's share in national income returns to its original level. When labor is divided into high- and low-skill workers, the same restrictions ensure that the skill premium increases in the short run but not the long run.

Assuming that robot capital is different from traditional capital in its degree of substitutability with human labor and that only capitalists and skilled workers save, Berg *et al.* (2018) present another model that shows that while automation is good for growth it is bad for equality, particularly in the short run. Despite these attempts at modeling AI and automation, as Frank *et al.* (2019) argue, a lack of empirically informed models of key micro level processes, and insufficient understanding of how cognitive technologies interact with broader economic dynamics and institutional mechanisms is a formidable barrier to measuring the effects of AI and automation on the future of work. A lack of high-quality data about the nature of work is another challenge.

Furthermore, most studies on the impacts of automation do not seem to differentiate between software, robotics, and AI. However, as Muro *et al.* (2019) note, these technologies may have very different impacts on the labor market outcomes. In particular, the impact of AI technology and its potential applications on productivity and labor market outcomes is delayed due to complementary investments and innovations (Ericsson, 2018). In a recently published working paper, Webb (2020) makes the distinctions between the technologies subsumed under automation. Applying a new method that uses the overlap between the text of job task descriptions and the text of patents, he constructs a measure of the exposure of tasks to these different technologies for the US. The analysis presented in the study predicts that, in contrast to software and robots, AI is directed at replacing high-skilled tasks. As one of the implications of this the author reports that AI will reduce 90:10 wage inequality but will not affect the top 1%.

There is a literature that examines the effects of offshoring on employment and wages. Some studies (e.g., Apte and Mason, 1995; Mithas and Whitaker, 2007) look at these issues through the lens of global disaggregation of information-intensive services that have been made possible largely by the advances in ICT. Apte and Mason (1995) develop a classification framework to identify the services and jobs, which are most amenable to service disaggregation. Building on this classification scheme, Mithas and Whitaker (2007) propose and empirically validate a theory of service disaggregation, which argues that a service with high information-intensity jobs makes it relatively more amenable for disaggregation. Their analysis shows that high information-intensive occupations requiring higher skill levels have experienced high growth in employment but a decline in salary growth. Furthermore, occupations with a higher need for physical presence have also experienced higher employment growth and lower wage growth. However, the scope of these changes in production and delivery of services (particularly, information-intensive services) is far greater than just spatial disaggregation of the supply chain, as noted by Karmarkar (2004). Along the same line, Blinder (2007) uses the US labor data to estimate that somewhere between 22% and 29% of the US jobs are or would be potentially offshorable within the following decade or so. However, as Barbe and Riker (2018) point out, the effects of offshoring on employment depends on a number of factors, such as skills and type of offshoring. Some studies tend to present evidence of adverse effects of offshoring on low-skill workers and of positive effects on high-skill workers. Similarly, different types of offshoring have either positive or negative impacts on employment in the home country. Given this heterogeneity, it is often difficult to assess the overall impact on employment in the economy.

When considered separately, these industrialization strategies seem to have significant negative impacts on employment. However, few studies examine the overall impacts of these strategies together. For some of these strategies (e.g., self-service, sharing economy), it is difficult to quantify the impacts as they may not impact a particular job in its entirety but may affect only certain aspects or tasks associated with the job leading to reorganization of tasks or re-engineering of processes (Brynjolfsson *et al.*, 2018).

3

Service Industrialization

By service industrialization we mean technology driven changes in the industrial processes by which information goods and services are produced and delivered.[1] The purpose is to identify the drivers of process changes, and the consequences for industry structure, competition, jobs, and wages. Industrialization itself is driven by many decisions, for the most part made locally and internally, by managers and decision makers in order to improve the competitive performance and profits of their firms and organizations.

There are analogies between the industrial revolution of the late 18th and 19th centuries, and the recent and ongoing changes in information economy. For manufacturing, industrialization was driven by a set of complementary factors including the application of sources of power such as water, steam and electricity, the mechanization and automation of processes to leverage human ability, and increases in the efficiency of transportation and logistics using rail, roads, and shipping. Important facilitating approaches included a process of standardization starting with products, going to processes, and leading to mass production. This

[1]The material in this section is partly drawn from Karmarkar (2004, 2010, 2014) and Apte *et al.* (2012, 2015).

required precision of specification and measurement to support product standardization.

All the driving factors for industrialization in manufacturing have now appeared in information production processes as well. Clearly there have been vast increases in basic processing capability as observed by Moore's Law (1965). Correspondingly, the ability to automate and leverage human capabilities in data and information processing has increased, starting with mechanical devices such as card sorters and calculators, and going to computers. The telegraph, telephone, radio, and TV were big leaps in communication capabilities that occurred decades ago. But they all had their limitations, of which one was the inability to integrate well with computers. Major advances came quite recently with packet switched data networks, the internet and the world-wide web. These innovations, enabled by protocols and standards as much as by hardware, created the explosion of information logistics in the 1990s. What is new about modern data communications systems is that they integrate seamlessly and digitally with the processing and storage resources, allowing for end to end integration of information chains and networks.

The process of standardization is also occurring in information production for goods and services, but the path is different in that it is associated more with processes rather than products. By and large, the starting point has been the standardization of the way information is represented in terms of symbols, and then bits. The next step has been the standardization of processes. An early step was the creation of a standardized process of production: printing with blocks or movable type. The two together allowed for the mass production of books. Modern computational tools of course depended upon binary arithmetic and Boolean algebra. Production, storage and processing tools evolved from the mechanical, to the electro-mechanical and to the electronic. So the standardization process for information products and services can be thought of in stylized form as

- standardization of information representation in symbolic form
- standardization of processing and processes at the machine, operating system and CPU level

- standardization of products and services with standards for processing, file formats and interfaces.

Just as with physical production, an eventual consequence of standardization has been process modularization. This has led to object oriented software, client-server and multi-tier system architectures, and distributed computing. Today we are in the middle of a new wave of modular operation with service oriented architectures, syndication, containers, Application Program Interface (API), and web services.

The standardization of information processes at the machine and process level, is now visibly migrating upwards into transaction handling and business processes. The most systematic example on the transaction side has perhaps been in telecommunications. At a basic level, standardization of business transactions has been widespread in banking and other financial services, and in inter-firm transactions facilitated first with standards like Electronic Data Interchange (EDI) and later with Extensible Markup Language (XML) and other document and file formats. With higher level business processes, the degree of agreement and standardization is far lower, but companies like SAP, IBM, Microsoft, Amazon, and Google are competing to define standardized business processes, though often in proprietary forms.

Industrialization could as well be thought of in large part as the creation and application of new technologies. Whether it is in the enhancement of processing power (computers), or in more effective logistics (telecommunications), new technologies are involved. The process of creating, commercializing and adopting technologies is a part and parcel of industrialization, and inseparable from it. Issues like standardization (for example, communications protocols) enable commercialization and adoption of technologies, just as they support industrialization. We might say that technology development and adoption processes are a major part of industrialization, though not all of it.

In manufacturing, industrialization was associated with scale economies and increased centralization of processing. But for information intensive processes, especially in recent decades, the trend has been towards miniaturization, low power, mobility, and the dispersion of processing. There are indeed scale economies associated with some aspects of processing as with server farms, telecom fiber lines, digital switches and network equipment. However, advances in technology as exemplified for many decades by Moore's Law have meant that productive capacity has advanced faster than physical scale even in these cases. Rapid, cheap, and ubiquitous transport has enabled efficient sharing of centralized processing, storage and logistics resources as services thereby reducing fixed costs and capital expenses for many users while improving the utilization of assets. The trend to everything-as-a-service (XaaS) and the growth of third party services has greatly reduced fixed costs for firms, and moved capital expenses to operating expenses. The end result is that the costs of entry and operations have dropped dramatically in information intensive sectors, thereby intensifying competition.

The "pull" aspect of industrialization, as with technological development, comes from the actions of firms both established and new, to compete more effectively and to create markets and profits. In practice, service firms industrialize to compete more effectively, and to increase or maintain profitability. The service industrialization that we observe at the level of process decisions (Apte *et al.*, 2015; Karmarkar, 2004; and Karmarkar and Apte, 2007) include

- Automation
- Off-shoring
- Outsourcing
- Process restructuring
- "Servicization" or "Servitization"
- New Markets and Exchanges, including asset sharing markets and micro-markets
- Social communication and interactive networks
- Operations shifting (within processes)
- Self-service (shifting operations to the customer)

Many of these strategies are analogous to factors in the industrialization of manufacturing, though some such as self-service and social networks are much more prevalent with information intensive services. There are also substantial new policy issues that arise in areas such as regulation, security, and contracting, as well as in the creation and operation of infrastructure (as with the internet), the assignment of rights (as with the radio spectrum and intellectual property), educational policy and taxation. However, our focus in this paper is mainly on service industrialization and its consequences for jobs, employment and wages.

4

Major Trends in the US Economy

The major structural changes at the macro level provide the broad context for service industrialization. We observe two relevant developments over past half of a century. The first is the gradual shift from products to services (see Chase and Apte, 2007). The service sector has become the dominant sector generating most of the wealth and employment in the economy.[1] The second development involves a shift of economic activities from material to the information domain of the economy. Machlup (1962) and Porat (1977) were among the first to identify and quantify this shift. Although there are methodological issues with both studies, they were followed and replicated in subsequent years.[2] Porat's (1977) method of measuring information economy is consistent with the conventional national income accounting (NIA) framework and therefore the measures can easily be compared with the government-published national income and product accounts measures. According to Apte *et al.* (2012), the share of the information economy in the US GNP grew

[1]Sociologists refer to this stage of society's development as the post-industrial society, a term popularized by Daniel Bell (1973).

[2]For example, see Machlup (1980), Rubin and Taylor (1981), OECD (1986), Apte and Nath (2007), Apte *et al.* (2008 and 2012).

from about 46.3 percent in 1967 to about 60 percent in 2007. An update of these measures places this share at about 62 percent in 2017.[3]

4.1 Broad Sectoral Changes

Apte *et al.* (2008) juxtapose the two broad trends discussed above to propose a conceptual framework for analyzing the structural changes in the US economy. The "double dichotomy", as they call it, divides the economy into four super sectors: material products, material services, information products, and information services. This decomposition and its evolution over time are extremely important for understanding service industrialization. There seems to be an endogenous relationship between the changes in the industrial and business processes involving production and delivery of information goods and services – which we have called service industrialization – and the evolution of the information services sector.

In terms of value addition to the US economy, the information services super sector is identified as the largest and fastest growing segment of the economy over a three decade period until the beginning of the 21st century. According to Apte *et al.* (2012), while it is still the largest super-sector, its relative growth has been somewhat slower in recent years. We update the calculations of Apte *et al.* (2012) for 2012 and 2017, and present the summary in Figure 4.1.[4] As the figure illustrates, the contribution of information services to the US GNP increased from about 36 percent in 1967 to more than 49 percent in 1992, the very beginning of the Internet era. These services grew faster than the other segments of the economy until the turn of the century, then slowed down, and finally have been growing faster again since 2012, Consequently, after a decline in its relative GNP share from about 57 percent in 2002 to less than 54 percent, it has grown to about 57 percent again in 2017. While cyclical fluctuations of the economy may have something to do with the slower growth, a spurt in industrialization activities after the great recession may be intricately related to this

[3] Appendix A includes a brief description of the methods and the updated measures.

[4] For details, see Appendix A.

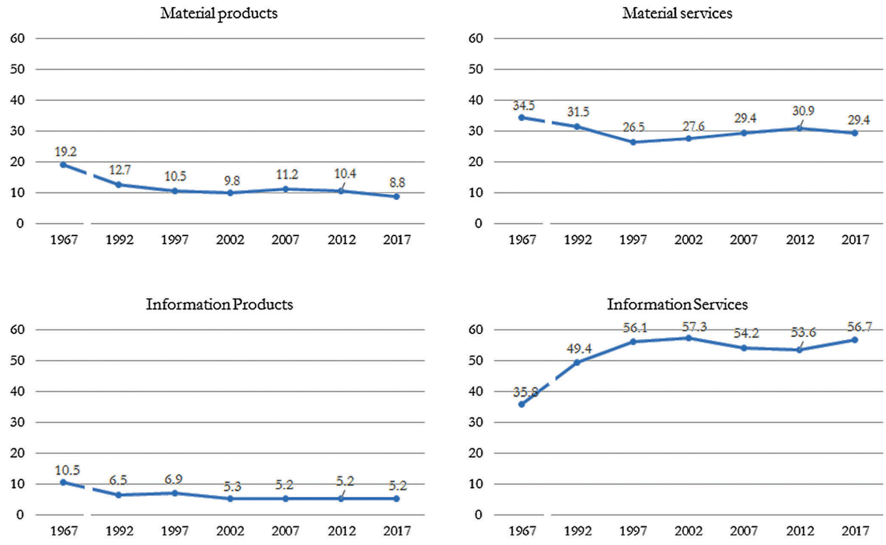

Figure 4.1: 2 × 2 decomposition of GNP in 1967, 1992, 1997, 2002, 2007, 2012, and 2017 (vertical axes represent percent share in GNP). Detailed data tables are included in Appendix A.

growth of the information services. However, these conjectures need formal validation, which is beyond the scope of this paper.

4.2 Broad Changes in Employment and Wages

As Apte *et al.* (2008 and 2012) argue, when a task-based classification of employment into information and non-information (material) is superimposed over the traditional products versus services classification of industries, it gives a new perspective that is pertinent to an understanding of the potential impacts of service industrialization on employment and wages.

Table 4.1 presents the 2×2 decomposition of total employment, wage bill, and average wages in the US economy for 1999, and at five-yearly intervals between 2002 and 2017.[5] Note that it included the year right after the 2001 recession, the time periods just before and after the great

[5]For a brief discussion on the methods, see Appendix A.

Table 4.1: 2×2 decomposition of employment, wage bill, and average wages in the US economy: 1999–2017

	Percentage Shares of Employment				**Percentage Shares of Wage Bill**				**Average Annual Wage (in Current USD)**		
	Products	**Services**	**Total**		**Products**	**Services**	**Total**		**Products**	**Services**	**Total**
1999											
Non-information workers	10.00	45.15	55.15	Non-information workers	8.63	37.46	46.09	Non-information workers	27,061	26,039	26,224
Information workers	4.00	40.86	44.85	Information workers	6.21	47.70	53.91	Information workers	48,793	36,629	37,713
Total	14.00	86.00	100.00	Total	14.84	85.16	100.00	All Workers	33,264	31,070	31,377
2002											
Non-information workers	8.48	43.73	52.21	Non-information workers	7.35	36.12	43.47	Non-information workers	30,796	29,362	29,595
Information workers	3.11	44.68	47.79	Information workers	4.76	51.77	56.53	Information workers	54,402	41,187	42,047
Total	11.59	88.41	100.00	Total	12.10	87.90	100.00	All Workers	37,127	35,338	35,545
2007											
Non-information workers	7.54	44.70	52.23	Non-information workers	6.37	36.83	43.20	Non-information workers	34,419	33,529	33,658
Information workers	2.80	44.96	47.77	Information workers	4.31	52.49	56.80	Information workers	62,691	47,502	48,392
Total	10.34	89.66	100.00	Total	10.69	89.31	100.00	All Workers	42,077	40,536	40,696

Continued.

Table 4.1: Continued

	Percentage Shares of Employment				Percentage Shares of Wage Bill				Average Annual Wage (in Current USD)		
	Products	**Services**	**Total**		**Products**	**Services**	**Total**		**Products**	**Services**	**Total**
2012											
Non-information workers	6.23	47.45	53.68	Non-information workers	5.02	37.86	42.88	Non-information workers	36,862	36,534	36,572
Information workers	2.94	43.38	46.32	Information workers	4.62	52.50	57.12	Information workers	71,946	55,412	56,462
Total	9.17	90.83	100.00	Total	9.64	89.46	100.00	All Workers	48,109	45,551	45,785
2017											
Non-information workers	5.87	48.33	54.20	Non-information workers	4.66	38.44	43.10	Non-information workers	40,198	40,261	40,254
Information workers	2.77	43.03	45.80	Information workers	4.28	52.62	56.90	Information workers	78,144	61,901	62,884
Total	8.64	91.36	100.00	Total	8.94	91.06	100.00	All Workers	52,367	50,452	50,618

Note: The figures for 1999, 2002, and 2007 are taken from Apte *et al.* (2012). For 2012 and 2017, authors' calculations based on OES data from BLS.

recession, and finally the year when the US economy seemed to have completely recovered from the great recession.

