Citi GPS

SKILLS THAT PAY

The Returns from Specific Skills as Demanded in Job Advertisements

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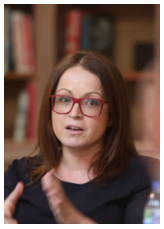

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SKILLS THAT PAY

The Returns from Specific Skills as Demanded in Job Adverts

Kathleen Boyle, CFA
Managing Editor, Citi GPS

What did you want to be when you grew up? As a kid, you probably chose occupations you saw in the local community or one that followed in your parents' footsteps. Maybe a teacher, doctor, nurse, or fireman. Television opened a whole new list of possibilities leading to visions of being an astronaut or a movie star. But in the 1970s, very few kids would have said they wanted to be a data scientist.

The Citi GPS "Technology at Work" report series launched with the statistic that 47% of jobs in the United States were at risk of automation over the forthcoming decades and similar shares were estimated for other countries. In subsequent reports, we looked at how the rise of e-commerce was affecting employment; the trends in the workforce from the COVID-19 pandemic; and the potential for outsourcing not only manufacturing jobs, but service jobs as well.

While we focused on how technology and automation could negatively affect jobs, we struggled to predict jobs yet to be invented. In the 2019 Citi GPS report *Technology at Work v4.0: Navigating the Future of Work*, we noted we were on the brink of a technological revolution with the advent of artificial intelligence. Although AI-enabled automation could affect low-income jobs typically performed by workers with no more than a high school degree, jobs less likely to be replaced would require at least a college degree and consist of tasks centered on complex social interactions and creative skills.

With AI now upon us and leading us into the "Fourth Industrial Revolution," this new report notes hiring has evolved from requiring specific education and experience criteria to looking more at detailed skills requirements. The report that follows looks at the changing demand for specific skills in this rapidly changing job market. It discusses the skills that are rising and falling in demand and explores how the wages for these skills are changing.

Looking at professional occupations, the authors identify two "soft" skills groups and seven "cognitive" skills groups that are increasingly relevant for the future of work and deemed important based on the frequency in which they appear in job advertisements. Overall, the soft skill collaborative leadership increased in importance over time in terms of demand and hourly wages. The study also found that cognitive skills in data science are constantly evolving, causing certain data science skills to attract a wage premium in one period, then lose it in the next. Looking specifically at AI, demand for AI skills has increased globally by 9 times for "Tech-AI" jobs and 11.3 times for "Broad-AI" ones since 2015.

Constantly evolving technology leads to shifting changes in skill set demand. Because of this, continuous learning will be critical in the future, particularly in data science, for employees to stay relevant. For corporates, this means workforce upskilling will be increasingly important. For investors, analyzing the skills being demanded by a company can determine if that company is seeking the skills most relevant in today's economy.

