12

Ensuring the Education and Skills Needed for ICT Employment and Economic Growth

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12.1 Overview

Information and communication technologies (ICTs) are becoming an increasingly important component of modern economies. Use of these technologies has been a principal, if not the most important, driver of economic growth over the past half century. They have enabled economies to transform from a physical labor manufacturing focus into ones based on the use of intellectual knowledge to provide services.

But associated with this transformation in productive techniques and outputs has been a radical change in required labor skills. Industrial manufacturing or office work during the first three quarters of the twentieth century required mostly blue and pink collar skills: laborers or skilled tradesmen and secretaries, clerks or typists. As ICTs developed and increased their influence over both the manufacturing and service sectors, this began to change. Rather than the physical laborer being the most important person on the assembly line, it became the designer or programmer of the manufacturing robot or other automation equipment, as well as the skilled worker who maintained and repaired this

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The analyses and conclusions developed in this chapter are those of the author alone, and should not be construed as representing any official position of AT&T.

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L. Pupillo et al. (eds.), *Digitized Labor*, https://doi.org/10.1007/978-3-319-78420-5_12

equipment. Offices and service production centers also were depopulated of secretaries, clerks, typists and mid to lower managers who had compiled paper reports and provided communication links between upper management and production workers. Instead, these tasks devolved upon computer and communication networks—and the persons who knew how to design, program and operate them.

Further, the skills needed to develop or use ICTs generally require education or training that differs substantially from the education and training required to be productive in the earlier twentieth century economy. Rather than trade apprenticeships, interpersonal relationships and on-the-job training, ICTs demand an educational background in science, technology, engineering and mathematics (STEM)—one which liberal-arts focused secondary and post-secondary educational institutions often struggle to provide on an efficient basis.

This chapter examines the growth and economic significance of ICTs and ICT employment in today's economy. It goes on to detail the particular skills and education required for workers to be productive participants in ICT-centric economies. It then discusses several education and training innovations that hold promise for workers to acquire efficiently these skills. Finally, it concludes by describing how one major ICT-focused corporation, AT&T, is promoting these ICT-based methods as a way to ensure that it has a productive workforce—and to provide an easy and efficient gateway for its business and residential customers to access the STEM skills necessary to make productive use of the ICT services that AT&T produces.

12.2 Influence of ICTs in Today's Economy

ICTs have a profound influence on today's economy. Not only is there a huge industry responsible for creating these technologies, but the ICT-creating industry is dwarfed by the segments of modern economies that make use of ICTs. Indeed, the influence of ICTs on the economy is much greater from their use than from their initial development and sale. But in addition to their vast influence on output markets, the unique demands of ICTs cause them to have an equally immense influence on markets for productive input factors, particularly labor. The following section will address the influence of ICTs on both output markets and labor markets.

12.2.1 What Are ICTs?

ICTs are multifaceted. Perhaps the most well-known embodiment of ICTs is in information processing equipment: computers. While in the past, computers were bulky mainframe equipment—housed in special climate-controlled rooms and tended to by a small cadre of specialist technicians, today this represents a minority of computing equipment. Today's typical computer is a desktop or laptop PC, at its largest—and goes down from there. Smartphones, digital cameras, GPS units, and even microwave ovens or clock radios, are all computers. But these are typically tended to by people whose principal profession is not computing, but who commonly have at least some knowledge or competence in the field.

Perhaps less visible than computing equipment is communications equipment. In the past, these were special purpose analog or digital switches or transmission equipment—also housed in special climate-controlled rooms or buildings and tended to by a small cadre of specialist technicians. But today, communications equipment is everywhere—not just inter-linking the large nodes of communications companies with each other and with their direct customers. Ordinary homes contain elaborate Ethernet, MoCA or Wi-Fi networks, and commercial communications use of the airwaves is everywhere—from mobile wireless to RFID sensor networks to satellite radio or television.[1]

Further, almost all present-day computing equipment also incorporates communications capabilities. The era of the standalone computer fed by punch cards and computer tapes, and outputting miles of paper printouts is over. Inputs to and outputs from today's computers now travel almost exclusively via digital communications technologies.

But ICTs are not just embodied in computing and communications equipment. Dwarfing this investment in equipment is investment in the software technologies that make this equipment operational and useful. This investment divides into two types. The first is the human investment sunk into developing the software that both operates the vitals of the ICT equipment as well as performs the applications that users intend the equipment to execute. But even more significant is the human investment in the users of this operating and applications software. While the former investment may be restricted to employees of the software companies creating these programs, the latter is diffused among all companies and individuals that actually use this equipment. Given the immenseness of this human investment, it is little wonder that operating and applications software frequently has useful lifespans many times longer than the equipment upon which it operates.