For each year, the distribution of employment and wage bill in terms of percentage shares among the four categories of workers is indicated by a combination of the descriptions along the relevant rows and columns. For example, in 2017, non-information workers in the products sector accounted for 5.87% of the total employment and only 4.66% of total wage bill in the US economy. The last column and the last row also present the total for the categories under each dimension of the double-dichotomy. Thus, workers in the products sector accounted for 8.64% of total employment and approximately 8.94% of total wage bill in 2017, while workers in the services sector accounted for the remaining 91.36% and 91.06% of employment and wages, respectively. In contrast, non-information workers constituted about 54.2% of total employment and about 43.1% of total wage bill in that year. Correspondingly, information workers accounted for about 45.8% and 56.9% of employment and wages, respectively. The figures under the "average wage" column represent average wages (in current dollars) of the four categories of workers. For example, a non-information worker in the products sector earned an average income of USD 40,198 in 2017. The table also presents average wages by broad categories. Thus, a worker in the products sector, on average, earned USD 52,367, while he/she earned USD 50,452 in the services sector in 2017. In contrast, a non-information worker, on average, earned USD 40,254, while an information worker earned USD 62,884 per year in the same year.

Figures 4.2 and 4.3 present the employment and wage-bill shares of information and non-information workers by product and service industries. In Figure 4.4, we show the evolution of average real wages (deflated by annual consumer price index–CPI–data with 1982–84 as the base year compiled by BLS) by these four categories of workers. We note that the average real wage for the information workers in the service industries increased more rapidly than that for other categories of workers from 2007 to 2017 although average real wage was the highest for information workers in product industries throughout the period.

Figure 4.2: 2×2 decomposition of employment by types of workers and industries (vertical axes represent percent share in total employment).

We make the following observations from the data analysis presented in the table and the figures. *First*, a majority of all workers were employed in the services sector. The share of services employment had increased from 86% in 1999 to approximately 91% in 2017. Within services, non-information workers were the largest constituent for almost all years with about 45% of total employment in 1999 and about 48% in 2017. The employment share of information workers rose from about 41% in 1999 to about 45% in 2007, becoming the largest category of workers in the economy. However, the share declined subsequently to about 43% in 2017. In the products sector, the employment shares of both information and non-information workers have been steadily falling. Along the information–non-information dichotomy, the non-information workers accounted for about 55% of total employment in 1999, and this share dropped to about 52% in 2007 but then it climbed up to about 54%.

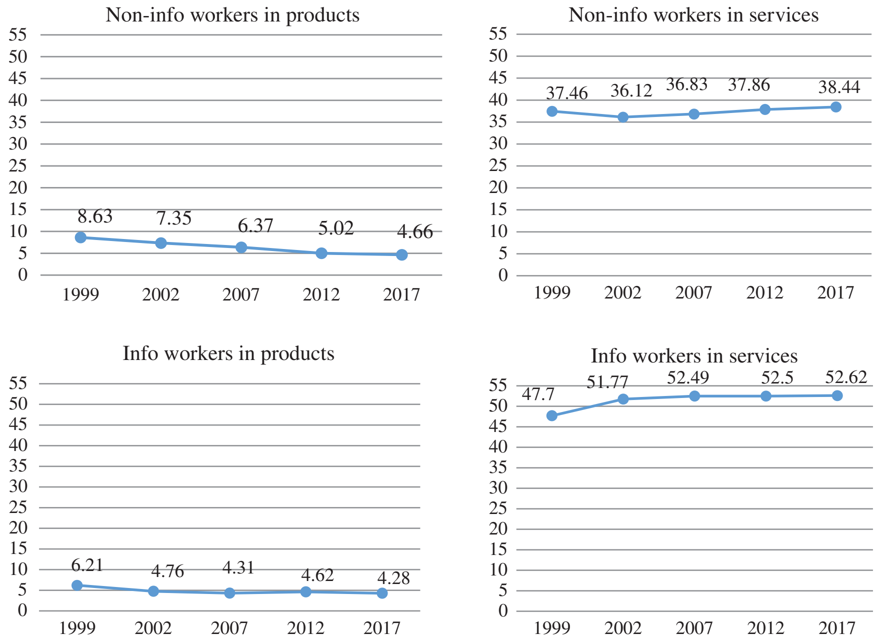

Figure 4.3: 2 × 2 decomposition of wage bill by types of workers and industries (vertical axes represent percent share in total wage bill).

Second, services workers received the largest share of the total wage bill in the US, and this share increased from about 85% in 1999 to about 91% in 2017. Within services, information workers received the largest share, accounting for about 48% of total wage bill in 1999. This share rose steadily to 53% in 2017. The wage bill share of the products workers steadily declined, with slight fluctuations for information and non-information workers over that period. Furthermore, the overall share of information workers in the total wage bill increased from about 54% in 1999 to more than 57% in 2012, and then it declined slightly.

Third, average wages were higher in the products sector. Within this sector, information workers in 2017, on average had earnings about 1.94 times higher than non-information workers. In the services sector, information workers earnings were about 1.54 times higher than those

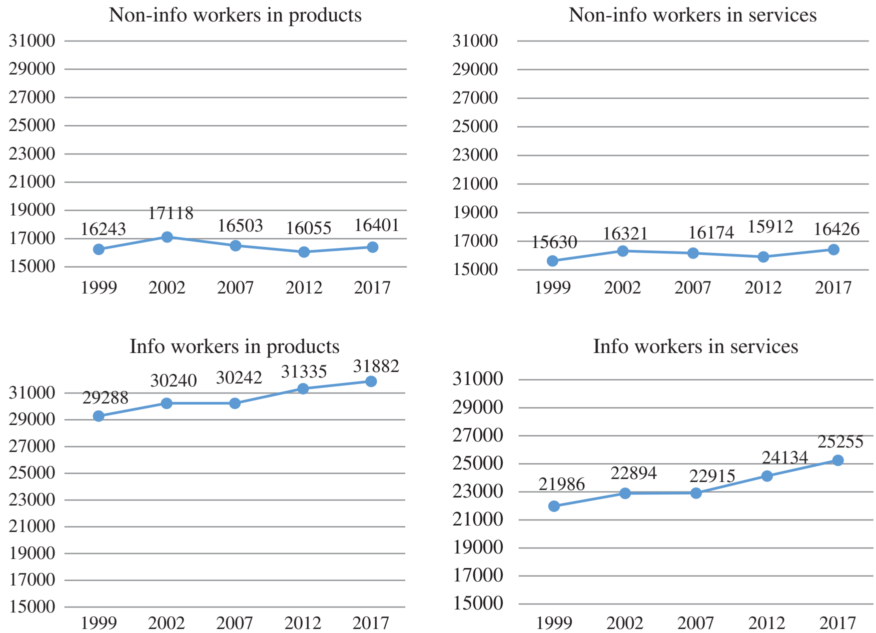

Figure 4.4: Average real wage by types of workers and industries (vertical axes represent average real wage at 1982–84 constant prices).

of non-information workers. Overall, the average wage of information workers was 1.56 times greater than that of non-information workers. However, there are sectoral differences in the earnings of information workers. On average, they earned about 1.04 times higher in the products sector than their counterparts in the services sector in 2017. This ratio has declined over the years. Higher average wages in the products sector appeared to be a reflection of the fact that most information workers in the products sector were engaged in "high-end" information jobs, while a large number of information workers in the service sector were engaged in "low-end" information jobs.[6] We also observes that the

[6] By "high-end" information jobs, we refer to those jobs that require high cognitive skills and innovative ideas, such as managerial jobs, scientists, designers, etc., and by "low-end" information jobs, we refer to those jobs that are routine or repetitive in nature and do not require very high cognitive skills or innovative ideas, such as travel agent, customer service representative, etc.

wage differences in average wages for non-information workers between products and services industries have disappeared in most recent years.

5

Service Industrialization, Jobs and Wages

In this section we examine the impact of service industrialization at a detailed level including specific occupations. In the following section, we consider the effects at an aggregate level of industry sectors and occupational categories. A major source here as in the following section, is the Occupational Employment Statistics (OES) database from the Bureau of Labor Statistics (BLS) that provides data on employment and wages for various SOC categories of occupations by NAICS categories of industries (sectors). Industrialization strategies are implemented via decisions and choices made by managers in companies, so as to improve profitability and competitiveness as summarized in Section 3 above. Some of the mechanisms that we discuss are also visible in aggregate at the sector or occupation level as described in the next section. However some effects are not, even when they are seemingly obvious to the casual observer at a company and job level. It is apparent, for example, that there are fewer tellers serving customers, and that retail banking is moving to automated online and mobile transactions quite rapidly. However it is not always easy to see significant movement in occupational categories at the industry and sector level. In some cases, there are other changes that can hide certain effects – for example, deregulation of banking resulted in a pattern of growth in bank branches that tended to hide the ongoing automation of teller functions. As an example, an FDIC report in 2014 noted that the number of bank and thrift offices actually grew about 23% from 1995 to 2009 despite substantial implementation of computers.[1] As a result, the number of teller jobs did not decline till after 2007. After 2009, there was a decline in the number of branches of almost 5% till 2014, but the cause of that was not clear and could have been the recession rather than technological change. In other words, in many cases following historical trends for aggregate data does not always provide clear evidence of the changes actually underway at the detailed job category and sector level.

In the remainder of this section we discuss the effects of industrialization strategies, and look for specific examples of leading indications of shifts in employment. These shifts can happen with dismaying rapidity with little time for adjustment by management or workers.

5.1 Automation

An aspect of industrialization that has received considerable attention in the past is the substitution of capital for labor in the form of automation including both soft and hard technologies, applied to production processes and the delivery of both goods and services. While the motivation for implementing automation is usually the reduction of recurring labor costs, automation can also improve quality, especially in the sense of conformance and reliability, and provide improved spatial and temporal access. Automation tends to apply typically at the level of operations, and occasionally at the level of processes. Automation, often anthropomorphized as the replacement of workers by "robots", has received considerable attention recently. We have discussed this literature in Section 2. Most of the studies in this literature deal with analytical models of substitution for labor; a few include data analyses.

The automation and mechanization of information related operations began a long time ago with printing, broadcasting and telecommunications, and later with equipment such as typewriters, cash registers, and

[1] https://thefinancialbrand.com/50382/fdic-branch-mobile-behavior-report/ (accessed September 15, 2019).

calculators. Productivity and efficiency increased, but the employment effects were largely positive in the aggregate. However, modern computers started a wave of automation that had a negative impact on certain jobs. In particular, many back-room tasks ranging from data management, recording, word processing, internal transactions and computation have been affected, and clerical, secretarial and accounting jobs are all impacted. The next wave of automation, still in process, includes what might be called “front office automation” affecting jobs in customer response, counter service, transaction handling and sales. One of the current shifts in service processes is the automation of transactions such as airline check-in and grocery check-out. The next level of automation includes tasks with more interaction and information processing, such as bank teller services. The employment of bank tellers (SOC code 43-3017) declined by over 52,000 between 2012 and 2017 and by over 107,000 between 2007 and 2017. Between 2012 and 2017, employment of Financial Clerks (SOC code 43-3000), a category that includes tellers as well as certain backroom data related tasks, declined by over 102,000. BLS studies forecast that bank teller employment (SOC code 43-3071) will decline by over 42,000 between 2016 and 2026.[2] Figure 5.1 presents a graph of teller employment from 2002 to 2018, and Figure 5.2 shows the same data in terms of job share. The patterns are basically similar. It is interesting that the employment numbers actually grew till about 2005, after which there has been a steady decline.

5.2 Outsourcing and Off-Shoring

Outsourcing of work to onshore providers may or may not always reduce jobs in the aggregate. However, with work that has economies of scale due to pooling effects, process efficiencies or capital substitution, job numbers can well be reduced. Off-shoring or the movement of jobs to other countries is typically employed to reduce labor costs, as when call centers are moved from the US to Asian locations such as the Philippines and India. Much software development has gone off-shore. Offshoring of course reduces employment. It also affects tax revenues, and the

[2] https://www.bls.gov/emp/tables/occupations-largest-job-declines.htm (accessed September 15, 2019).

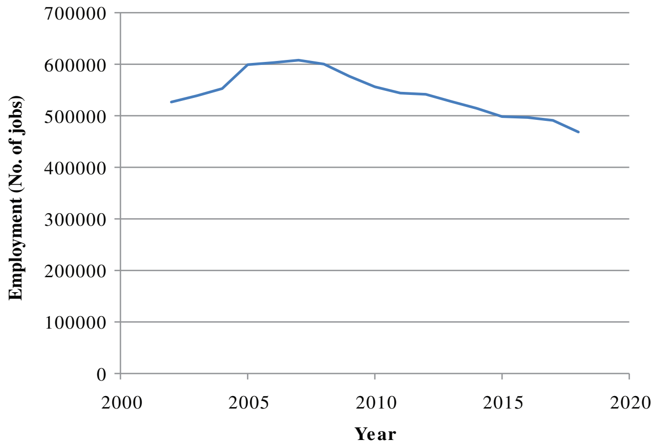

Figure 5.1: Employment of tellers (banking), number of jobs (2002–18).

multiplier effects of expenditures by wage earners. An early paper on the technology enabled disaggregation and geographical dispersion of jobs is Apte and Mason (1995). Other recent work on the impact of off-shoring includes the papers by Apte and Karmarkar (2007), Blinder (2007), and Blinder and Krueger (2013).

Call centers are a well-known example of outsourcing and off-shoring. Many countries are involved in off-shore provisioning of business services,

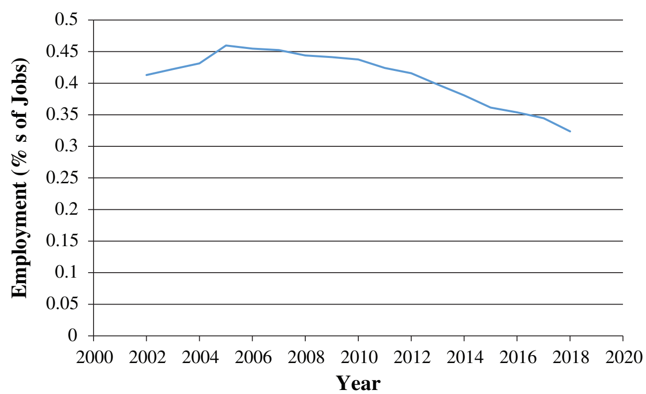

Figure 5.2: Job share of tellers (banking) as % of total private employment (2002–18).

with India, China and Malaysia being the leading locations in 2019.[3] India was the leader for call center services for the US for a period but was overtaken by the Philippines in 2011.[4] In 2011, the Philippines had over 400,000 workers in call centers and India still had over 350,000 agents. These numbers by implication are indicative of the substantial impact on US employment.

Another consequence of outsourcing and off-shoring is the continued decline of jobs for computer programming, even as the information economy has grown. Employment for programmers (OCC code 15-1131) declined by 69,600 from 2012 to 2017. The Bureau of Labor Statistics (BLS) forecasts that employment in that category will decline by over 21,000 from 2016 to 2026.[5]

5.3 Operations Shifting and Self Service

Operations shifting refers to the movement of a task from one part of a process to another. It often results in the elimination of a process step and the associated job(s). For example, a significant proportion of document formatting now gets done at the point of creation of a document by the author, with the use of the automated capabilities of word processing software.

In 1984, "Secretary" was the leading occupation in almost all states in the US. By 1990, this was no longer the case, and after 2000 it was true for just a few states.[6] The jobs that were done by secretaries historically included document preparation, document filing, phone response, calendar maintenance, scheduling, office administration and sundry tasks for managers and other office personnel. Many of these tasks and operations have shifted to the personnel served, so that most managers now answer their own phones, work on their own documents, respond to calls, and manage their own schedules. The employment

[3] https://www.statista.com/statistics/329766/leading-countries-in-offshore-business-services-worldwide/ (accessed September 15, 2019).

[4] https://www.nytimes.com/2011/11/26/business/philippines-overtakes-india-as-hub-of-call-centers.html (accessed September 15, 2019).

[5] https://www.bls.gov/emp/tables/occupations-largest-job-declines.htm, op.cit.

[6] https://www.npr.org/sections/money/2015/02/05/382664837/map-the-most-common-job-in-every-state (accessed September 15, 2019).