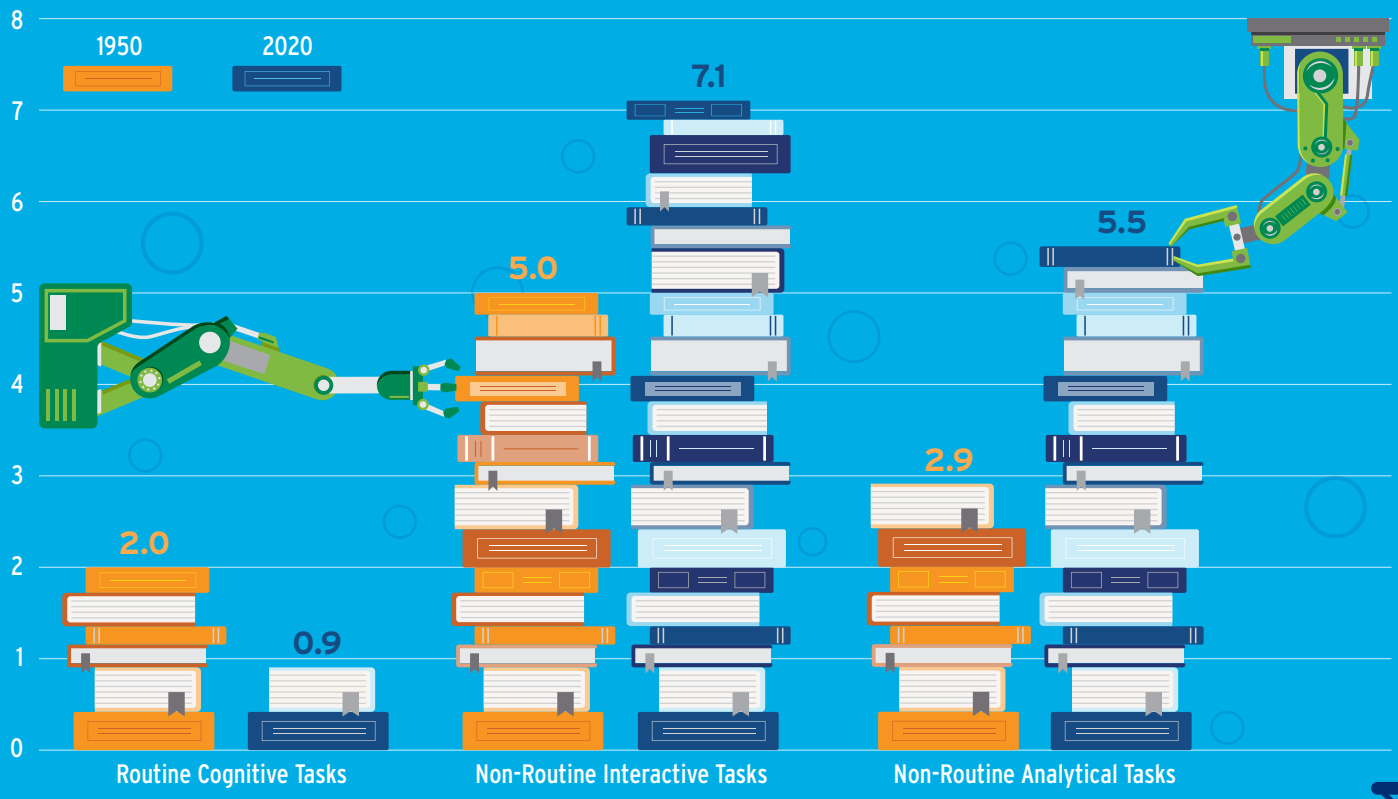
Dreaming about being a data scientist as a kid would have been a great choice; collecting the skills to meet the role's changing requirements as an adult is an even better one.

Skills That Pay

RISE OF THE MACHINES

Global labor markets are in transition, with automation increasingly replacing workers for routine tasks. This shift is reflected in a rise in demand for workers with interactive and analytical skills in non-routine work.

Skills Demand 1950 vs. 2020 (Number of Mentions per 1,000 Job Ad Words)



Source: Atalay et al. (2020), Citi Global Data Insights

WHICH SKILLS ARE IN DEMAND?

Using data from job advertisements, we examine the specific skills that are rising and falling in demand across two time periods. Collaborative leadership registers the steepest increase in demand, reflecting its importance in fostering inclusive environments for innovation.