12.2.2 Influence of ICTs on Economic Growth

ICT has three major pathways of influence on the economy: via the provision of physical ICT infrastructure, via the development and provision of ICT-based applications, and via the use of ICT infrastructure and applications by businesses and residential users.

The most direct and obvious influence of ICTs on the economy is via the production of ICT infrastructure. ICT infrastructure includes items like Internet Protocol networks, electronic computing and communications equipment, the user devices connected to the network and the special-purpose building structures that may house this equipment. In 2013, US companies invested $94 billion in computers and their peripheral equipment, invested $110 billion in communications equipment, and invested $13 billion in communications structures (U.S. Department of Commerce 2015). But these communications networks and computers are of little value without operating software to bring them to life and without applications software to make them useful for the tasks that business and residence customers seek to accomplish. Investment expenditures on this software amounted to $299 billion in the US in 2013. Altogether, these ICT investments have accounted for roughly 20% of all private fixed investment in the US in recent years. The growth history of each of these categories of ICT investment is displayed in Fig. 12.1. While investment in ICT equipment and structures has been relatively stable over the past ten years, investment in software has expanded significantly.

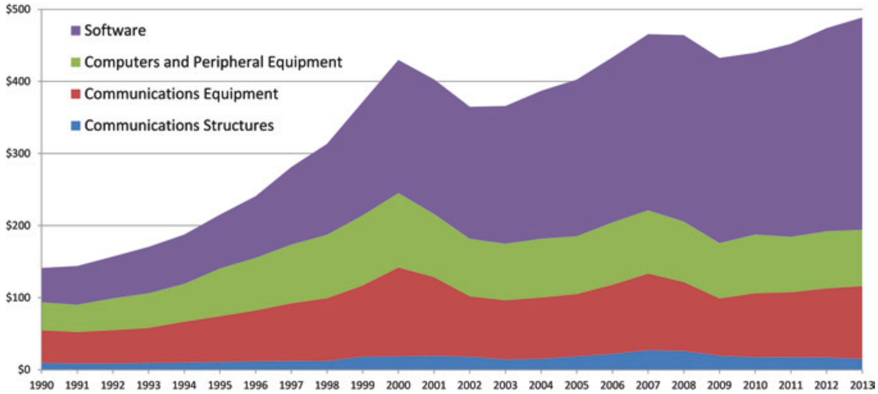

Fig. 12.1 Annual investment in ICTs in the United States: 1990–2013 (billions) (*Data source* Brogan 2014)

While these infrastructure and software investments by themselves amount to over 3% of annual US Gross Domestic Product, ICT investments represent only the tip of ICT iceberg. The most profound economic impact from ICTs derives not from the production of computers, communication networks or software, but from the use of these ICT components by businesses and residences in their productive activities. This is because the percentage of all businesses and consumers using ICTs is very much larger than the percentage of businesses creating them.

The influence of all of this ICT investment on the US national economy is nothing short of massive. Over the thirty years between 1974 and 1994, ICTs are estimated to have accounted for roughly 50% of total labor productivity growth in the US economy. While from 2004 to 2012 this share has dropped to around 40%, ICT's influence on total US growth remains very strong (Byrne et al. 2013; Miller and Atkinson 2014). Indeed, software alone is estimated to be responsible for over 15% of all US labor productivity growth between 2004 and 2012 (Shapiro 2014).

12.2.3 Influence of ICTs on Employment and Wage Growth

While it is clear that ICT production and use have had massive, positive influences on overall economic growth, their effects on labor employment and wages are more complex. This is because ICT use may displace non-ICT services and labor—which may result in some economic sectors and their workers suffering employment loss or wage reductions. Thus, the immediate effect of expanded use of ICTs on total employment and average wages may be ambiguous.

Note, first, that ICT-centric jobs exist within both ICT-producing sectors (e.g., businesses that manufacture computers or communications equipment and firms producing software or operating or installing networks) as well as in ICT-using sectors such as finance or aerospace. Note, further, that ICT-producing businesses also employ many workers engaging in non-ICT-centric jobs. As a result, ICT-related employment consists of both these groups. This is illustrated in the following graphic (Fig. 12.2).