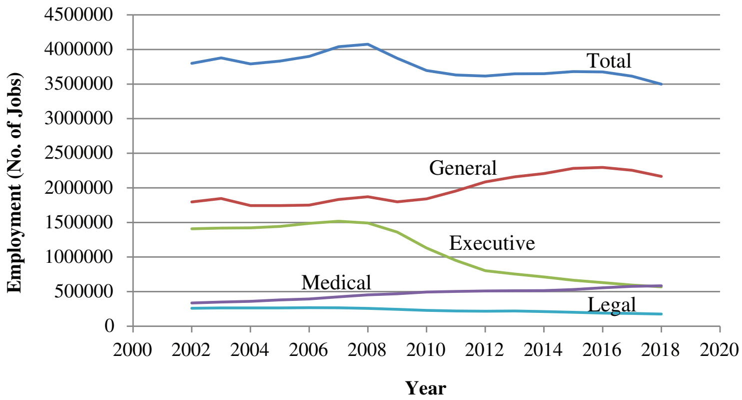

Figure 5.3: Employment of secretaries (total, general, executive, medical, and legal), number of jobs (2002–18).

of Secretaries and Administrative Assistants (OCC code 43-600) has dropped by over 16,000 from 2012 to 2017. BLS forecasts suggest that those jobs will decline by over 192,000 in the period from 2016 to 2026.[7]

Figure 5.3 shows the number of secretarial jobs over the period 2002–2018. The total across all categories is flat till about 2008, and then drops steadily. Looking at the breakdown of the total across categories, we see that executive secretary jobs are the major factor in the decline of the total number, dropping sharply after 2008. Legal secretary jobs show a steady decline over this period, while medical secretary jobs increase. The "all other" or general category of secretaries actually shows gains till 2016, and then begins to decline. Figure 5.4 presents the same data in terms of employment share as a percentage of total private sector employment.

Self-service is a major form of operations shifting; there are many examples related to transactional services such as sales, e-commerce and retail banking, which are increasingly done by customers and clients interfacing with an automated system. Such shifts can increase productivity and efficiency by reducing communications and transactions in the system, or by using more efficient and lower cost resources. The secretarial jobs mentioned above partly involve self-service by managers

[7] https://www.bls.gov/emp/tables/occupations-largest-job-declines.htm, op.cit.

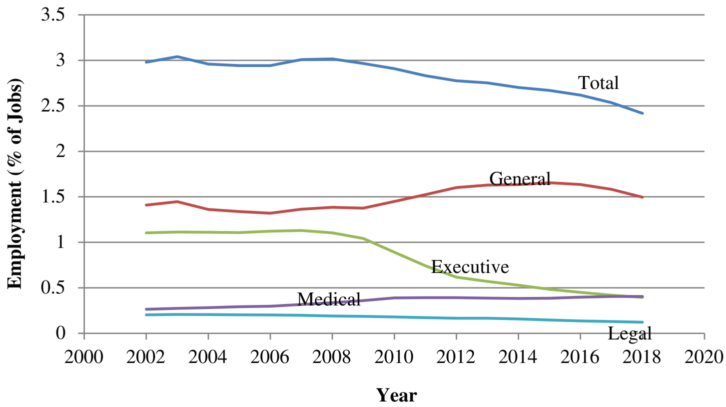

Figure 5.4: Job share of secretaries (total, general, executive, medical and legal), percentage of total private employment (2002–18).

who have taken on many tasks that secretaries would have done for them in the past.[8]

Consumers are increasingly performing many functions which used to be done by service providers. Automation aided self-service has the potential for affecting customer facing jobs for transactions like grocery checkouts and airline check-ins. One example is the purchase of travel services such as airline flights. The number of travel agents (OCC code 41-3041) has declined by over 20,000 from 2007 to 2017. BLS studies forecast that travel agent employment will decline by over 9,000 jobs between 2016 and 2026.[9] Figure 5.5 shows the employment decline for travel agents and reservation and travel clerks for the period 2002–2018. For travel agents, after an initial decline up to 2009, there is some recovery till about 2017, with a decline perhaps resuming after that. The number of reservation and travel clerks declines steadily. Figure 5.6 presents this data in terms of the percent share of total private sector employment, and it is clear that these categories are declining in their contribution to total employment.

The decline of tellers (mentioned above) can also be connected to self-service as might the secretarial services decline of the previous section.

[8]https://newrepublic.com/article/121712/slow-death-secretary (accessed September 15, 2019).

[9]Ibid.

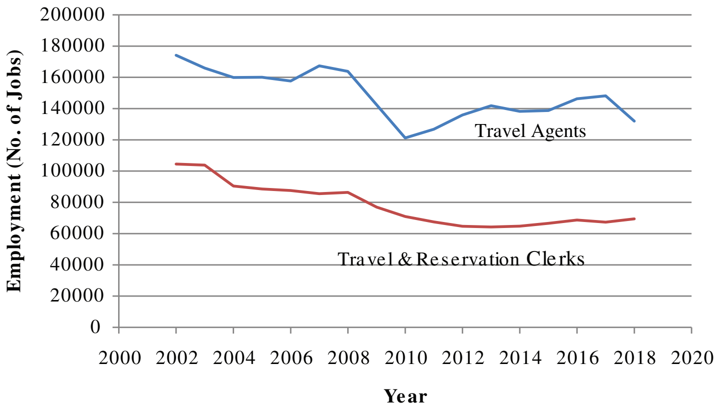

Figure 5.5: Employment of travel agents and travel and reservation clerks; number of jobs (2002–18).

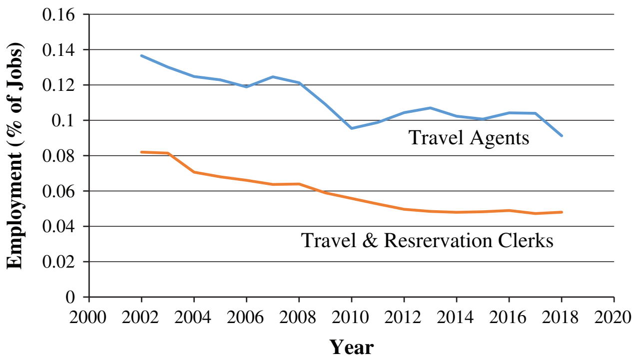

Figure 5.6: Job share of travel agents and travel and reservation clerks; percentage of total private employment (2002–18).

As mentioned elsewhere, self-service is often directly associated with and complemented by automation. Automation of functions such as flight check-in, grocery store checkout without cashiers (as with Amazon Go), and further expansion of automated retailing with vending machines, will support self-service in these areas.[10,11] These all also demonstrate

[10] https://apex.aero/2018/02/13/automated-checkin-manual-flight-checkin-passing-on (accessed September 15, 2019).

[11] https://www.theverge.com/2018/9/17/17869294/amazon-go-store-chicago-cashier-less (accessed September 15, 2019).

the application of automation, and the complementarity of automation and self-services. Of course, the collateral effect is reduced jobs and employment.

5.4 Process Redesign and New Services

Process redesign is often enabled by new technologies and followed by consequences for jobs. In some cases, existing service processes are being replaced with entirely different processes. For example, online distribution has changed many sectors which involved content delivery. An example with large employment consequences is the replacement of physical (paper) letters by email and messaging. This has had clear and severe effects on the US postal system. The shift to digital imaging has affected film and camera sectors with the large decline of photo processing and development services. Online video distribution is beginning to affect film and television. Consumer banking transactions are going online and today shifting to mobile devices thereby affecting teller jobs. The same is true for e-commerce and retailing.

Online technologies and devices have also created new services and new service designs. Online maps and GPS have substantially replaced paper map usage in countries like the US. Further, they have created new location based services such as live traffic guidance, local advertising and emergency services. These new services could lead to an increase in jobs related to system design, software development, system operations and maintenance.

5.5 New Market Mechanisms and Exchanges

New market mechanisms can permit alternative industry structures which may be substantially different. First, since an online sales "location" does not hold inventories, it has low costs of operation. Inventories are pushed further back at suitable locations in the relevant supply chains. The online retail site becomes an order taker, rather than an inventory, delivery, and/or shipment point. In some cases, a retail platform can act as a channel for other sellers, as with Amazon and Alibaba. The traditional structure of manufacturer/producer, wholesaler and retailer can change substantially. First, the retail channel consolidates into fewer sites. It is possible for a new “order fulfillment” inventory layer to appear, that can also be highly consolidated. Amazon also takes on that role. The wholesale layer may still retain bulk aggregation, variety provision, and warehousing functions. However, in the extreme case it is possible that the wholesale layer could disappear for some sectors if logistics chains are reorganized to provide smaller shipments directly from producer to end customer with so called “drop shipping”. With information content, this is a very likely outcome. With books in electronic form (e-books), there is really no wholesale role left. Publishing is initially likely to fragment, which is already happening with the appearance and rapid growth of “indie” publishing with new entry including direct to customer sales, aided by the low costs of entry and distribution.[12] Eventually, the publishing role could be shared between creators and retailers possibly with third party editing services supporting one or both of these.

Changes in information chains have job impacts at all levels, including retail and wholesale distribution, as well as logistics and transportation. It is possible that the fragmentation of roles at the production and aggregation levels could have a positive impact on jobs and wages, but this is not entirely clear as yet.

By exchanges we mean mechanisms for sharing outputs, without direct monetary transactions between provider and consumers. Examples are websites and platforms where individuals share content, not necessarily in a reciprocal manner. Examples include YouTube, Instagram and Pinterest. On the one hand these sites do not directly create jobs in the sense of one entity hiring another or a buyer paying a vendor. However, there are many individuals that make money through advertising income earned from views of their content. The top few earners on YouTube in 2017 made around $10 million per year; however most make much less. The total net advertising earnings for YouTube in 2017 were $3.5 billion and the share going to associates might be

[12] http://www.bowker.com/news/2018/New-Record-More-than-1-Million-Books-Self-Published-in-2017.html; https://www.geekwire.com/2018/traditional-publishers-ebook-sales-drop-indie-authors-amazon-take-off/ (accessed September 15, 2019).

around $2.5 billion.[13,14] While not inconsiderable, this number is not very significant in the context of the US economy. On the other hand, such sharing exchange sites, now occupy a substantial amount of the time and attention of users. At least some of this time is not spent either in consuming other (paid) services, or in production of goods and services. The former may reduce the money flows from the activities which have been substituted, while the latter could result in decreased net productivity. It is possible that the net result in aggregate could be a decrease in jobs and earnings, though not in aggregate consumption.

5.6 Sector Disruption

In many cases the changes for sectors go beyond the alteration of a process, to severe disruption of entire sectors. Technological substitution, automation, outsourcing and other industrialization strategies are often implemented concurrently at the level of operations and sub-processes. With such substitution, while local operations are altered, the overall process structure can remain much the same. For example, as classroom teaching goes from blackboards to whiteboards to slide projection, the overall education process does not change very much. Even at a larger scale, as in the case of outsourcing and offshoring, there may be simply a different geographical dispersion and distribution of essentially the same processes. However, when combined with new process and service designs and new market mechanisms, the entire structure of a sector or industry can be radically changed. As teaching goes further towards recorded lectures and online distribution, the education sector is liable to be significantly changed in terms of its structure and "business model". The consequences may include new entry, new production and delivery processes, changes in supply side contracts, price declines, declines in total revenue to the sector, job losses, failures of some firms, and consolidation in the industry. At this point, a sector can fairly be said to have been "disrupted".

[13] https://beebom.com/highest-paid-youtubers-2017/ (accessed September 15, 2019).

[14] https://www.statista.com/statistics/289660/youtube-us-net-advertising-revenues/ (accessed September 15, 2019).

The creation of new markets and exchanges can create changes in industry structure in a couple of different ways. Even straightforward automation of an existing marketplace, has the potential to create substantial changes. Online sales and e-commerce are having large impacts on many sectors. Sales of books in paper form were Amazon's first line of business. While Amazon may not be the sole reason, many book chains have gone out of business in the past two decades, including Atlantic Books, B. Dalton, Crown Books, Kroch's and Brentano's and Waldenbooks. The growth of e-books will only accelerate this trend.

Recently, some sectors related to content creation, processing and distribution have been severely disrupted by technological shifts in processes. One example is the recorded music industry which has been completely restructured as the mode of distribution shifted from physical recording media to downloaded files and now to streamed music. Along with that, there have been reductions in the costs of recording, storage and processing. Music distribution revenues have gone from a peak of $21 billion in 1999 to about $7 billion in 2015 (inflation adjusted). There was then an increase in the next two years due to a very rapid growth of streaming with the associated subscription revenues, to about $9 billion in 2017.[15] It is likely that streaming will continue to grow, while physical media and file downloads continue to decline. There is already growing competition in streaming services, and we expect that it will affect prices and revenues after a couple of years. We expect that total revenues will grow for a couple of years, and then plateau or perhaps even decline slightly as other media disappear. However, the industry will probably not recover to historical levels.

Similarly, newspaper publishing revenues which were largely from advertising, have dropped from a peak of about $60 billion in 2004 to less than $32 billion in 2014 and are likely to fall much further to a point of near extinction of print news by 2025.[16] Employment in US newspapers fell from a peak of around 460,000 in 1990 to 183,000 in

[15]https://www.riaa.com/u-s-sales-database/ (accessed September 15, 2019).

[16]http://www.pewresearch.org/fact-tank/2017/06/01/circulation-and-revenue-fall-for-newspaper-industry/ (accessed September 15, 2019).

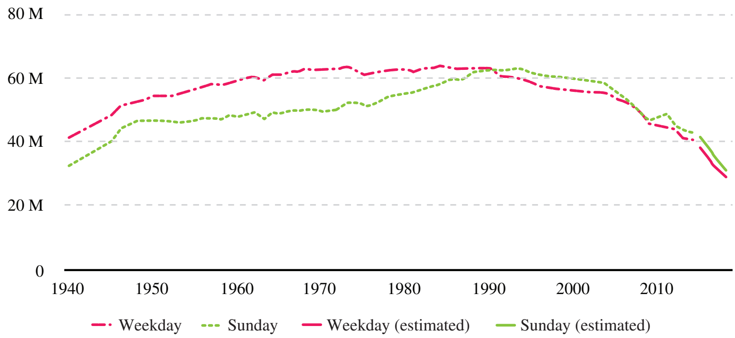

Figure 5.7: Total US newspaper circulation (Pew Research Center); https://www.journalism.org/fact-sheet/newspapers/ (accessed October 15, 2019).

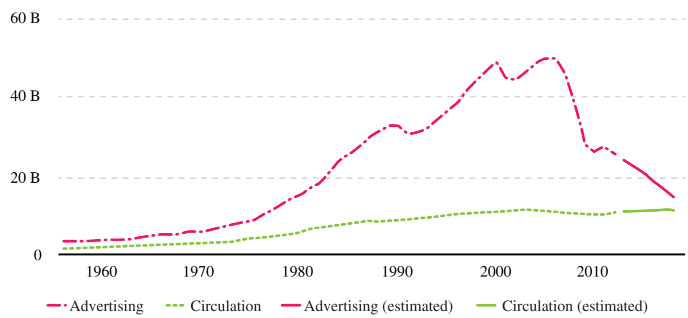

Figure 5.8: Total US newspaper revenues (Pew Research Center); https://www.journalism.org/fact-sheet/newspapers/ (accessed October 15, 2019).

2016, a decline of almost 60 percent.[17] These are dramatic changes in earnings and employment though they are not highly visible at the aggregate industry or occupation level. Incumbent firms are moving to online channels, but that shift does not at all compensate for the losses.

Figure 5.7 shows the total circulation numbers for US weekly and Sunday newspapers from 1940 to 2012, with projections till 2020. The recent declines are rapid. More telling is the revenue data in Figure 5.8, which first of all makes it clear that it is advertising revenue and not circulation revenue that is important for newspaper publishing.

[17] https://www.bls.gov/opub/ted/2016/employment-trends-in-newspaper-publishing-and-other-media-1990-2016.htm (accessed September 15, 2019).

Circulation revenues actually seem to be holding up; however, the decline in advertising revenues is substantial and is driven by the shift of advertising money to online channels.

5.7 The "Gig" and Freelance Economy

In the past two decades we have seen a shift to a new kind of work. The traditional "full-time job with benefits" is becoming less common, replaced by new "gig" or "freelance" work where individuals engage in supplemental, temporary, or project- or contract-based work. Recent surveys suggest that about 57 million Americans or about 36% of US workforce have some type of gig work arrangement.[18,19] Furthermore, 43% of workers work remotely at least some of the time.