Share of Job Adverts Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

Soft Skills **Cognitive Skills**

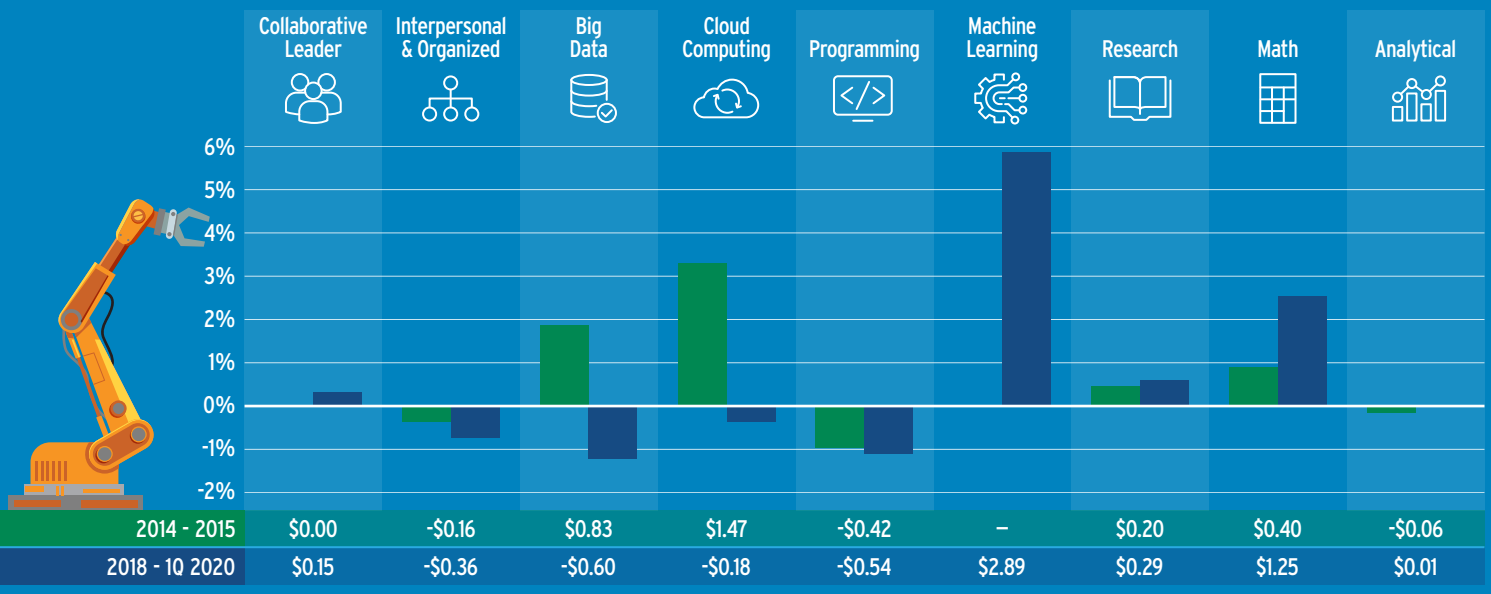
		Collaborative Leadership	Interpersonal & Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-2015	%	50.14%	24.70%	1.63%	13.60%	N/M	1.76%	16.19%	0.19%	31.19%
	#	71,718	35,335	2,325	19,448	N/M	2,524	23,152	273	44,607
2018-1Q 2020	%	61.07%	30.85%	2.49%	13.03%	0.19%	4.88%	18.94%	0.21%	35.83%
	#	374,087	188,981	15,246	79,827	1,155	29,911	115,996	1,288	219,461

Source: LinkUp, London School of Economics, Citi Global Data Insights

DATA SCIENCE EVOLUTION CHANGES SKILLS PRIORITIES

When we look at the wage impact of a 10-percentage point increase in demand, certain data science skills (i.e., big data and cloud computing) attract a wage premium in the first period, then lose it in the second as those skills became more abundant in the marketplace. Machine learning – a more recent technology – is an exception, reflecting constant evolution in data science.

Occupational-Level Wage Response to a 10-Percentage Point Increase in Demand (%, $ per Hour)