As the above graphic also indicates, ICT occupations both inside and outside of the ICT-producing sector are growing rapidly—with a total of 7.0 million jobs in 2010 estimated to rise to 8.0 million by 2020. In addition, the growth of the ICT-producing sector has resulted in the increased employment of other occupations in the sector—rising from 3.8 million jobs in 2010 to an estimated 4.2 million in 2020 (Brogan 2012, 2013).

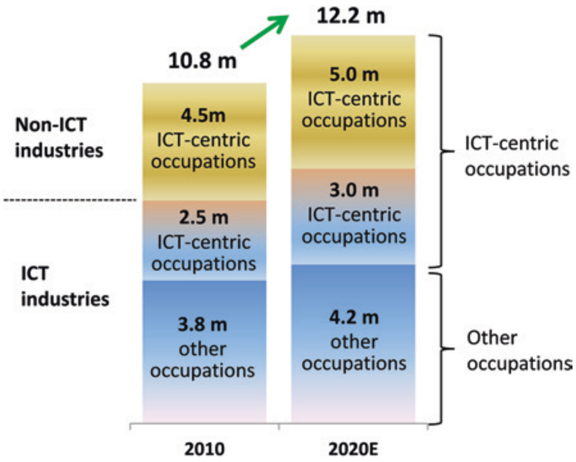

Fig. 12.2 Distribution and growth of US ICT-related occupations (*Data source* Brogan 2012)

Currently, ICT-related jobs account for over 7.5% of all employment in the United States, and this may be expected to expand because ICT-related industry sectors are among the fastest growing in the United States. Indeed, six of the eight fastest growing US industry sectors (computer manufacturing, software publishing, computer systems design, data processing and information services, securities and financial, and semiconductors) are ICT-focused. Further, seven out of the twenty US industry sectors projected to have the largest absolute amounts of output growth over the 2012–2022 period are ICT-related sectors.

As a result of this dynamic growth, not only do ICT-related jobs account for 7.5% of national employment in the United States, they pay far better than national averages. Wages for all occupations employed within ICT industries boast wage levels that are 137% of the US average wage—and 152% of the US median wage. These pay premiums are even more pronounced when one looks exclusively at ICT-centric occupations within US industries. Wages for ICT-centric occupations are 141% of the overall US average, and 176% of the US median (Brogan 2012).

Of course, this employment growth will not occur unless there are adequate numbers of workers trained and prepared to staff these ICT-related jobs—which overwhelmingly will require some form of post-secondary education for entry. Indeed, nineteen out of the thirty occupations projected to grow the fastest from 2012 to 2022 will require such post-secondary education (U.S. Department of Labor 2015).

12.3 Educational Requisites for ICT-Related Employment

If workers were interchangeable between ICT-related jobs and other jobs, the impact of the ICT revolution on labor markets would be minimal. Workers would simply flow laterally from declining sectors of non-ICT employment into the faster-growing ICT sectors. But this simple movement is unlikely to be the case. ICT-related positions are much more likely to require a post-secondary educational background and STEM knowledge than other jobs in the economy. This double requirement presents a huge challenge to labor markets and to educational institutions. Further, enhanced education is not only necessary for the workers whose jobs involve ICTs. This education is also extremely valuable to enable ordinary consumers to use ICTs effectively. Thus, the fact that an enhanced education, particularly in STEM fields, makes it more likely for a worker to find a job, for the job to pay well and for the worker and his or her family to take advantage of ICTs in their home life; makes STEM education triply valuable for the economy and society.

But just as enhanced STEM education provides a triple benefit to workers and their families, it provides a double benefit to the ICT-related companies that employ them. This is because not only are such workers more productive, they are also more likely to buy and use at home the ICT-related technologies and services that their employers produce. Indeed, this virtuous cycle is akin to that attributed to Henry Ford who in 1914 doubled the wages he paid to his automotive factory workers to $5 per day. By this simple action Ford not only gained access to more productive workers—but their employment now provided them with an income adequate for them to afford to buy one of the Model T cars they were producing—and thereby increased Ford's sales (Nilsson 2014; Cwiek 2014).

12.3.1 Challenges Facing the Current Educational System

STEM education is widely provided by today's educational system, but it presents this system with many challenges. First, current high school and college degree requirements may not require the collection of many STEM credits—often as few as four classes over the course of a four-year educational program. Given that student minds tend to be far more plastic in accepting new forms of knowledge in their adolescent and young adult years than subsequently, failure to acquire substantial STEM knowledge while young and still in school is a lost opportunity that is far more difficult to recover from than to address early.