It is difficult to define gig or freelance work since there are at least four types of freelancers: independent contractors, moonlighters, diversified workers, and temporary workers. With such a broad diversity of workers there are many reasons why they choose to do the gig work, but two most common reasons are to "earn extra money" and to "have flexibility in schedule". Gig work certainly has its challenges including the two biggest obstacles which are a "lack of stable income" and "difficulty in finding work". Emerging technology is now making it a little easier to find work. Specifically, the low transaction costs and flexibility of online markets have enabled the growth of the "gig" or "freelance" economy, the size of which is currently estimated to be about $1 trillion.[20]

The effect of gig work on jobs and wages could be mixed. On the one hand, the ability to get and execute part-time work is enhanced. On the other hand, the competition for work may become more intense, resulting in lower wages to workers. There could also be a reduction in the benefits available to workers.

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[18] https://www.gallup.com/workplace/240929/workplace-leaders-learn-real-gig-economy.aspx (accessed September 15, 2019).

[19] https://www.upwork.com/press/2019/10/03/freelancing-in-america-2019/ (accessed February 9, 2020).

[20] https://www.upwork.com/press/2019/10/03/freelancing-in-america-2019/ (accessed February 9, 2020).

5.8 Asset Sharing, Micro-Markets, and Matching Platforms

As with the previous case, the low transaction costs and broad reach of online market mechanisms have enabled the growth of a "sharing" economy, in which assets can be more easily rented or leased rather than bought (Apte and Davis, 2019). Sharing services represent a new wave of businesses that use platforms and cloud-based technology to match customers with providers of services such as short-term apartment rentals, car rides, and household tasks. Airbnb, HomeAway, Uber, and Lyft are some of the best known and most successful sharing economy service (SES) companies. Most individuals do not use their most expensive assets very intensively, be they cars, homes or many household goods and furnishings. If individuals could, at their own discretion, share some of these underutilized assets with others, they would recover some of the marginal cost of using those assets, resulting in lower average costs. This notion of sharing underutilized assets and recovering the marginal cost of using them, plus a portion of the fixed cost of owning these assets, is an important driver of today's sharing economy.

The impact of the sharing economy on jobs and wages presents a mixed picture. A fundamental issue is demand elasticity. As prices drop with increased entry and competition, demand may not increase correspondingly. In ride sharing, even if demand increases substantially, the income to individual drivers could still be small due to many entrants and the wages of incumbents could drop over time. As ride sharing services have enabled the entry of many individuals in the market for providing short term transportation, the costs of rides have dropped. Furthermore, the competition from new entrants and the growth of supply have affected the wages earned by traditional taxi and limousine drivers and vehicle or fleet owners. Of course, for the case of taxi and ride services, the industry will eventually be substantially disrupted even further by autonomous vehicles resulting in a large loss of jobs and wages for drivers.

6

Aggregate Changes in Employment and Wage Bill Shares

To obtain an overview of the current distribution and recent changes in employment and wages, we employ data organized along two dimensions. One of these is by industry where we consider industries at the 2-digit level of NAICS codes, giving 20 aggregate sectors. The second dimension is that of occupational categories using the SOC system at the 2-digit level of aggregation, which gives 22 job categories. As mentioned earlier, these data are available from the OES database of BLS. The resulting data can be organized as a matrix with 440 cells for all the sector-occupation category combinations. For each combination (cell) we have compiled data on the number of jobs, average hourly wage rates, and total wage bill for 2002, 2007, 2012, and 2017, covering a span of 15 recent years at 5-yearly intervals. This breakdown allows for examination of effects that occur at the sector level, at the job level, or both.

As a first step, we look at the employment and wage share of the sectors and occupational categories separately. We transform the data in terms of the percentage shares of total employment and total wage bill. This to some extent normalizes for changes in population and work force, although not for demographic pattern changes. The share data also enables a clear look at which sectors and work categories provide the jobs in the economy and at where changes are occurring in the relative levels of the provision of jobs and the capture of wages and income. We examine the changes that have occurred in these percent shares over the period of 15 years (from 2002 to 2017). Looking at these changes allows us to identify the sectors and occupational categories that are the most significant for growth or decline in employment and total wages.

The summary data are presented in Appendix B. Tables B.1 and B.2 show employment shares as percentages for the 20 sectors (NAICS 2-digit categories) for four years in the 15 year period, and the changes in the percentages over the three five years intervals 2002–07, 2007–12 and 2012–17 as well as over 15 year interval. Tables B.3 and B.4 show wage bill shares as percentages and changes in those percentages, for the same periods for industry sectors. Tables B.4, B.5, B.6, B.7 and B.8 provide information on employment and wage bill shares and changes in shares for the 22 occupational categories (2-digit SOC codes). The data on employment and wage share trends by industry sectors in Tables B.1 and B.3, are also shown graphically in Figures 6.1 and 6.2, so that the trends can be easily seen. Similarly, Figures 6.3 and 6.4 show employment and wage share trends for occupational categories.

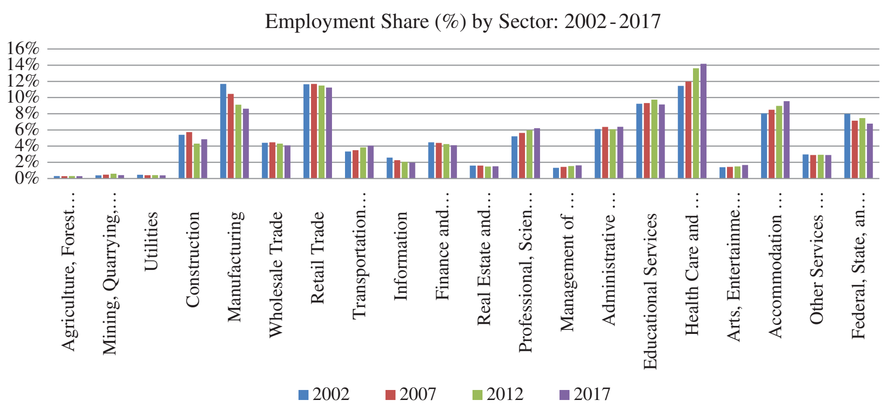

Figure 6.1: Share of total employment (%) by sector (2-digit NAICS codes) in 2002, 2007, 2012, and 2017.

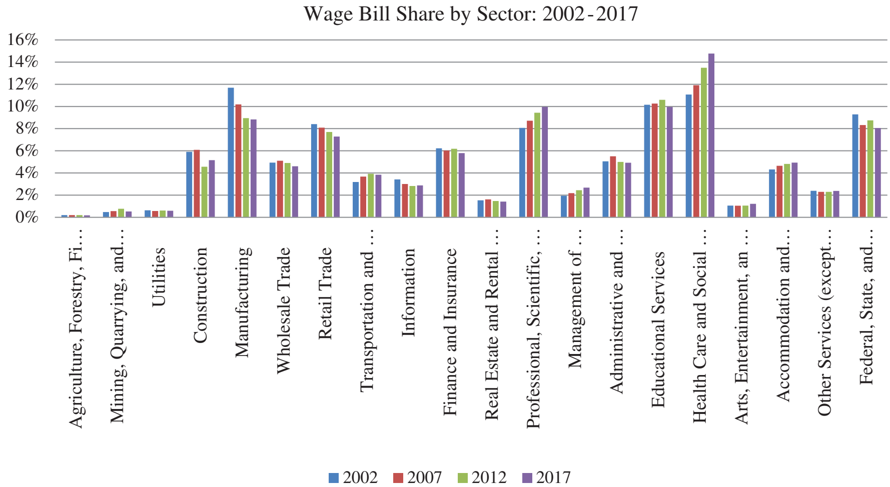

Figure 6.2: Share of the total wage bill (%) by sector (2-digit NAICS codes) in 2002, 2007, 2012, and 2017.

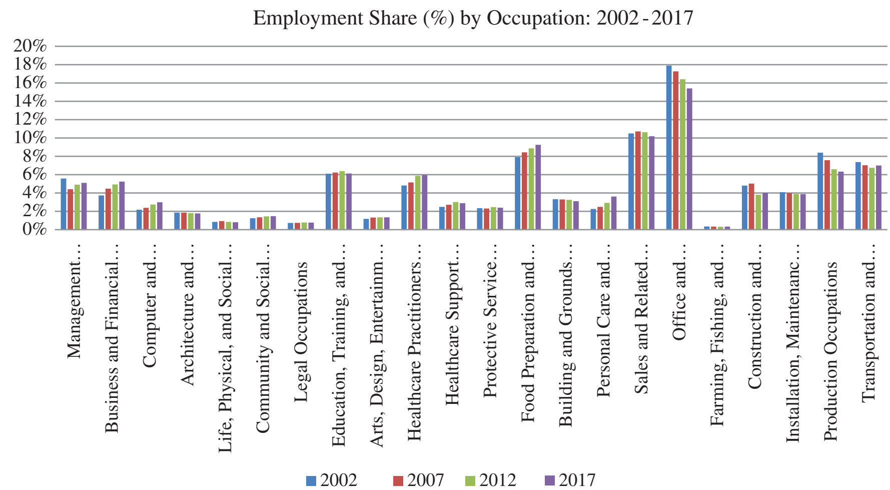

Figure 6.3: Share of total employment (%) by occupational category (2-digit SOC codes) in 2002, 2007, 2012, and 2017.

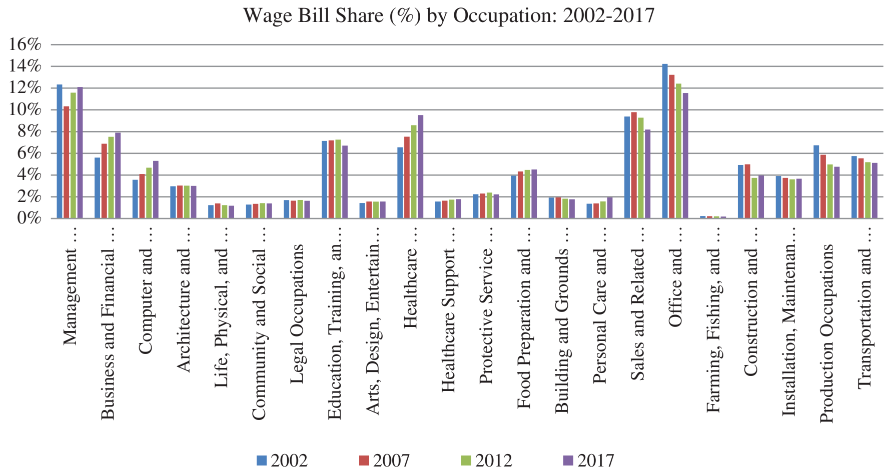

Figure 6.4: Share of wage bill (%) by occupational category (2-digit SOC codes) in 2002, 2007, 2012, and 2017.

6.1 Employment and Wage-Bill Share Changes for Sectors and Occupations

The service sectors with the largest job shares over the period from 2002 to 2017 (Table B.1) are Health Care, Retail Trade, Accommodation and Food Services, Educational Services, Federal, State and Local Government, Administrative and Support services, and Professional Scientific and Technical Services. The service sectors with the largest shares of the wage bill (Table B.3) include Health Care and Social Assistance, Educational Services, Professional Scientific and Technical Services, Federal, State, and Local Government, Retail Trade, and Finance and Insurance.

For occupational categories which involve service provision (Table B.5), large employment shares accrued to Office and Administrative Support, Sales and Related, Food Preparation and Serving, Transport Workers, Education, Training and Library, and Healthcare Practitioners. Occupational categories with the largest wage bill shares (see Table B.7) were Office and Administrative Support Workers, Management, Sales and Related, Health Care Practitioners and Technicians, Education, Training and Library, and Business and Financial occupations.

Of all service sectors, Federal, State and Local Governments had the largest declines in job share from 2002 to 2017 (Table B.2). Other large losers were Information, Construction, Retail Trade, Finance and Insurance, and Wholesale Trade. These sectors also showed the largest wage bill declines (see Table B.4). Sectors gaining in job share were Health Care and Social Assistance, Accommodation and Food Services, Professional, Scientific and Technical Services, and Transportation and Warehousing. The largest gains in wage bill share were in Health Care and Social Assistance, and Professional Scientific and Technical Services. Also gaining in wage bill share were the Management of Companies, Transportation and Warehousing and Accommodation and Food Services.

For Occupational Categories, the largest declines in job share from 2002 to 2017 (see Table B.6) were for Office and Administrative Support Occupations, Construction and Extraction, Management Occupations, Transportation and Material Moving and Sales and Related. The largest gains were for Business and Financial Operations, Personal Care and Service, Food Preparation and Serving, Health care Practitioners and Computer and Mathematical Occupations. The largest declines for wage bill shares were for Office and Administrative Support, Sales and Related, Construction and Extraction, Transportation and Material Moving and Management Occupations (see Table B.8). The largest wage bill share growth came in Healthcare Practitioners and Technical, Business and Financial Operations, Computer and Mathematical, Personal Care and Service, and Food Preparation and Serving.

Some of the changes that are occurring in the US employment and wage bill picture, are due to factors such as global competition in product markets (which continues to impact manufacturing jobs), the aging of the US population (affecting health care and personal care sectors and occupations), and significant declines in construction, which are perhaps a consequence of the recession and the subsequent problems in housing markets. So there are certainly large job share changes that are due to both long term secular trends as well as short term economic shocks. Those causes aside, we examine the effects for jobs and wages that may be attributed to "service industrialization".

Perhaps the most significant and broad impact of service industrialization is the shift of work away from low end white collar jobs in administration, office and clerical work, both in terms of employment (job share) and in wage bill share. Secretarial jobs have declined substantially as that work is increasingly dispersed to be performed by all. This is a form of "operations shifting" or self-service. The decline of jobs in the Office and Administration category cuts across many industry sectors including construction, utilities, manufacturing, real estate and rental management, and educational services.

The Information sector continues to see decreases in job share, as the outsourcing and off-shoring of information work such as software development, information systems development, and system management continue. The wage bill share of this sector does not decline to the same extent, since the jobs that remain tend to be at higher levels of sophistication. So the average wage rate in the sector has actually risen.

The Finance and Insurance sector was very early to employ information and communication technologies, first in back-room data base applications, then for B2B transaction handling, and now in the B2C customer interface for access and transactions. However, these changes coincided with the removal of regulations on interstate banking and inclusion of other financial services with banking. As a result there was a period of mergers and acquisitions and of geographic expansion which to some extent masked the effects of industrialization. However, the global recession has intensified the reasons for using industrialization strategies, and we see that the job share as well as the wage bill share has declined for this sector. Examining job categories within the sector shows that the largest decline in jobs is for office and administrative support positions and this is also where wage bill share declines have occurred.

The Retail Trade sector has declined in job share but the decline in wage bill share is even larger. Going deeper into the data shows that job declines are the largest in Sales while there is some growth of jobs in Office and Administrative Support. The wage bill declines are also largest in Sales, but there are also wage share declines in Office, Administration and Management. Then there are declines in both jobs and wage share for Transportation and Materials Movement. It would appear that ecommerce, and online sales are having their expected effect on sales jobs and to a lesser extent on management, administration and logistics.

Educational Services as of now have not yet experienced the full impact of what is likely to occur in the future with online education. However, we see a decline in job share, which falls on those providing education, while there is an increase in management positions. Correspondingly, there is a decline in wage share which falls disproportionately on the educator positions, while wage shares have risen for management and business occupations within education. This is a sector which could potentially see considerable disruption due to technology in the future.

There are some sectors where there have already been substantial changes and disruptions due to technology, but the effects are swamped at the level of aggregate data due to the size of the US economy. As described in the previous section, music distribution has been decimated as the mode of distribution has shifted from physical recording media, to downloaded files and now to streamed music. Music distribution revenues have dropped dramatically, but the decline is not large enough to show up at the aggregate sector level. Employment in US newspapers fell about 60% from 1990 to 2016.[1] Again, this drop is not visible at the aggregate industry or occupation level.

[1] https://www.bls.gov/opub/ted/2016/employment-trends-in-newspaper publishing-and-other-media-1990-2016.htm (accessed September 15, 2019).