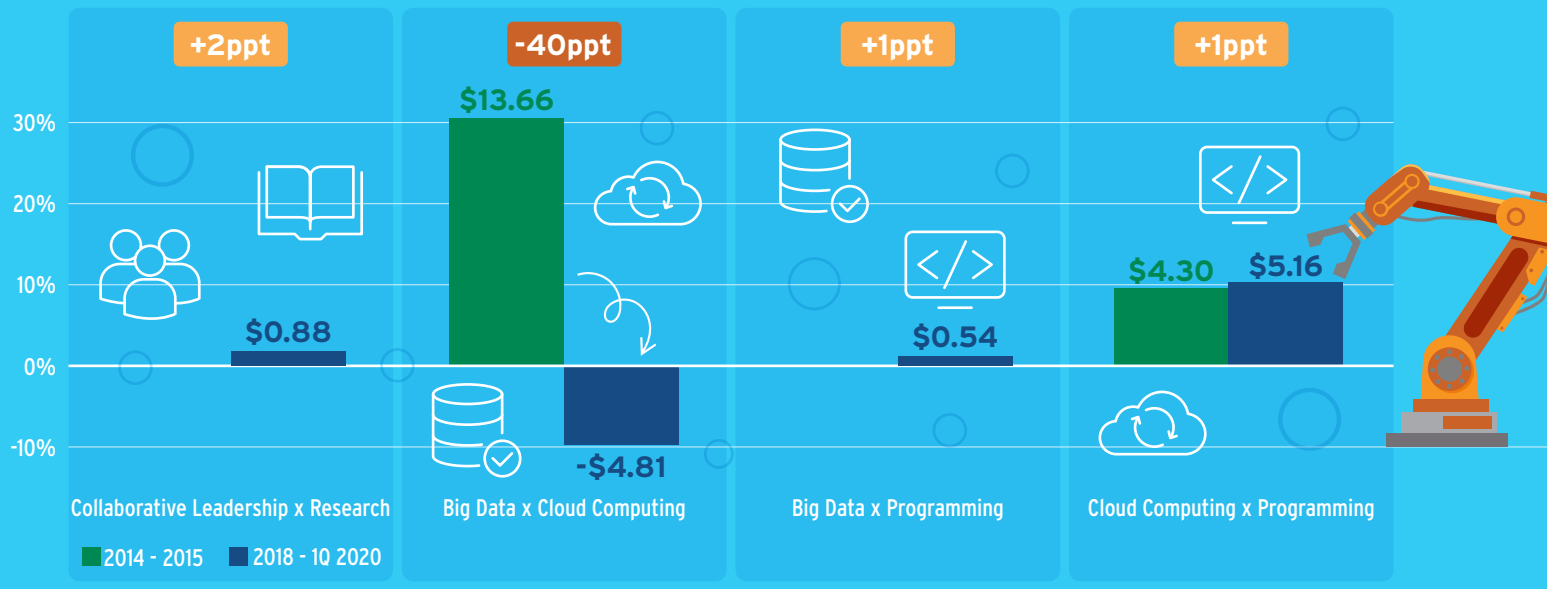
	Collaborative Leader	Interpersonal & Organized	Big Data	Cloud Computing	Programming	Machine Learning	Research	Math	Analytical
2014 - 2015	$0.00	-$0.16	$0.83	$1.47	-$0.42	–	$0.20	$0.40	-$0.06
2018 - 1Q 2020	$0.15	-$0.36	-$0.60	-$0.18	-$0.54	$2.89	$0.29	$1.25	$0.01

Source: LinkUp, London School of Economics, Citi Global Data Insights

COMPLEMENTARY SKILLS

There is a positive interaction between collaborative leadership and research skills in terms of wages. This aligns with literature indicating that automation increases the need for social skills alongside advanced cognitive skills like logical reasoning.

Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Select Interactions Between Skills Groups (Bars Represent %, $ per Hour Embedded)



Source: LinkUp, London School of Economics, Citi Global Data Insights

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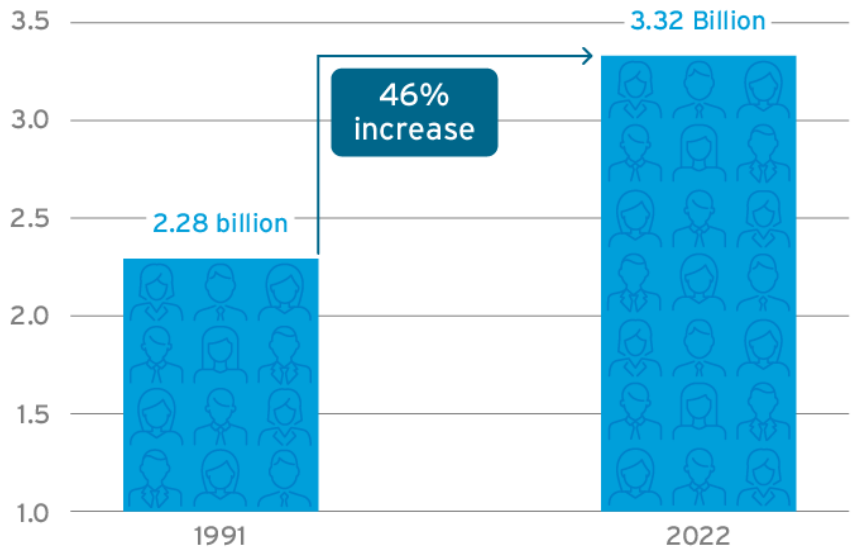
Background