Second, STEM education as currently presented is among the most expensive for schools to convey. While mathematics may require minimal investments in school infrastructure beyond books, a lecture room and a blackboard; science, technology and engineering education commonly requires substantial physical infrastructure. Laboratory facilities need to be provided, as well as significant computing facilities. Further, while an ordinary lecture class may involve as little as three or four hours of classroom occupancy a week, laboratory classes may require much more than this per student. These laboratory and computing facilities are also not static, they may require continual renewal and reinvestment as technologies evolve.

Third, traditional STEM degrees, especially at the post-secondary level, tend to be broad programs—often covering a far wider range of topics and skills than a student may need for any particular job they eventually acquire. While acquiring these skills pre-emptively while in school may allow the student a wider selection of possible jobs when entering the labor market, it also means that a substantial fraction of the student's learning may end up being unexploited in their acquired position, and thus possibly wasted.

Finally, STEM educators are scarce and expensive to acquire. Because the United States produces so few STEM graduates relative to other countries, those that it does produce can command substantial wage premiums—as educational institutions need to bid not only against other educational institutions but also against commercial ICT-creating and using industries for this talent (National Association for Alternative Certification 2009).

12.3.2 Possible Solutions to These Educational Challenges

While all of the above factors may create a "perfect storm" threatening the increased provision of STEM-educated workers, the technology that the ICT industry creates may provide some promising ways to address these challenges.

For example, the shortage of STEM teachers may possibly be addressed by the development of Massive Online Open Courses (MOOCs). By using technology to address a class of thousands, rather than the few hundred that is likely to be the maximum capacity of a physical lecture hall, the productivity of STEM educators may be multiplied many fold. MOOCs also may hold the promise of allowing students to be taught by higher quality teachers. Educators commonly span a wide quality range, from lower quality ones who fail to communicate well and to motivate students, to higher quality ones who are superb communicators and provide students with real inspiration. ICTs that allow a higher quality teacher to direct a MOOC may increase the average teacher quality experienced by students.

ICTs also enable online learning. This, too, may result in wider and less expensive conveyance of STEM education. Learning online reduces the need for expensive schoolrooms. It also reduces the amount of transportation and time needed by students to attend classes. But perhaps most importantly, it allows time-shifting. By allowing the student flexibility over the time during which he or she chooses to "attend" class, conflicts with work schedules or childcare are reduced substantially. All of this reduces the "cost" to the student of gaining the desired education.

Innovative ICTs may also permit online learning to rival or exceed the immersiveness of an in-class education. By allowing the student to proceed at his or her own pace, and to pause the presentation to pose questions or conduct side investigations as issues arise—rather than after the lecture or physical class is over—may result in students that have better apprehended and assimilated the course's contents. Further, because of the ability of computer-generated graphics to demonstrate relationships or simulate physical experiments individually in front of each student, it is possible that this form of information presentation may be more impressionable upon students than demonstrations or experiments performed at the front of a traditional lecture hall.

Another manner in which ICTs may permit post-secondary students to acquire STEM skills at less cost is via nanodegrees (Mehrotra 2014). These programs differ from traditional university-like degrees and courses in that they are far more compressed in time and coverage. While a traditional university course runs for three or four months, a nanodegree course generally runs for only one to three months. And because nanodegree programs are far more focused in subject area than traditional degree programs, they are typically completed in six to twelve months—rather than the two to four years for traditional post-secondary degrees. Finally, because these nanodegree courses are taught via MOOC format, they are also highly economic—often costing only several hundred dollars per course—rather than the several thousand dollar price tag for traditional post-secondary STEM courses.

12.4 AT&T Educational Initiatives

AT&T is a large telecommunications and video distribution company. Every year AT&T hires roughly 25,000 new employees, nearly 75% of which will work in STEM fields (Anderson 2014). In addition improving the quality of AT&T and its business partners' workforces, better and wider STEM education will also improve the ability of consumers to use the ICT-related services that AT&T produces. To help in improving STEM education, AT&T takes a two-pronged approach. One prong is to provide support for general improvements in secondary or high school education. The other is to support specific post-secondary STEM career skills acquisition and improvement.