7

Observations and Conclusions

Jobs are continually created and destroyed in the economy at rates much higher than the net result. For example, in 2014, about 16 million jobs were created while about 13 million jobs were destroyed, resulting in a net increase of about 3 million jobs.[1] In the recession year of 2008, the net change was a loss of about 3.57 million jobs. It is worth noting that typically, the number of jobs created or destroyed may be four to seven times the net change. Of course, one could expect that the variability in the net difference numbers would be much higher than that in the increases or decreases. While in "normal" years, the net rate of job creation can be surprisingly stable, that is not the case around recessions. Furthermore, there is considerable heterogeneity in the rates seen in different industry sectors in both absolute and relative terms.[2] For the last decade, most of the changes in jobs have come from services, but there have been substantial continuing losses in manufacturing. It is also likely that the patterns of job creation and decline are in transition

[1] https://www.glassdoor.com/research/jobs-created-jobs-destroyed-what-to-watch-in-fridays-jobs-report/ and https://www.bls.gov/data/ (accessed September 15, 2019).

[2] https://www.bls.gov/opub/ted/2001/may/wk2/art02.htm (accessed September 15, 2019).

as the mix of jobs in the economy changes towards services and towards information intensive services, as well as in the other ways shown in the previous section in terms of the growth and decline of sectors and categories.

In the large, the biggest factors driving changes in employment and wages are technology, demographics, and global trade.[3] All of these have demand and supply side implications. Apart from quantity correlations, there could also be scale effects and shifts in sector sizes. Demographic patterns affect sectors like education and health care directly. The retirements of baby-boomers are a factor across all sectors and for employment levels and GNP levels. Another factor that is significant for US demographic patterns is immigration, or rather its decline. Trade and global competition have had a major impact on manufacturing jobs, and much of the decline there can be traced to imports of goods from lower cost suppliers. The US has a surplus in agricultural product trade, but that does not translate into job increases, though agricultural employment is clearly related to the history of immigration, legal or otherwise. The connection between technology and employment happens via several aspects of service industrialization, since services are today and in the future, the major source of employment.

7.1 Service Industrialization

It is apparent that technology driven service industrialization has had and continues to have a substantial impact on the structure of the US economy, with the largest effect being a growth in the GNP, job and wage share of information intensive industries. The growth in wage share of the latter super-sector has implied a growth in aggregate income inequality, since, the average wage rate in that sector is significantly higher than in the material product and service sectors. So as job share increases for information intensive industries, there will initially be an

[3] The effects of demographic changes and global trade on employment and wages have been extensively discussed in academic literature as well as in media outlets. For example, see Little and Triest (2002), Docquiera *et al.* (2018), and Bivens (2008). For growth of the US trade in information-intensive services-which may have implications for employment and wages, see Apte and Nath (2012).

increase in the variance of wage levels across the working population. This also happens to other measures of inequality like the Gini Index till the proportion of the higher wage level jobs exceeds 50%. At that point the effect reverses. There are changes at detailed sector and occupation levels which have the same effects within those categories.

A striking and substantial effect of service industrialization is the recent decline in white collar jobs including those at the customer interfaces as in Sales and Related (SOC code 41-000), and in the back-room as with Office and Administrative Support (43-000), in terms of both employment share and wage share. This is a new phenomenon, as those categories grew substantially during the 20th century, and were a major source of jobs for college educated workers. These declines cut across most industry sectors, which is to be expected, since the mechanisms causing the declines are common and applicable in many sectors. Specific examples of declining job categories include sales counter employees, tellers in banks, and clerks in financial and other institutions.

It is often said that the automation of some basic jobs will allow the reassignment of that workforce to more challenging and interesting jobs. There is some truth to that, as evidenced by increases in the occupational categories of Management (11-000), Business and Financial Operations (13-000), and Computer and Mathematical (15-000) for both employment and wage shares. The growth is especially noticeable for wage share since these are all high wage job categories. However, the increase in job share is not large, and does not compensate for the decreases in the lower paid white collar job categories in job numbers. There is also a higher requirement for education and ability, which may not permit easy mobility between job categories. Again, looking at just these white collar categories in aggregate, there is a net decline in jobs, with an increase in the inequality of wages within the white collar professions.

Other industry sectors showing declines in employment and wage share due to service industrialization include Retail Trade (NAIC Codes 44-45), Wholesale Trade (NAIC Code 42), and Finance and Insurance (NAIC Code 52). The former (trade) sectors are affected by the automation of sales and front office transactions, automation of physical processes, and automation of data management. For Finance and Insurance, the declines are due to the automation of white collar work (as above), with some off-shoring and outsourcing effects as well.

While it appears that the Arts, Entertainment and Recreation sector (NAIC Code 71) is in aggregate holding up in share, there are declines in specific subsectors related to content distribution. In particular, music distribution and news publishing have seen severe declines in revenues and employment. However, since these sub-sectors are not all that large, the declines do not show up in the aggregate sector numbers. Nevertheless, these disruptions are due to some common factors that cause changes in the entire acquisition and delivery chain, including ease of access by customers, consumption via personal (mobile) devices, low cost content storage with no declines on sale, instantaneous response to demand, and very low costs of transport and delivery. There is every reason to believe that these same factors will soon affect other content delivery subsectors such as publishing, and broadcast entertainment including radio and TV. A large content intensive sector which is eventually very likely to be threatened is education. The first signs of disruption are showing up there over the last decade.

7.2 Demography

Like most other advanced economies, the US is "aging", which is to say that the decline of birth rates, the large bulge of aged baby boomers, and longer life expectancy are causing a rise in the average age of the population. Furthermore, the baby boomer generation has reached retirement age, so that over the next few years, many individuals will retire at rates higher than historical average rates. The consequence is that the total size of the workforce is already flattening and may soon decline though that also depends on immigration policy and patterns. Many jobs will open up because of retirements and there may not be enough workers available to fill them. While in the past, immigration was a source of population and workforce growth for the US, it is not clear today if this will continue to be the case in the near future in the same way as in past decades. This situation is already visible (in 2019) when the number of jobs available exceeds the number of individuals searching for jobs.[4] Of course, there may still be unemployment, since the skills of those searching for jobs do not necessarily match the skills required for the available jobs.

A second demographic factor is the economic and ethnic mix of the US population. This also correlates with the age distribution in the population. The proportion of "non-Hispanic whites" or "whites of European descent" in the US is declining, while other minorities are showing increases, with the largest group being "Hispanics". This is due to both past immigration rates and higher birth rates in the Hispanic population.[5] The changes in ethnic mix have implications for income distribution, educational attainment, demand patterns, and thence for jobs and wages.

7.3 Other Factors

There are several other issues that affect jobs and wages, such as global competition and government policies. We do not study them in this paper, but some are directly and indirectly visible in the data and analysis of Sections 5 and 6. Global competition has had very significant implications for many sectors in the US including automotive, apparel, household goods, electronic products, and energy, which in turn have had large consequences for jobs and wages. Economic development around the world is likely to raise the level of competition in some of these sectors. Global markets are also likely to grow with such development. The US is a leading exporter in many product sectors, and in agriculture and services. Trade is also closely associated with off-shoring, which is a part of global competition. Within the US, there also appear to be many concerns regarding education, especially relative to the direction of the economy.[6]

Government policies have substantial effects for employment and wages. Public sector employment including the defense services is a

[4] https://www.cbsnews.com/news/the-u-s-has-1-million-more-job-openings-than-unemployed-workers/ (accessed September 15, 2019).

[5] http://news.bbc.co.uk/2/hi/americas/7559996.stm (accessed September 15, 2019).

[6] https://www.brookings.edu/blog/social-mobility-memos/2016/12/23/the-declining-productivity-of-education/ (accessed September 15, 2019).

major source of jobs which has gone through many changes in recent decades. Policy examples include welfare and social subsidies, minimum wage limits, and requirements on benefits. Trade policies being put forward by the current administration (in 2018), and the responses to those by other countries could have large effects on competition and productivity in the US as well as in other countries.

8

Implications for Management and Public Policy

The depth of the changes due to service industrialization implies that managers and decision makers at all levels of firms are affected. At the process level, industrialization strategies are core management levers for process improvement. One way to think about any organization is that it is a bundle of processes that provide services to internal and external customers. The internal processes and services are very much subject to industrialization. There are some broader structural effects that should be understood. One of these is modularization. It is technically easier to break processes into smaller modules, and to recompose or recombine them in different ways. These changes can be supported by the appropriate use of technology and process design. Apart from cost and efficiency, such changes can also deliver higher reliability, wider access, and better variety and customization. In sum, there are many opportunities for improved process design and operations management, which are likely to be very important for competition, profitability and even the survival of firms (Karmarkar and Apte, 2007).

Taking a broader view, industry processes are also liable to modularization, and their outputs to commoditization, due to the general availability of technologies. This suggests making better choices with respect to company positioning, since commodity processes which are not high contributors to profit can be more easily outsourced. Labor intensive steps show prospects for automation, outsourcing and off-shoring. The changes in process economics can mean more entry and more intense competition, including higher levels of segmentation and niche formation. All of these changes can be highly disruptive, and may result in very significant repositioning of firms and restructuring of sectors.

There are of course, rather substantial implications for individuals in the work force. It is well known that returns to all kinds of college education are quite high, with significant advantages over the high school (GED) and Associate level education. However, this could change for many college majors, due to declines in routine white collar jobs, in both numbers and wage rates. There are some indications that the returns to education in aggregate are already diminishing.[1] At the same time, there appear to be more jobs with high wage levels, requiring higher levels of education in management and technical specializations including health care delivery (as shown in Section 6). So returns are likely to depend on the specific area of education, with better results for management and technical areas, and less so for general liberal arts than in the past.

There are concomitant implications for decision makers in public institutions. First of all, employment in government is declining, and industrialization is likely to take that further. The US is not yet seen as a leader in "e-government" today and does not make the "top-ten" lists.[2] But it is likely that the pressure to improve on that dimension will continue to increase, with the downside of job losses. The demand for higher skills and specialization in every government function is also likely to increase, especially in areas related to security and defense. So again, there may be a combination of growth in technical and specialized areas in both employment and wage share, with declines in basic white collar categories.

[1] https://www.wsj.com/articles/the-diminishing-returns-of-a-college-degree-1496605241 (accessed September 15, 2019).

[2] https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2018 (accessed September 15, 2019).

A major challenge for government is to recognize that distributed, myopic and un-coordinated private sector and market mechanisms cannot cope with many of the issues raised by industrialization with respect to jobs and employment. The trends of the last few decades as outlined in this paper suggest that there are likely to be large shifts in employment between sectors, potential increases in income inequality, and higher returns to certain kinds of education for all kinds of jobs. A related issue is the surprisingly low and flat rate of social mobility in the US.[3] There appears to be a need for improved policies that can compensate for what the private sector seems to be unable and unmotivated to correct.

Finally, we believe that the issues raised and the trends apparent for jobs and wages are likely to continue to operate and to become more serious. It appears that the solutions to these issues will require significant policy initiatives on the part of the government as well as socially conscious actions by businesses and managers.

[3] https://www.brookings.edu/blog/social-mobility-memos/2018/01/11/raj-chetty-in-14-charts-big-findings-on-opportunity-and-mobility-we-should-know/ (accessed September 15, 2019).

9

Future Research

The effects of technology and industrialization on jobs are mixed, but with a net job decline, especially in white collar jobs in the "front office" and "back room". These job effects are ameliorated by a growth in physical services such as food services, personal services, and health care, so that there are enough jobs and the unemployment rate is likely to remain low for many years. However, the distribution of income and wages is being changed, with increases in income inequality that could become worse.

There are many issues that future research could address. One issue that has caught attention of corporate leaders, government policy makers, as well as the common man, is the emergence of Artificial Intelligence (AI) and its potential impact on employment and loss of jobs. Current estimates about the loss of jobs, made mostly by the consulting companies, range from 10–15% at the low end to 40–50% at the high end. We believe that studying the impact of AI on the nature of occupations and estimating potential losses and gains in number of jobs is an important research question.

Since AI is likely to transform how firms make decisions and interact with their stakeholders, investigating this potential change and how

AI systems and humans can beneficially work together is another area of important research. It would also be valuable to analyze changes occurring by industry sector and by occupational category. That could help to identify potential future changes in jobs and wages. That in turn might provide useful information to identify the kind of education that would be demanded, and that could provide improved job opportunities. A potential problem for employment in near future is that while there will be jobs available, there is likely to be a mismatch between the jobs and the skills available in the population pointing to the governmental policy issues.

Appendices

A

Measuring the Double Dichotomy of the US Economy: Data, Methodology, and Major Findings

This appendix describes the data and methodology underlying our calculations of (a) the GNP shares of the four super sectors of the US economy, namely material products, material services, information products, and information services; (b) the employment and wage bill shares of information and non-information workers in product and service industries. It also presents trends for GNP shares of the super-sectors as well as changes in GNP shares, industry size, and information share for selected industries.

A.1 GNP Decomposition

A.1.1 Data and Methodology

We obtain the relevant data for measuring the size and structure of the US information economy in this article from four major sources. They are: (1) 2007 Benchmark Input-Output (I-O) Accounts, for value-added data at the 6-digit level of industrial classification; (2) Annual Industry Accounts, for data on value added by 3-digit industries for 2012 and 2017; (3) Fixed Assets in the National Economic Accounts for data on depreciation of private nonresidential fixed assets–all compiled and maintained by the Bureau of Economic Analysis (BEA); and (4) Occupational Employment Statistics (OES), compiled and maintained by the Bureau of Labor Statistics (BLS). Most data are available online at the BEA and BLS websites.

We closely follow the framework and methodology developed by Porat (1977).[1] Under his scheme, the US economy is divided into two distinct but inseparable domains: one is "involved in the transformation of matter and energy from one form into another" and the other is involved "in transforming information from one pattern into another," where information is defined as the "data that have been organized and communicated." The term "material" refers to the first domain, and "information" refers to the second domain. An operational definition of "information" encompasses "all workers, machinery, goods, and services that are employed in processing, manipulating, and transmitting information."[2]

Porat (1977) further subdivides the information sector into (1) the Primary Information Sector (PRIS) that produces information goods and services, and (2) the Secondary Information Sector (SIS) that represents the part of the value created by information workers, information capital, and information activity of the proprietor in the process of production of a "material" good or a "material" service. In case of an industry belonging to the PRIS, its total value addition is counted as a part of the information domain of the economy. For example, the total value added generated by the semiconductor industry (semiconductor is an information product) and the telecommunication industry (telecommunication is an information service) is a part of the information economy value added. In contrast, only a part of an SIS industry value added is counted toward the information economy. Thus, information value added of an SIS industry includes (1) employee compensation of information workers, (2) a part of proprietors' income and corporate profits earned for performing informational tasks, and (3) capital consumption allowances (depreciation) on information machines. For example, for the textile industry (textile is a material product) or the

[1]Depending on the availability of data and the changes in definitions, we made certain modifications.

[2]Porat (1977), Vol. 1, p. 2.

transportation industry (transportation is a material service), only the value-added contributions of the information workers (e.g., managers, accountants), the information capital (e.g., computers) employed in those industries–measured by wages and capital consumption allowances of information capital goods, respectively–*plus* a part of the proprietors' income and corporate profits, are counted as a part of the information economy. Thus, for these two industries, the total value added is decomposed into a material component and an information component.

We use the detailed Benchmark I-O tables compiled and published by the BEA, to identify the industries at the 6-digit level of industrial classification belonging to the PRIS and we aggregate their value-added figures at the 3-digit level of aggregation that roughly matched the level of disaggregation at which we obtain the SIS value-added data. For the SIS, the OES data compiled by the BLS are used to construct matrices of employment and wages by occupations and industries. The occupational employment data for industries belonging to the PRIS are excluded.[3] For the remainder, the occupations are classified as belonging either to information or non-information categories according to the scheme described in Porat (1977). The information workers are broadly defined as those who were primarily engaged in the production, processing, or distribution of information.

The data on depreciation of information capital assets are obtained from the Fixed Assets dataset of the BEA. The list of information capital assets was slightly different from Porat's.[4] It includes computer and peripheral equipment, software, communications equipment, photocopy and related equipment, and office buildings, communication, religious, and educational structures. We further use data on net operating surplus from Annual Industry Accounts to add a portion of the proprietors' income accrued for performing information activities. Although the proportion of time allocated by proprietors toward information activities may have changed over the years due to the changing nature of economic activities, in the absence of relevant information, we use the same time

[3]Some 3-digit industries belong entirely to the PRIS while, for others, only a part belongs to it.