Over the past three decades, the global population has registered an increase of 45%, growing from 5.5 billion to close to 8 billion, according to data from the World Bank. At the same time, the labor market has grown 46% — pretty much in line with population growth — with the number of employees worldwide increasing from 2.3 billion to 3.3 billion. Masked beneath these growth numbers is the effect of the Third Industrial Revolution, which dramatically changed the demand for skills. With the onset of the Fourth Industrial Revolution upon us, the demand for skills is likely to be altered again.[1]

Figure 1. Number of Employees Worldwide (Billions, Over 15 Years Old)



Source: International Labour Organization

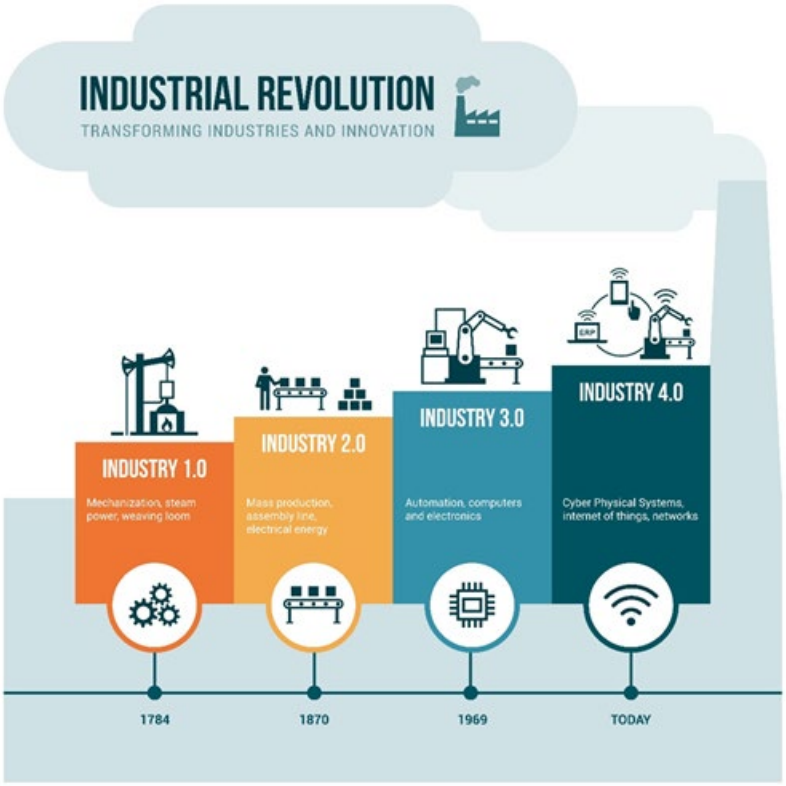
Labor Markets Are Shifting and Require Investments in Skills

Global labor markets are currently in transition, with rising automation and technological innovation increasingly leading to the replacement of humans in the workplace by machines. The Third Industrial Revolution, which started in the second half of the 20th century, brought forth the rise of electronics, telecommunications, and computers. It also resulted in the replacement of humans in jobs that were easily codified because they largely consisted of routine tasks, e.g., tasks that are repetitive in nature, and caused a large reduction in jobs in the middle of the income distribution, mainly in the manufacturing sector.[2]

[1] See Figure 2 for definitions of the different industrial revolutions.

[2] David H. Autor and David Dorn, "The Growth of Low-Skill Service Jobs and the Polarization of the U.S. Labor Market," *American Economic Review*, Vol. 103, No. 5, August 2013; Grace Lordan and David Neumark, "People Versus Machines: The Impact of Minimum Wages on Automatable Jobs," *Labour Economics*, Vol. 52, June 2018.