12.4.1 General Educational Support

Aspire is the name of AT&T's initiative to support general secondary education in the United States. This program is run through the AT&T Foundation and is committed to provide $350 million in funds over the 2008–2017 period.[2] Aspire's projects cover a broad range of initiatives, including programs to improve secondary education directly, as well as to reduce high school dropout rates and to provide students with mentoring opportunities from AT&T employees.[3]

Certain Aspire initiatives try to capitalize on the fact that you rarely need to nag an adolescent to pay more attention to his or her computer, mobile or gaming device. By funding the development of learning materials or programs that take advantage of modern mobile, broadband or video technologies and communications to convey information in an engaging manner, Aspire seeks to harness the capabilities of these ICT technologies to improve secondary education.

But in addition to improving the education that students receive when they attend school, it is vital that young people do attend school and not drop out. For this reason, Aspire also supports programs offered by organizations such as GradNation or Communities in Schools which provide out-of-school, community-based programs for at-risk students aimed at increasing their high school graduation rates.[4]

Finally, there is nothing like one-on-one or small group exposure to actual working people and their jobs to demystify what is involved with "having a job" or to relate why schooling is valuable to achieving this end. For this reason, thousands of AT&T employees donate their time to meet with secondary school students, allow them to "shadow" them in their jobs for a day, and answer questions about things like what high school classes they have found to have been the most valuable for performing their current responsibilities, what a job interview consists of, or any number of other questions whose answers may seem obvious to someone already within the world of work, but like a black box to a young student. In all, over 100,000 high school students a year participate in AT&T's job shadow program. Many of these students who go on to college may also participate in summer internship programs that AT&T sponsors.

12.4.2 Post-secondary STEM Education Initiatives

Once education reaches the post-secondary level, today's STEM education tends to become much more specialized, and generally a lot more expensive—both in terms of direct cost as well as the opportunity costs incurred by both the student and possibly the student's employer when productive labor is foregone for extended periods while pursuing a traditional college-level or graduate degree. Clearly, any educational innovations that can reduce study time and expense while providing the student with the specific STEM-skills needed to further their employment will be highly welcome.

For the above reasons, AT&T Aspire supports a nanodegree project called Udacity.[5] This project, which is a joint initiative of AT&T, Google, Facebook and other leading ICT companies, offers nanodegrees in multiple ICT-related subject areas such as web and app development, digital entrepreneurship, programming, and many others. As noted earlier, these courses are highly economic—both in terms of direct cost and students' (and possibly their employers') time. Udacity nanodegree courses only take a month or two to complete—with a full multi-course program typically being accomplished within six months to a year. Further, the cost of each course is only around $200. As a result, large numbers of leading companies like GE or CapitalOne have agreed to accept credentials offered by these Udacity nanodegrees (Schacht 2016).

For more advanced professional training, AT&T and Udacity have partnered with Georgia Institute of Technology to develop a full 36 credit-hour Master of Science in Computer Science curriculum. This program, offered via MOOC format, costs students between $7000 and $8000 in tuition to complete the full degree—only about one-fifth of what a traditionally-taught computer science Master's program would cost.[6]

Because nanodegrees are a relatively recent innovation in educational technology, large-scale data are not yet available demonstrating their degree of efficacy, but initial anecdotal reports suggest they are a success (Fenton 2015; Yegulalp 2015).[7]

12.5 Summary

There is no question but that over the last forty years, ICTs have been the most important source of economic growth and sectoral change in both US output and labor markets. Indeed, it is hard for anyone under the age of 50 to remember a time when manual processes were the exclusive way of conducting a financial transaction or making an airline reservation.

But with these changes in technology have come great changes in the educational requisites for workers. STEM knowledge and advanced education are now the key to productive employment and a middle class lifestyle. While traditional educational systems have faced difficulties in providing widespread STEM education on an efficacious basis, ICTs themselves may offer at least a partial solution. By harnessing the ability of ICTs to convey STEM education via MOOCs or nanodegrees, it may be possible to ensure that the economic revolution that ICTs have wrought in modern society will continue well through the twenty-first century.

Notes

1. Ethernet is a computer networking technology used in both local and metropolitan area networks (https://en.wikipedia.org/wiki/Ethernet). MoCA or Multimedia over Coax Alliance is a home networking technology that uses the coaxial cable already present in many houses for video and digital data distribution (http://www.mocalliance.org/about/technology.htm). Wi-Fi is the well-known wireless networking technology used for short-range communications in homes and businesses (https://en.wikipedia.org/wiki/IEEE_802.11). RFID or Radio-Frequency Identification is a wireless technology used to identify and track objects (https://en.wikipedia.org/wiki/Radio-frequency_identification).
2. https://www.att.com/Common/about_us/files/pdf/aspire/att_aspire_flyer.pdf.
3. http://www.about.att.com/content/csr/home/possibilities/at-t-aspire.html.
4. See http://gradnation.americaspromise.org/ and https://www.communitiesinschools.org/.
5. https://www.udacity.com/ and http://about.att.com/content/dam/csr/11_18assets/PCassets/Aspire_nanodegree_one-pager_11-21-14.pdf.
6. http://www.omscs.gatech.edu/.
7. See also https://www.quora.com/Are-Udacity-nanodegrees-worth-it-for-finding-a-job.