[4]Note that some of the information-capital assets either did not exist or were not previously considered as capital assets.

allocation ratios as Porat's. We provide a detailed description of how these data are incorporated in the calculation of SIS value added in the online data appendix to this article.

We gain useful insights into the structural changes that has taken place in the US economy by combining this material-information dichotomy with the product-service dichotomy. At the aggregate level, this exercise decomposes the economy into four super-sectors, as shown in Apte *et al.* (2008, 2012). This study uses a product-service classification scheme that is slightly different from the conventional "goods-services" classification used in economics, but is the same as the one used by Apte *et al.* (2008). Furthermore, because of the switch from the old product-based SIC (Standard Industrial Classification) system to the new process-based NAICS in 1997, there have been some changes even in the conventional product-service classification used in economic data (see Lawson *et al.*, 2002). The classification scheme used in this research reflected some of the important changes that have taken place in production and consumption due to technological changes. Nevertheless, the difference in terms of aggregate value added is expected to be minimal because most industries belonging to the product and services category under these two classifications are the same.

The proposed classification scheme is based on three distinct criteria.

(1) *Market transaction or delivery mode*: Products are in standard units, not differentiated by customer, priced by unit, and pre-produced while services are processed, produced, and customized on demand, and priced by process rather than by unit.

(2) *Form*: Products are tangible, while services are intangible or experiential.

(3) *Production process*: Products are produced entirely by suppliers, while services are often co-produced with the customer present.

After the industries are classified into the product and services category, the material and information value-added data are aggregated separately to construct a 2×2 matrix similar to Figure 1.1 in Apte *et al.* (2012) for each year. Two different versions of this matrix are created to display

(1) actual value in current prices and (2) percentage distribution of shares in total GNP.

It would be ideal to compute value added at constant dollars for these four super-sectors of the US economy as it would facilitate calculations of their growth over the years in a meaningful way. However, there are some formidable constraints. Since 1996, the BEA began using an "ideal chain index" to construct real value-added series. This step purported to eliminate some of the problematic issues associated with the fixed-weight index that was in common use until then. Although this new method of constructing real series in chained dollars improved the quality of the data, it introduced certain other limitations. One of them is the non-additivity of disaggregate series: Unlike with fixed-weight series, the chained dollar series can not simply be added to construct aggregate series.[5] Furthermore, there could be significant differences in price changes between the material and information components of value added and, as such, one would like to use different deflators for these two components. Unfortunately, separate price indices are not available and it is not straightforward to construct such indices from available data.

Note that the detailed benchmark I-O tables are available at 5-year intervals, and the most recent tables that are publicly available are for 2007. There will be no more separate detailed benchmark I-O tables and they are now being integrated into annual I-O tables. In the absence of detailed (more disaggregated) industry-level data, we applied PRIS value-added ratios at the 3-digit level of industries for 2007 to the 2012 & 2017 value-added data to arrive at some approximate measures of the PRIS for those years. Since most of the relevant data for SIS are available, the SIS measures for 2012 and 2017 are consistent with 2007 and the earlier years.

[5] For a detailed discussion, see Landefeld and Parker (1997) and Whelan (2002).

A.1.2 Major Findings

A.1.2.1 Size and Structure of the US Information Economy from 1967 to 2017

Table A.1 presents the value-added contributions–both in current dollar value and percentages–of primary and secondary information sectors to the US GNP in 2007, 2012, and 2017.[6] We revised our 2007 calculations presented in Apte *et al.* (2012). The detailed Benchmark Input-Output data were not available at that time and our earlier calculations were based on aggregate annual industry account data for 2007 and the industry structures as reflected in the Detailed Benchmark Input-Output Tables of 2002. This revision has brought the PRIS share down from about 39% of GNP to 37.3%. However, the revised SIS share is slightly up from 21.2% to 22.1%. Overall, the information share is slightly down from the original 60.2% to 59.4%. As we can see from column 1 of Table A.1, about 8.7 trillion USD or about 59.4% of the total GNP in 2007 was generated in the information sector. Slightly above two fifths of the GNP was generated in the material sector of the US economy. In contrast, the value-added contributions of the information sector in 2012, which was of the magnitude of 9.6 trillion USD, accounted for about 58.7% of the GNP. While the PRIS share in GNP went up slightly from 37.3% to 38%, there was a drop in the GNP share of SIS between 2007 and 2012. Interestingly, the information sector generated 12.2 trillion USD – that accounted for 61.7% of GNP – a 3 percentage point increase over 2012. Some of these changes over this period may have reflected the structural changes that are taking place in response to the great recession of 2007–09.

In order to get a long-run perspective, we present percentage share contributions of PRIS, SIS, total information, and material sectors to the

[6] Since the beginning of the 1990s, GDP, instead of GNP, is used as a measure of national income in the US. Whereas GDP measures all income generated in the US, GNP measures all income earned by US nationals. Numerically, the difference between GDP and GNP in the US has been insignificant. We use GNP to make our calculations comparable to those of Porat (1977).

Table A.1: Size and structure of the US information economy: 2007, 2012, and 2017

Description/ Year	2007		2012		2017	
	Value-Added (Millions of Current USD)	Percentage Share in GNP (%)	Value-Added (Millions of Current USD)	Percentage Share in GNP (%)	Value-Added (Millions of Current USD)	Percentage Share in GNP (%)
	(1)	(2)	(3)	(4)	(5)	(6)
Primary information sector (PRIS)	5438484	37.3	6248923	38.0	7746639	39.3
Secondary information sector (SIS)	3217536	22.1	3399609	20.7	4491517	22.8
Total information	8656020	59.4	9648533	58.7	12181734	61.7
Total material	5904863	40.6	6780777	41.3	7547325	38.3
Gross national product	14560884	100.0	16429308	100.0	19729061	100.0

Source: Authors' calculations from the Bureau of Economic Analysis (BEA) data.

GNP for different years from 1967 to 2017 in Table A.2.[7] We observed steady growth (in terms of percentage share in GNP) of the PRIS between 1967 and 2002, then a decline in 2007, and an upward trend since then. The SIS experienced a significantly large increase between 1992 and 1997 and a steady decline thereafter until 2012. In 2017, the SIS share increased by more than 2 percentage over its 2012 value. Considering the fact that the 1990s were a period of unprecedented advances in ICT, it is not surprising that the PRIS, the SIS, and the total information share increased significantly between 1992 and 1997. The

[7]The OECD (1981) study includes the US information economy measures for 1958, 1967, and 1972 (1974). Although it follows Porat's methodology, it makes a few modifications to make the measurements comparable across 10 OECD member countries. *First*, instead of using GNP, it uses GDP. *Second*, it uses value added at factor cost to avoid potential distortions caused by differential tax rates across the countries. Because of these modifications, the numbers presented in the OECD study are not quite comparable with calculations and therefore we did not report them here.

remarkable growth of the SIS seemed to be partly a reflection of the fact that industries not producing information goods and services (non-PRIS sector) were investing in information capital and hiring information workers at a significantly higher rate in the process of adopting the new ICT.[8] Besides, as Apte and Nath (2007) discuss, the SIS measures for 1997 might have reflected the upward bias that stemmed from the fact that the SIS measures for 1997 were based on employment and wage data for 1998 with reasonable adjustments back to the previous year. However, it is unlikely that this upward bias explained the entire growth in percentage share of the SIS in GNP between 1992 and 1997.

Apte *et al.* (2012) considered a number of factors for the decline of the SIS, and therefore the size of the information economy, in terms of their share in GNP since 1997. *First*, the IT bust and the recession of the early 2000s may have had an impact on the decline of the SIS. *Second*, business innovations complementary to the ICT, such as restructuring and reorganization (of which outsourcing–both onshore and offshore–is a part), led to greater specialization, particularly of information activities. One of the obvious initial consequences would be an enlargement of the PRIS. Although it needs further investigation, the increase in the share of the PRIS between 1997 and 2002 is an indication that it might have been the case. However, the subsequent decline in the PRIS share is somewhat puzzling and needs more investigation. Offshore outsourcing of information services could have been one of the reasons for the slowdown.[9] Faster productivity growth on the supply side or/and satiation on the demand side could potentially explain the decline or the slow down.[10] *Third*, decreases in the relative prices of information goods and services also explained the slowing down of the growth of the PRIS share

[8] Tevlin and Whelan (2003) discuss the special behavior of investment in computers that contributed to the investment boom of the 1990s. Further, Wolff (2006) finds that there were significant increases in the employment of information workers over the years and argues that this increase is attributed to changes in production technology. Nevertheless, these studies provide only indirect support to this conjecture and it needs further investigation.

[9] Bardhan and Kroll (2003) give an account of a new wave of offshore outsourcing in the early 2000s.

[10] See Karmarkar *et al.* (2015) for an explanation on how these factors can have an impact on the relative size of these factors.

Table A.2: Size and structure of the US information economy: 1967–2017

Description/Year	**1967**	**1992**	**1997**	**2002**	**2007**	**2012**	**2017**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Primary information sector (PRIS)	25.1	33.0	35.2	38.7	37.3	38.0	39.3
Secondary information sector (SIS)	21.1	22.9	27.8	23.2	22.1	20.7	22.8
Total information	46.3	55.9	63.0	61.9	59.4	58.7	61.7
Total material	53.7	44.1	37.0	38.1	40.6	41.3	38.3
Gross national product	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: This table is compiled from various sources: Porat (1977) for 1967; Apte and Nath (2007) for 1992 and 1997; Apte *et al.* (2012) for 2002; and authors' calculations from the BEA data.

and the decline in the share of the SIS and of the overall information economy.[11]

Furthermore, the increasing amount of "shadow work," the unpaid work done in a wage-based economy, being performed by the customers, may also have contributed to the decline in the size of the information economy since 1997. The growth of information technology, together with the increasing use of the "self service" strategy by many businesses, has led to a situation in which the customers are increasingly engaging in shadow work. We may consider the airline industry as an example. The self-service check-in kiosks at the airports allow travelers to perform the job previously performed by airline counter personnel. Similarly, the travelers nowadays, instead of using travel agents to purchase airline tickets with suitable fare and itinerary, spend their own time searching the Internet for flights and fares to create their own itinerary and purchase their tickets online. Since the travelers are not compensated for the shadow work they perform, this work and its associated value is not captured in the formal economy. Hence, even if the real share of information economy in GNP are on the rise, its share in the formal economy could decline, as we see in Table A.2.

[11] There is a literature that investigates productivity growth and falling prices of ICT goods and services. See, for example, Gordon (2000).

Delivery Form

End Market		**Product (Manufacturing)**	**Service (Process)**
	Material (Atoms)	Chemicals Steel Automobiles Aerospace	Transportation Construction Maintenance & Repair Hospitality Retailing
	Information (Bits)	Computers TV, Radio Books CDs, DVDs	Financial Services Professional Services Telecommunications Education

Figure A.1: A framework for categorizing major industry sectors in the information economy.

A.1.2.2 Decomposition of the US GNP

The product–services dichotomy has proved to be a useful tool in discussing the differences in process characteristics and management requirements across different firms and sectors. In the preceding discussion, we have presented another useful dichotomy which could be described as material versus information, physical versus symbolic, or to use the popular phrase, atoms versus bits. We can overlay these two dichotomies to give us a simple yet useful 2×2 table (see Figure A.1) defining four super-sectors of the economy. We have given some examples of industries belonging to each super-sector. First note that certain physical manufacturing and service examples (e.g., computers, telecom) fall in the information sector following the definition by Porat. Interestingly, many industries do not really lie entirely inside one cell. For example, both Machlup and Porat arrived at nearly identical results about the health care industry: it breaks down just about evenly across the material and information sectors.

We present the 2×2 decompositions of the US GNP for 1967 and at 5-yearly intervals from 1992 to 2017 in Table A.3. For each year we present both the percentage shares as well as the size, in terms of millions of dollars, for each of the four super-sectors in Table A.3. The decompositions for years 1967, 1992, 1997 and 2002 are taken from Apte *et al.* (2012). Since 1997, information services accounted for

Table A.3: 2 × 2 decomposition of the US GNP

	Products	Services	Total		Products	Services	Total
	1967				**1967**		
Material	19.2	34.5	53.7	Material	152514	274775	427289
Information	10.5	35.8	46.3	Information	83370	284730	368100
Total	29.7	70.3	100.0	Total	235884	559505	795389
	1992				**1992**		
Material	12.7	31.5	44.1	Material	788844	1961990	2750834
Information	6.5	49.4	55.9	Information	402520	3080551	3483071
Total	19.1	80.9	100.0	Total	1191364	5042541	6233905
	1997				**1997**		
Material	10.5	26.5	37.00	Material	877051	2211055	3088106
Information	6.9	56.1	63.00	Information	577631	4679908	5257539
Total	17.40	82.60	100.00	Total	1454682	6890963	8345645
	2002				**2002**		
Material	9.8	27.6	37.3	Material	1026716	2898656	3925372
Information	5.3	57.3	62.7	Information	561569	6031763	6593332
Total	15.1	84.9	100.0	Total	1588285	8930419	10518704
	2007				**2007**		
Material	11.2	29.4	40.6	Material	1626924	4277941	5904864
Information	5.2	54.2	59.4	Information	762203	7893816	8656020
Total	16.4	83.6	100.0	Total	2389127	12171757	14560884
	2012				**2012**		
Material	10.4	30.9	41.3	Material	1711859	5068916	6780775
Information	5.2	53.6	58.7	Information	849681	8798852	9648533
Total	15.6	84.4	100.0	Total	2561540	13867768	16429308
	2017				**2017**		
Material	8.8	29.4	38.1	Material	1737088	5810238	7547326
Information	5.2	56.7	61.9	Information	1019384	11218772	12238156
Total	13.9	86.1	100.0	Total	2756472	17029010	19785482

Note: The figures for 1967, 1992, 1997, and 2002 are taken from Apte *et al.* (2012). For 2007, 2012, and 2017, authors' calculations from the BEA data.

more than half of the US economy in terms of GNP share. However, the GNP share reached a maximum of 57.3% in 2002 and it steadily declined until 2012 after which it increased rapidly to about 56.7% in 2017. In contrast, information products were the smallest sector with a small but steady contribution of slightly over 5% to the US GNP since 2002. The relative share of material products decreased from 2007 to 2017 and that of material services fluctuated between 29 and 31% during that period. It is difficult to speculate whether these variations are due to transitory factors associated with business cycles or due to some permanent shocks that lead to long-run structural changes.

A.1.3 Information-Material Decomposition at the Industry Level

In Tables A.4 and A.5, we present some relevant facts about the size and structure of the information economy at the industry level for the 25 private industries that experienced the largest growth in GNP shares between 2007 and 2012 and between 2012 and 2017 respectively. Since government accounted for about 13% of GNP, we also included the government. Note that these 25 industries and the government together accounted for about 57% of the GNP in 2007 and 2012. The industries are ranked according to the percentage point changes between the relevant years in descending order. Col. 2 shows the percentage point changes in GNP share from 2007 to 2012. Col. 3 includes the GNP shares in 2007 and Col. 4 includes the information share in total industry value added. Note that seven of these 25 industries generate their entire value added in information goods or services. However, they account for slightly above 9 percent of GNP. During that period, real estate, ambulatory health care services, and hospitals and nursing and residential care facilities are three largest industries that also experienced large increases in their GNP shares. The information share in their respective value added for these industries range between 41% for real estate to about 78% for ambulatory health care services.

Table A.5 presents the same information for the five year period between 2012 and 2017. During this period 'data processing, internet publishing, and other information services' experienced the highest growth in its GNP share. However, its GNP share in 2012 was less than 1%. Other entirely information intensive industries that grew in their GNP shares included 'insurance carriers and related activities',

Table A.4: Changes in GNP shares, industry size, and information share for selected industries: 2007–2012

Sl. No.	Industry	Change in GNP Share: 07-12	GNP Share in 2007	Info Share in Industry Value Added in 2007
	(1)	(2)	(3)	(4)
1	Ambulatory health care services	0.45	3.05	77.6
2	Hospitals and nursing and residential care facilities	0.43	2.76	57.7
3	Computer systems design and related services	0.39	1.15	100.0
4	Miscellaneous professional, scientific, and technical services	0.36	4.02	97.5
5	Educational services	0.35	0.95	100.0
6	Real estate	0.24	11.47	41.0
7	Federal Reserve banks, credit intermediation, and related activities	0.23	2.89	100.0
8	Data processing, internet publishing, and other information services	0.19	0.44	100.0
9	Wholesale trade	0.16	5.91	59.8
10	Farms	0.13	0.78	2.2
11	Performing arts, spectator sports, museums, and related activities	0.10	0.51	100.0
12	Food services and drinking places	0.10	1.86	11.9
13	Utilities	0.09	1.61	18.1
14	Support activities for mining	0.07	0.35	18.0
15	Air transportation	0.06	0.47	28.9
16	Pipeline transportation	0.06	0.09	33.7
17	Management of companies and enterprises	0.06	1.78	100.0

Continued.