Figure 2. Industrial Revolution Timelines



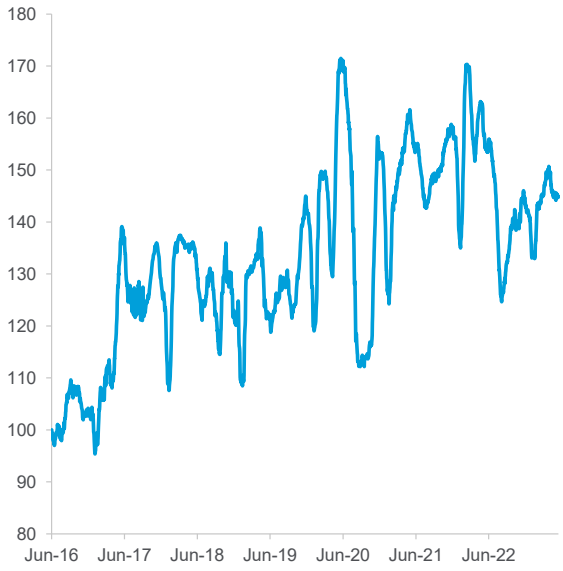
Source: Shutterstock

The Fourth Industrial Revolution, which started in 2015, is bringing with it artificial intelligence (AI), robotics, quantum computing, genetic engineering, and the Internet-of-Things (IoT). Together, these new technologies promise to further shape the nature of work. In particular, we expect significant changes to the skills being demanded in the workplace. In their 2022 study, Cecily Josten and Grace Lordan analyzed patents in detail to determine the skills of the future and concluded that "people" skills and abstract thinking skills were the most future-proof skills in terms of getting and keeping a job.[3]

The COVID-19 pandemic accelerated the Fourth Industrial Revolution through the development of technologies with the power to greatly shape the day-to-day work experience.[4] One example is remote working, which was driven by an increase in technology adoption across industries and an improvement in technological equipment that enabled virtual transactions and exchanges. As Figure 3 shows, the Online Labour Index 2020 provides an indication of how standard employment is increasingly being supplemented and substituted by temporary gig work mediated by digital platforms.[5]

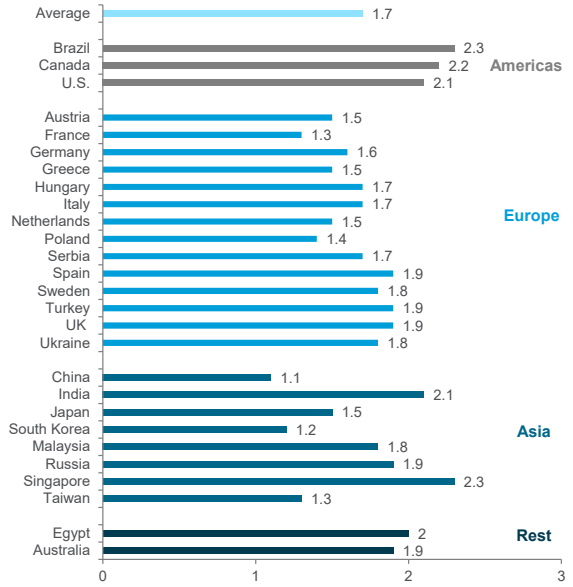
[3] Cecily Josten and Grace Lordan, "Automation and the Changing Nature of Work," *PLoS ONE*, Vol. 17, No. 5, 2022.
[4] Jonathan Dingel and Brent Neiman, "How Many Jobs Can Be Done at Home?" *Journal of Public Economics*, Vol. 189, No. 104235, September 2020.
[5] The Online Labour Index 2020 is part of the Online Labour Conservatory at the Oxford Internet Institute. See Fabian Stephany et al., "Online Labour Index 2020: New Ways to

Figure 3. Online Labour Index, 2020



Source: Online Labour Index 2020

Figure 4. Average Number of Work from Home Days per Week That Employees Desire



Source: Cevat Giray Aksoy et al. (2022)