References

Anderson, Nicole. 2014. “AT&T Pledges to Support 100Kin10, National Network to Grow STEM Initiatives.” November 20. http://about.att.com/content/csr/home/blog/2014/11/at_t_pledges_to_supp.html.

Brogan, Patrick. 2012. “Broadband and ICT Ecosystem Directly Supports Nearly 11 Million High-Paying U.S. Jobs.” *USTelecom Research Brief*, February 28. https://www.ustelecom.org/sites/default/files/documents/022812_Employment-Research-Brief-final.pdf.

Brogan, Patrick. 2013. “Broadband and Tech Jobs Drive Economic Future.” *USTelecom Blog*, December 20. http://www.ustelecom.org/blog/broadband-and-tech-jobs-drive-economic-future.

Brogan, Patrick. 2014. “Migration to Modern Networks: What Do the Latest Data Show?” *USTelecom Webinar*, August 13. http://origin-qps.onstreammedia.com/origin/InfiniteConferencing/Web%20Recordings/DatedRecordings/081314/USTelecom/081314USTelecom-Edited.mp4.

Byrne, David M., Stephen D. Oliner, and Daniel E. Sichel. 2013. “Is the Information Technology Revolution Over?”, March. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2240961.

Cwiek, Sarah. 2014. “The Middle Class Took Off 100 Years Ago … Thanks to Henry Ford?” *All Things Considered, NPR*, January 27. http://www.npr.org/2014/01/27/267145552/the-middle-class-took-off-100-years-ago-thanks-to-henry-ford.

Fenton, William. 2015. “Udacity Review & Rating.” *PCMag*, May 29. https://www.pcmag.com/article2/0,2817,2484810,00.asp.

Mehrotra, Anushka. 2014. “Could Online Nanodegrees Replace 4-Year College Degrees?” *USA Today—College*, June 23. http://college.usatoday.com/2014/06/23/could-online-nanodegrees-replace-4-year-college-degrees/.

Miller, Ben, and Robert D. Atkinson. 2014. “Raising European Productivity Growth Through ICT.” Information Technology and Innovation Foundation Whitepaper, June. https://itif.org/publications/2014/06/02/raising-european-productivity-growth-through-ict.

National Association for Alternative Certification. 2009. “STEMing the Teacher Shortage Tide.” November. https://www.uschamberfoundation.org/sites/default/files/publication/edu/STEMing%20the%20Teacher%20Shortage%20Tide_FINAL.pdf.

Nilsson, Jeff. 2014. “Why Did Henry Ford Double His Minimum Wage?” *The Saturday Evening Post,* January 3. http://www.saturdayeveningpost.com/2014/01/03/history/post-perspective/ford-doubles-minimum-wage.html.

Schacht, Jack. 2016. “Does a Nanodegree Really Guarantee a Job?” *My College Planning Team Blog*, August 16. http://mycollegeplanningteam.com/2016/08/nanodegree-really-offer-guaranteed-job/.

Shapiro, Robert J. 2014. "The U.S. Software Industry: An Engine for Economic Growth and Employment." Software and Industry Information Association Whitepaper. https://www.siia.net/Admin/FileManagement.aspx/LinkClick.aspx?fileticket=yLPW0SrBfk4%3D&portalid=0.

U.S. Department of Commerce, Bureau of Economic Analysis. 2015. "National Income and Product Accounts." Tables 5.3.6, 5.4.6 and 5.5.6. Webpage visited December. http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=1&isuri=1.

U.S. Department of Labor, Bureau of Labor Statistics. 2015. "Projections of Occupational Employment, 2014–24." December. http://www.bls.gov/career-outlook/2015/article/projections-occupation.htm.

Yegulalp, Serdar. 2015. "Even at Half Off, Is a Udacity Nanodegree Worth It?" *Infoworld Tech Watch*, July 7. https://www.infoworld.com/article/2944070/certifications/udacitys-half-off-deal-for-online-certifications-bonus-or-bust.html.