Table A.4: Continued

Sl. No.	Industry	Change in GNP Share: 07-12	GNP Share in 2007	Info Share in Industry Value Added in 2007
	(1)	(2)	(3)	(4)
18	Securities, commodity contracts, and investments	0.04	1.38	105.7
19	Transit and ground passenger transportation	0.04	0.18	19.7
20	Machinery	0.04	0.89	49.0
21	Social assistance	0.03	0.55	64.2
22	Rail transportation	0.02	0.22	17.0
23	Waste management and remediation services	0.02	0.24	29.4
24	Mining, except oil and gas	0.00	0.40	9.5
25	Warehousing and storage	0.00	0.28	36.7
	Government	0.06	13.08	69.2

Source: Authors' calculations from the BEA data.

'computer systems design and related services' and 'management of companies and enterprises'. All of them are service industries producing high-end services. Another service industry with high information content (about 98% of its value added) that experienced high growth was 'miscellaneous professional, scientific, and technical services'. It accounted for 4.38% of GNP in 2012 and it slightly increased. Food and drinking services is one industry that has low information share but experienced high growth in its share.

The governments at all levels, local, state and federal, accounted for about 13% of GNP. Within the government, information activities contributed about 69% in 2002 and declined to 61% in 2007. While the government share slightly increased between 2002 and 2007, its share declined from 2012 to 2017.

Table A.5: Changes in GNP shares, industry size, and information share for selected industries: 2012–2017

Sl. No.	Industry	Change in GNP Share: 12-17	GNP Share in 2012	Info Share in Industry Value Added in 2012
	(1)	(2)	(3)	(4)
1	Data processing, internet publishing, and other information services	0.70	0.64	100.0
2	Construction	0.59	3.37	36.9
3	Real estate	0.28	11.72	41.6
4	Insurance carriers and related activities	0.27	2.47	100.0
5	Food services and drinking places	0.21	1.96	17.8
6	Air transportation	0.15	0.53	35.9
7	Administrative and support services	0.14	2.62	87.0
8	Publishing industries, except internet (includes software)	0.13	1.23	99.6
9	Motor vehicles, bodies and trailers, and parts	0.10	0.70	28.8
10	Computer systems design and related services	0.10	1.54	100.0
11	Ambulatory health care services	0.10	3.49	74.9
12	Rental and leasing services and lessors of intangible assets	0.08	1.05	75.4
13	Securities, commodity contracts, and investments	0.06	1.42	96.1
14	Social assistance	0.06	0.58	56.1
15	Pipeline transportation	0.05	0.15	23.0
16	Waste management and remediation services	0.05	0.26	34.1
17	Accommodation	0.04	0.78	25.8

Continued.

Table A.5: Continued

Sl. No.	Industry	Change in GNP Share: 12-17	GNP Share in 2012	Info Share in Industry Value Added in 2012
	(1)	(2)	(3)	(4)
18	Nonmetallic mineral products	0.04	0.26	24.1
19	Wood products	0.04	0.16	24.7
20	Warehousing and storage	0.04	0.29	37.3
21	Management of companies and enterprises	0.03	1.84	100.0
22	Food and beverage and tobacco products	0.03	1.33	16.7
23	Miscellaneous professional, scientific, and technical services	0.03	4.38	97.5
24	Amusements, gambling, and recreation industries	0.02	0.43	30.7
25	Furniture and related products	0.02	0.14	53.8
	Government	−0.71	13.14	61.2

Source: Authors' calculations from the BEA data.

A.2 Employment and Wage Bill Decomposition

A.2.1 Data and Methodology

We obtain the relevant data from the OES database, compiled and published by the BLS. Annual data on the number of workers and the average annual wages for more than 800 occupations are available for 2- and 3-digit-level SIC industries between 1999 and 2001, and for 2-, 3-, 4-, and 5-digit-level NAICS industries since 2002. To get a clear sense of the long-run trends, we consider the data for 1999, and at 5-yearly intervals between 2002 and 2017.

Following Apte *et al.* (2008 and 2012), we classify occupations into information and non-information categories. This scheme - based on the framework developed by Apte and Mason (1995) and used by

Apte *et al.* (2008) - recognizes that every occupation uses information at various intensities. Following Apte and Mason (1995), the information intensity of an occupation is defined as the fraction of time spent in dealing with information-intensive tasks (i.e., in creating, processing, and communicating information). We classify the occupations according to five levels of information intensity. An occupation requiring creating, processing, and communicating information, but no physical presence in a specific location or physical action by the worker, is classified as an information occupation. In contrast, if an occupation requires only physical action and does not involve creation, processing, and communication of information, we call it a non-information occupation. Occupations that involves creation, processing, and communication of information as well as physical action (including physical presence in a particular location) are classified into one of three intermediate categories based on the fraction of time spent on information actions versus non-information actions: high (75% information and 25% non-information), medium (50% information and 50% non-information), and low (25% information and 75% non-information). However, there are no clear guidelines for assessing the information intensity of various occupations. We use the detailed descriptions of occupations from the *Dictionary of Standard Occupational Classification (SOC) Codes*, available from the BLS as well as at the O*Net Online database (https://www.onetonline.org/), to determine information intensity. We then apply the weights: 100%, 75%, 50%, 25%, and 0%, to total employment to decompose it into the two broad categories: information and non-information for each disaggregate industry. The decomposition of total employment in industry j into the information and non-information category is based on the following equations:

$$IE_i = \sum_{j=1}^{n} v_j E_{ji} \quad \text{and} \quad NE_i = \sum_{j=1}^{n} (1 - v_j)\, E_{ji} \tag{A.1}$$

where IE_i and NE_i are, respectively, the full-time equivalent (FTE) information and non-information employment in industry i; v_j is the information-intensity weight applied to the jth occupation and $v_j \in [0, 0.25, 0.50, 0.75, 1]$, and E_{ji} is the number of workers employed in occupation j in industry i.

We use a similar equation to calculate wage bills for information and non-information categories in industry i:

$$IE_i = \sum_{j=1}^{n} v_j E_{ji} W_{ji} \quad \text{and} \quad NE_i = \sum_{j=1}^{n} (1 - v_j) E_{ji} W_{ji} \qquad \text{(A.2)}$$

where W_{ji} is the annual average wage for occupation j in industry i. We then apply the product-service classification to the industries, and aggregate the information and non-information employments for each of these two broad categories. We also calculate the total wage bills for information and non-information workers in each industry. Then, we classify the industries into the product or service category, and obtain the aggregate wage bills for these two broad categories. Thus, we decompose the resulting data on employment and the total wage bill into four major categories, as shown in Table 4.1 in the main text, for the years: 1999, 2002, 2007, 2012, and 2017. This decomposition gave another broad long-run perspective on the structural changes that had taken place in the US economy focusing on the labor market.

B

Job and Wage Bill Shares by Sectors and Occupations

Table B.1: Share of total jobs (%) by industry sector (2-digit NAICS codes) in 2002, 2007, 2012, and 2017

NAICS Code	Industry	Employment Share (%)			
		2002	**2007**	**2012**	**2017**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
11	Agriculture, Forestry, Fishing and Hunting	0.30	0.29	0.30	0.30
21	Mining, Quarrying, Oil and Gas Extraction	0.39	0.48	0.60	0.41
22	Utilities	0.46	0.41	0.42	0.39
23	Construction	5.40	5.74	4.31	4.84
31-33	Manufacturing	11.69	10.45	9.11	8.63
42	Wholesale Trade	4.41	4.47	4.32	4.10
44-45	Retail Trade	11.64	11.68	11.49	11.23
48-49	Transportation and Warehousing	3.33	3.50	3.85	4.06
51	Information	2.58	2.26	2.06	1.96
52	Finance and Insurance	4.48	4.40	4.25	4.11
53	Real Estate and Rental and Leasing	1.60	1.60	1.48	1.51
54	Professional, Scientific, & Technical Services	5.22	5.63	5.97	6.21
55	Management of Companies and Enterprises	1.33	1.43	1.54	1.63
56	Administrative/Support, Waste Management and Remediation Services	6.11	6.37	6.08	6.39
61	Educational Services	9.23	9.33	9.74	9.15
62	Health Care and Social Assistance	11.44	11.98	13.61	14.18
71	Arts, Entertainment, and Recreation	1.39	1.44	1.49	1.66
72	Accommodation and Food Services	8.05	8.49	8.97	9.55
81	Other Services (except Public Admin)	2.97	2.91	2.93	2.91
99	Federal, State, and Local Government (excluding state/local schools & hospitals)	7.98	7.14	7.46	6.78

Source: Authors' calculations from the OES database of BLS.

Table B.2: The changes in job shares (in percentage points) by sector (2-digit NAICS codes) from 2002 to 2007, 2007 to 2012, and 2012 to 2017

NAICS Code	Industry	Change in Employment Shares (% Points)			
		2002–07	**2007–12**	**2012–17**	**2002–17**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
11	Agriculture, Forestry, Fishing and Hunting	−0.01	0.01	0.00	0.00
21	Mining, Quarrying, Oil and Gas Extraction	0.09	0.12	−0.19	0.02
22	Utilities	−0.05	0.02	−0.04	−0.07
23	Construction	0.34	−1.43	0.53	−0.56
31-33	Manufacturing	−1.24	−1.34	−0.49	−3.07
42	Wholesale Trade	0.06	−0.15	−0.22	−0.31
44-45	Retail Trade	0.04	−0.19	−0.26	−0.41
48-49	Transportation and Warehousing	0.16	0.35	0.21	0.72
51	Information	−0.32	−0.20	−0.10	−0.62
52	Finance and Insurance	−0.08	−0.15	−0.14	−0.37
53	Real Estate and Rental and Leasing	0.00	−0.12	0.03	−0.09
54	Professional, Scientific, & Technical Services	0.41	0.34	0.24	0.99
55	Management of Companies and Enterprises	0.11	0.10	0.09	0.30
56	Administrative/Support, Waste Management and Remediation Services	0.26	−0.29	0.31	0.28
61	Educational Services	0.10	0.42	−0.60	−0.08
62	Health Care and Social Assistance	0.54	1.63	0.56	2.73
71	Arts, Entertainment, and Recreation	0.05	0.05	0.17	0.27
72	Accommodation and Food Services	0.45	0.47	0.58	1.50
81	Other Services (except Public Admin)	−0.07	0.02	−0.02	−0.07
99	Federal, State, and Local Government (excluding state/local schools & hospitals)	−0.85	0.32	−0.69	−1.22

Source: Authors' calculations from the OES database of BLS.

Table B.3: Share of the total wage bill by sector (2-digit NAICS codes) in 2002, 2007, 2012, and 2017

NAICS Code	Industry	Wage Bill Share (%)			
		2002	2007	2012	2017
	(1)	(2)	(3)	(4)	(5)
11	Agriculture, Forestry, Fishing and Hunting	0.21	0.20	0.20	0.18
21	Mining, Quarrying, Oil and Gas Extraction	0.48	0.56	0.77	0.53
22	Utilities	0.64	0.57	0.61	0.59
23	Construction	5.90	6.09	4.56	5.16
31-33	Manufacturing	11.69	10.18	8.95	8.83
42	Wholesale Trade	4.94	5.10	4.91	4.61
44-45	Retail Trade	8.41	8.09	7.70	7.28
48-49	Transportation and Warehousing	3.19	3.67	3.93	3.85
51	Information	3.42	3.01	2.83	2.88
52	Finance and Insurance	6.23	6.03	6.18	5.80
53	Real Estate and Rental and Leasing	1.53	1.62	1.47	1.42
54	Professional, Scientific & Technical Services	8.07	8.71	9.43	9.96
55	Management of Companies and Enterprises	1.95	2.18	2.45	2.68
56	Administrative/Support, Waste Management and Remediation Services	5.06	5.50	5.00	4.93
61	Educational Services	10.16	10.26	10.60	9.96
62	Health Care and Social Assistance	11.07	11.92	13.49	14.77
71	Arts, Entertainment, and Recreation	1.06	1.05	1.06	1.21
72	Accommodation and Food Services	4.32	4.65	4.82	4.94
81	Other Services (except Public Admin)	2.40	2.30	2.30	2.38
99	Federal, State, and Local Government (excluding state/local schools & hospitals)	9.28	8.33	8.75	8.05

Source: Authors' calculations from the OES database of BLS.

Table B.4: The changes in share of the total wage bill (in percentage points) by sector (2-digit NAICS codes) from 2002 to 2007, 2007 to 2012, and 2012 to 2017

NAICS Code	Industry	Change in Wage Bill Shares (% Points)			
		2002–07	2007–12	2012–17	2002–17
	(1)	(2)	(3)	(4)	(5)
11	Agriculture, Forestry, Fishing and Hunting	−0.01	0.01	−0.02	−0.02
21	Mining, Quarrying, Oil and Gas Extraction	0.08	0.21	−0.24	0.05
22	Utilities	−0.07	0.04	−0.02	−0.05
23	Construction	0.18	−1.52	0.59	−0.75
31-33	Manufacturing	−1.51	−1.24	−0.12	−2.87
42	Wholesale Trade	0.16	−0.19	−0.30	−0.33
44-45	Retail Trade	−0.32	−0.38	−0.42	−1.12
48-49	Transportation and Warehousing	0.49	0.26	−0.08	0.67
51	Information	−0.41	−0.18	0.05	−0.54
52	Finance and Insurance	−0.20	0.15	−0.38	−0.43
53	Real Estate and Rental and Leasing	0.08	−0.15	−0.05	−0.12
54	Professional, Scientific & Technical Services	0.64	0.72	0.53	1.89
55	Management of Companies and Enterprises	0.23	0.27	0.23	0.73
56	Administrative/Support, Waste Management and Remediation Services	0.45	−0.50	−0.07	−0.12
61	Educational Services	0.10	0.34	−0.64	−0.20
62	Health Care and Social Assistance	0.84	1.58	1.28	3.70
71	Arts, Entertainment, and Recreation	−0.01	0.01	0.16	0.16
72	Accommodation and Food Services	0.33	0.17	0.12	0.62
81	Other Services (except Public Admin)	−0.10	0.00	0.09	−0.01
99	Federal, State, and Local Government (excluding state/local schools & hospitals)	−0.96	0.42	−0.70	−1.24

Source: Authors' calculations from the OES database of BLS.

Table B.5: Share of total jobs (%) by occupational category (2-digit SOC codes) in 2002, 2007, 2012, and 2017

SOC Code	Occupation	Employment Share (%) 2002	2007	2012	2017
	(1)	(2)	(3)	(4)	(5)
11-0000	Management	5.58	4.41	4.91	5.11
13-0000	Business and Financial Operations	3.73	4.47	4.93	5.24
15-0000	Computer and Mathematical	2.18	2.38	2.75	2.99
17-0000	Architecture and Engineering	1.86	1.86	1.81	1.77
19-0000	Life, Physical, and Social Science	0.84	0.94	0.85	0.81
21-0000	Community and Social Service	1.24	1.34	1.45	1.47
23-0000	Legal	0.73	0.75	0.78	0.77
25-0000	Education, Training, and Library	6.11	6.23	6.38	6.12
27-0000	Arts, Design, Entertainment, Sports, and Media	1.18	1.32	1.34	1.35
29-0000	Healthcare Practitioners and Technical	4.82	5.15	5.88	5.97
31-0000	Healthcare Support	2.49	2.71	3.01	2.89
33-0000	Protective Service	2.35	2.31	2.46	2.39
35-0000	Food Preparation and Serving Related	7.91	8.44	8.87	9.25
37-0000	Building and Grounds Cleaning, Maintenance	3.32	3.29	3.26	3.10
39-0000	Personal Care and Service	2.25	2.48	2.93	3.62
41-0000	Sales and Related	10.50	10.72	10.63	10.19
43-0000	Office and Administrative Support	17.90	17.27	16.40	15.41
45-0000	Farming, Fishing, and Forestry	0.35	0.33	0.32	0.33
47-0000	Construction and Extraction	4.80	5.02	3.82	4.02
49-0000	Installation, Maintenance, and Repair	4.08	3.98	3.89	3.88
51-0000	Production	8.39	7.58	6.59	6.33
53-0000	Transportation and Material Moving	7.38	7.02	6.74	7.00

Source: Authors' calculations from the OES database of BLS.

Table B.6: The changes in job shares (in percentage points) by occupational category (2-digit SOC codes) from 2002 to 2007, 2007 to 2012, and 2012 to 2017

SOC Code	Occupation	Change in Employment Shares (% Points)			
		2002–07	2007–12	2012–17	2002–17
	(1)	(2)	(3)	(4)	(5)
11-0000	Management	−1.17	0.50	0.20	−0.47
13-0000	Business and Financial Operations	0.74	0.46	0.31	1.51
15-0000	Computer and Mathematical	0.20	0.37	0.24	0.91
17-0000	Architecture and Engineering	−0.01	−0.05	−0.04	−0.10
19-0000	Life, Physical, and Social Science	0.10	−0.09	−0.04	−0.03
21-0000	Community and Social Service	0.10	0.10	0.03	0.23
23-0000	Legal	0.02	0.04	−0.02	0.04
25-0000	Education, Training, and Library	0.12	0.15	−0.26	0.01
27-0000	Arts, Design, Entertainment, Sports, and Media	0.14	0.03	0.01	0.18
29-0000	Healthcare Practitioners and Technical	0.33	0.73	0.09	1.15
31-0000	Healthcare Support	0.22	0.29	−0.12	0.39
33-0000	Protective Service	−0.04	0.16	−0.07	0.05
35-0000	Food Preparation and Serving Related	0.53	0.43	0.39	1.35
37-0000	Building and Grounds Cleaning Maintenance	−0.03	−0.03	−0.16	−0.22
39-0000	Personal Care and Service	0.23	0.44	0.69	1.36
41-0000	Sales and Related	0.22	−0.09	−0.44	−0.31
43-0000	Office and Administrative Support	−0.63	−0.86	−0.99	−2.48
45-0000	Farming, Fishing, and Forestry	−0.02	−0.01	0.01	−0.02
47-0000	Construction and Extraction	0.22	−1.20	0.19	−0.79
49-0000	Installation, Maintenance, and Repair	−0.10	−0.09	−0.02	−0.21
51-0000	Production	−0.81	−0.99	−0.26	−2.06
53-0000	Transportation and Material Moving	−0.35	−0.29	0.26	−0.38

Source: Authors' calculations from the OES database of BLS.

Table B.7: Share of the total wage bill by occupational category (2-digit SOC codes) in 2002, 2007, 2012, and 2017

SOC Code	Occupation	Wage Bill Share (%)			
		2002	2007	2012	2017
	(1)	(2)	(3)	(4)	(5)
11-0000	Management	12.34	10.33	11.58	12.09
13-0000	Business and Financial Operations	5.61	6.88	7.52	7.90
15-0000	Computer and Mathematical	3.56	4.09	4.68	5.30
17-0000	Architecture and Engineering	2.97	3.03	3.03	3.01
19-0000	Life, Physical, and Social Science	1.23	1.39	1.23	1.18
21-0000	Community and Social Service	1.28	1.35	1.42	1.40
23-0000	Legal	1.69	1.64	1.71	1.63
25-0000	Education, Training, and Library	7.14	7.20	7.26	6.71
27-0000	Arts, Design, Entertainment, Sports, and Media	1.42	1.57	1.56	1.57
29-0000	Healthcare Practitioners and Technical	6.55	7.53	8.59	9.52
31-0000	Healthcare Support	1.57	1.64	1.74	1.78
33-0000	Protective Service	2.23	2.30	2.39	2.23
35-0000	Food Preparation and Serving Related	3.94	4.33	4.47	4.52
37-0000	Building and Grounds Cleaning and Maintenance	1.92	1.95	1.83	1.77
39-0000	Personal Care and Service	1.36	1.40	1.57	1.95
41-0000	Sales and Related	9.39	9.79	9.28	8.19
43-0000	Office and Administrative Support	14.23	13.22	12.41	11.55
45-0000	Farming, Fishing, and Forestry	0.23	0.21	0.20	0.19
47-0000	Construction and Extraction	4.92	4.99	3.74	3.96
49-0000	Installation, Maintenance, and Repair	3.91	3.74	3.61	3.67
51-0000	Production	6.74	5.87	4.98	4.76
53-0000	Transportation and Material Moving	5.75	5.54	5.18	5.12

Source: Authors' calculations from the OES database of BLS.

Table B.8: The changes in share of the total wage bill (in percentage points) by occupational category (2-digit SOC codes) from 2002 to 2007, 2007 to 2012, and 2012 to 2017

SOC Code	Occupation	Change in Wage Bill Shares (% Points)			
		2002–07	**2007–12**	**2012–17**	**2002–17**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
11-0000	Management	−2.01	1.25	0.51	−0.25
13-0000	Business and Financial Operations	1.27	0.64	0.38	2.29
15-0000	Computer and Mathematical	0.53	0.59	0.62	1.74
17-0000	Architecture and Engineering	0.06	0.00	−0.02	0.04
19-0000	Life, Physical, and Social Science	0.16	−0.16	−0.05	−0.05
21-0000	Community and Social Service	0.07	0.07	−0.02	0.12
23-0000	Legal	−0.05	0.07	−0.08	−0.06
25-0000	Education, Training, and Library	0.06	0.06	−0.56	−0.44
27-0000	Arts, Design, Entertainment, Sports, and Media	0.14	−0.01	0.01	0.14
29-0000	Healthcare Practitioners and Technical	0.98	1.06	0.93	2.97
31-0000	Healthcare Support	0.07	0.10	0.04	0.21
33-0000	Protective Service	0.07	0.09	−0.16	0.00
35-0000	Food Preparation and Serving Related	0.39	0.13	0.05	0.57
37-0000	Building and Grounds Cleaning and Maintenance	0.03	−0.12	−0.06	−0.15
39-0000	Personal Care and Service	0.03	0.18	0.38	0.59
41-0000	Sales and Related	0.40	−0.50	−1.10	−1.20
43-0000	Office and Administrative Support	−1.01	−0.81	−0.87	−2.68
45-0000	Farming, Fishing, and Forestry	−0.01	−0.01	−0.02	0.04
47-0000	Construction and Extraction	0.07	−1.25	0.22	−0.96
49-0000	Installation, Maintenance, and Repair	−0.17	−0.13	0.06	−0.24
51-0000	Production	−0.87	−0.88	−0.22	−1.97
53-0000	Transportation and Material Moving	−0.21	−0.35	−0.06	−0.62

Source: Authors' calculations from the OES database of BLS.

References

Acemoglu, D. and D. Autor (2011). “Skills, tasks and technologies: Implications for employment and earnings”. In: *Handbook of Labor Economics*. Vol. 4. Amsterdam: Elsevier-North. 1043–1171.

Acemoglu, D. and P. Restrepo (2018). “The race between man and machine: Implications of technology for growth, factor shares and employment”. *American Economic Review*. 108(6): 1488–1542.

Apte, U. and M. Davis (2019). “Sharing economy services: Business model generation”. *California Management Review*. 61(2): 104–131.

Apte, U. and U. Karmarkar (2007). “Business process outsourcing (BPO) and globalization of information intensive services”. In: *Managing in the Information Economy: Current Research Issues*. Chapter 3 in Ed. by U. Apte and U. Karmarkar. New York, NY: Springer Science + Business Media. 59–81.

Apte, U., U. Karmarkar, and H. Nath (2008). “Information services in the US economy: Value, jobs and management implications”. *California Management Review*. 50(3): 12–30.

Apte, U., U. Karmarkar, and H. Nath (2012). “The U.S. information economy: Value, employment, industry structure, and trade”. *Foundations and Trends in Technology, Information and Operations Management*. 6(1): 1–179.

Apte, U., U. Karmarkar, and H. Nath (2015). "The growth of information-intensive services in the US economy". In: *Handbook of Service Business: Management, Marketing, Innovation and Internationalization.* Chapter 10 in Ed. by J. Bryson and P. Daniels. Camberley, Surrey, UK: Edward Elgar Publishing, Ltd.

Apte, U. and R. Mason (1995). "Global disaggregation of information-intensive services". *Management Science.* 41(7): 1250–1262.

Apte, U. and H. Nath (2007). "Size, structure and growth of the U.S. information economy". In: *Managing in the Information Economy: Current Research Issues.* Chapter 1 in Ed. by U. Apte and U. Karmarkar. New York, NY: Springer Science + Business Media. 1–28.

Apte, U. and H. Nath (2012). "U.S. trade in information-intensive services". *The Business and Information Technologies (BIT) Project: A Global Study of Business Practice.* Singapore: World Scientific Books. 117–144.

Autor, D. H. (2014). "Skills, education, and the rise of earnings inequality among the 'other 99 percent'". *Science.* 344: 843–851.

Autor, D. H. (2015). "Why are there still so many jobs? The history and future of workplace automation". *Journal of Economic Perspectives.* 29(3): 3–30.

Autor, D. H., L. F. Katz, and A. B. Krueger (1998). "Computing inequality: Have computers changed the labor market?" *The Quarterly Journal of Economics.* 113(4): 1169–1213.

Autor, D. H., L. F. Katz, and M. S. Kearney (2008). "Trends in US wage inequality: Re-assessing the revisionists". *Review of Economics and Statistics.* 90(2): 300–323.

Barbe, A. and D. Riker (2018). "The effects of offshoring on domestic workers: A review of the literature". *Journal of International Commerce and Economics.* June. URL: https://www.usitc.gov/journals.

Bardhan, A. D. and C. Kroll (2003). "The new wave of outsourcing". *Fisher Center Research Report*, UC Berkeley (available at URL: http://escholarship.org/uc/item/02f8z392).

Bell, D. (1973). *The Coming of Post-Industrial Society.* New York: Basic Books.

Berg, A., E. Buffie, and L.-F. Zanna (2018). "Should we fear the robot revolution? (The correct answer is yes)". *Journal of Monetary Economics*. 97: 117–148.

Bivens, J. (2008). "Trade, jobs, and wages: Are the public's worries about globalization justified?" *Issue Brief* # 244, Economic Policy Institute (May 6).

Blinder, A. (2007). "How many U.S. jobs might be offshorable?" In: *CEPS Working Paper No. 142*. Retrieved from URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.360.5806&rep=rep1&type=pdf.

Blinder, A. and A. Krueger (2013). "Alternative measures of offshorability: A survey approach". *Journal of Labor Economics*. 31(2): S97–S128. Retrieved from URL: http://www.jstor.org/stable/10.1086/669061.

Brynjolfsson, E. and A. McAfee (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. WW Norton & Company.

Brynjolfsson, E., D. Rock, and C. Syverson (2018). "The productivity J-curve: How intangible complement general purpose technologies". *NBER Working Paper*. 25148.

Carneiro, P. and S. Lee (2009). "Trends in quality-adjusted skill premia in the United States, 1960–2000". *CEMMAP Working Paper*. CWP02/09.

Chase, R. and U. Apte (2007). "A history of research in service operations: What is the big idea?" *Journal of Operations Management*. 25(2): 375–386.

Chui, M., J. Manyika, and M. Miremadi (2015). *Four Fundamentals of Workplace Automation*. McKinsey Q. 1–9.

Cortada, J. W. (1998). *Rise of the Knowledge Worker*. Boston, MA: Butterworth-Heinemann.

Docquiera, F., Z. L. Kone, A. Mattoo, and C. Ozden (2018). "Labor market effects of demographic shifts and migration in OECD countries". *Policy Research Working Paper* 8676, World Bank.

Ericsson (2018). "Creative machines: How artificial intelligence will impact the future labor market". *Ericsson Consumer & Industry Lab Insight Report*.

Ford, M. (2015). *Rise of the Robots: Technology and the Threat of a Jobless Future*. Basic Books.

Frank, M., D. Autor, J. Bessen, E. Brynjolfsson, M. Cebrian, D. Deming, and M. Feldman (2019). "Toward understanding the impact of artificial intelligence on labor". *Proceedings of the National Academy of Sciences*. 116(14): 6531–6539. DOI: 10.1073/pnas.1900949116.

Freeman, R. B. (2002). "The labour market in the new information economy". *NBER Working Paper*. 9254.

Frey, C. and M. Osborne (2017). "The future of employment: How susceptible are jobs to computerisation?" *Technological Forecasting & Social Change*. 114: 254–280.

Gordon, R. J. (2000). "Does the 'new economy' measure up to the great inventions of the past?" *The Journal of Economic Perspectives*. 14(4): 49–74.

Karmarkar, U. (2004). "Will you survive the services revolution?" *Harvard Business Review*. June 2004.

Karmarkar, U. (2010). "The industrialization of information services". In: *The Handbook of Services Science*. Ed. by M. Paul, C. Kieliszewski, and J. C. Spohrer. NY: Springer Science.

Karmarkar, U. (2014). "Service industrialization". In: *Managing Consumer Services: Factory or Theater*. Chapter 2 in Ed. by E. Baglieri and U. Karmarkar. Heidelberg: Springer.

Karmarkar, U. and U. Apte (2007). "Operations management in the information economy: Information products, processes and chains". *Journal of Operations Management*. 25: 438–453.

Karmarkar, U. S., K. Kim, and H. Rhim (2015). "Industrialization, productivity and the shift to services and information". *Production and Operations Management*. 24(11): 1675–1695.

Katz, L. and K. Murphy (1992). "Changes in relative wages: Supply and demand factors". *Quarterly Journal of Economics*. CVII: 35–78.

Landefeld, S. and R. Parker (1997). "BEA's chain indexes, time series, and measures of long-term economic growth". *Survey of Current Business*. May: 58–68.

Lawson, A., K. Bersani, M. Fahim-Nader, and J. Guo (2002). "Benchmark input-output accounts of the United States, 1997". *Survey of Current Business*: 19–109.

Little, J. S. and R. K. Triest (2002). “The impact of demographic change on US labor market”. *New England Economic Review*. First Quarter, 47–68.

Machlup, F. (1962). *The Production and Distribution of Knowledge in the United States*. Princeton, NJ: Princeton University Press.

Machlup, F. (1980). *Knowledge: Its Creation, Distribution and Economic Significance, Volume 1: Knowledge and Knowledge Production*. Princeton, NJ: Princeton University Press.

Mithas, S. and J. Whitaker (2007). “Is the world flat or spiky? Information intensity, skills, and global service disaggregation”. *Information Systems Research*. 18: 237–259.

Moore, G. (1965). “Cramming more components onto integrated circuits”. *Electronics*: 114–117.

Muro, M., J. Whiton, and R. Maxim (2019). “What jobs are affected by AI? Better-paid, better-educated workers face the most exposure”. *Metropolitan Policy Program Report*. Brookings Institute.

OECD (1981). *Information Activities, Electronics and Telecommunications Technologies: Impact on Employment, Growth and Trade Volumes*. Vol. I and II. Paris: OECD.

OECD (1986). *Trends in the Information Economy*. Paris: OECD.

Osberg, L., E. N. Wolff, and W. J. Baumol (1989). *The Information Economy: The Implications of Unbalanced Growth*. Halifax (Canada): The Institute for Research on Public Policy.

Porat, M. (1977). *The Information Economy (9 Volumes), Office of Telecommunications Special Publication 77-12*. Washington D.C: US Department of Commerce.

Rubin, M. R. and E. Taylor (1981). “The U.S. information sector and GNP: An input-output study”. *Information Processing and Management*. 17(4): 163–194.

Tevlin, S. and K. Whelan (2003). “Explaining the investment boom of the 1990s”. *Journal of Money, Credit, and Banking*. 35(1): 1–22.

Webb, M. (2020). “The impact of artificial intelligence on the labor market”. *Working Paper*. Stanford University (available online at: https://web.stanford.edu/~mww/webb_jmp.pdf).

Whelan, K. (2002). “A guide to U. S. chain aggregated NIPA data”. *Review of Income and Wealth*. 48(2): 217–233.

Wolff, E. (2006). “The growth of information workers in the US economy, 1950–2000: The role of technological change, computerization, and structural change”. *Economic Systems Research*. 18(3): 221–255.

World Bank (2016). *World Development Report 2016*. Washington, D.C.: The World Bank.