According to a recent survey on working arrangements in 27 countries conducted between mid-2021 and early 2022, working from home has become a global norm with employees wanting 1.7 work-from-home days, while employers plan an average of 0.7 work-from-home days per week.[6] These tensions remain to be worked out with senior leaders of firms across different sectors disagreeing about whether or to what extent remote working should stay in place. By mid-2023, levels of remote work, measured by share of days worked from home, seem to have converged around 25%.[7]

Overall, the dynamics of the labor market owed to the Fourth Industrial Revolution have ramifications for the skills being demanded by employers. The technologies available have the potential to be a powerful complement to professional workers. For example, video communication through software such as Zoom or Microsoft Teams has made remote working possible, and thereby allows companies to hire the best global talent. Machines, such as medical AI tools, complement doctors in making the right decisions by providing large amounts of data and calculating risks (e.g., different kinds of clinical decision support software). Technology is also advancing as a powerful substitute for jobs done by low-skilled workers. For example, modern translating tools such as DeepL could effectively make human translators redundant as it claims to be able to translate even the most complex texts. For many occupations, technology is improving to the point of at least partly substituting for employees. An example is Construction Automation's patented bricklaying robot, which built its first house in 2020.

Measure the World's Remote Freelancing Market," *Big Data & Society*, Vol. 8, No. 2, September 15, 2021.

[6] Cevat Giray Aksoy et al., *Working from Home Around the World*, Becker Friedman Institute for Economics at UChicago, Working Paper No. 2022-124, September 2022.

[7] Jose Maria Barrero, Nicholas Bloom, and Steven J Davis, "The Evolution of Working from Home," Stanford Institute for Economic Policy Research, June 2023.

It follows that the demand for specific skills from humans is also changing, as firms adopt available technologies that complement and substitute for tasks previously done by the workers they hired. In this report, we discuss the specific skills that are rising and falling in demand, and explore how the wages for these skills are changing. We also examine how demand is changing for combinations of specific skills and how this is reflected in the price of wages for occupations that demand them.

Our analysis yields useful insights in a number of contexts:

- It sheds light on the skills that are valuable in today's labor market. This information is useful in terms of hiring, planning, training, and upskilling workers for daily tasks, but importantly, it can also help firms strengthen the employee value proposition to attract and retain talent.
- It provides information to firms on the price volatility for specific skills.
- It offers a new lens through which investors can take a pulse of a company's potential for innovation. That is, investors can analyze the skills being demanded by a company in which they are contemplating making an investment and determine if the company is seeking the skills that are most relevant in today's economy for a specific occupation.
- Finally, our work helps to analyze and compare rates of corporate technological adoption by measuring how quickly companies hire a workforce to implement new technologies.

Defining Soft Skills and Cognitive Skills

In this report we focus on cognitive and soft skills (or non-cognitive skills). Soft skills are an individual's "patterns of thought, feelings, and behaviors and encapsulate a range of characteristics about a person that are not easily observable or calculable."[8] They describe how people think, feel, and act.[9] Examples include conscientiousness, empathy, creativity, and collaborative skills. Social skills (or people skills) are a subset of soft skills that center around human interactions. These skills include leadership, negotiation, and successful cooperation.

Cognitive skills center around human cognition, intelligence, and thinking. They can be defined as "the ability to acquire and interpret higher quality data for decision-making," and involve the ability to learn and adapt to change.[10] Examples are mathematical skills or problem-solving skills. In an occupation, cognitive skills can be very specific and centered around the ability to perform a certain task, for example, the knowledge of specific computing software to perform data science within a company. Concretely, to become a data scientist, a candidate needs to not just be generally mathematically and quantitively inclined but potentially also know programming languages such as Hadoop or Python. Employers measure the attainment level of such skills by either screening for degree qualifications or certificates or, increasingly, using technical evaluations or internal screening tools.

[8] Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021.
[9] Lex Borghans, Bas Ter Weel, and Bruce A. Weinberg, "People Skills and the Labor-Market Outcomes of Underrepresented Groups," *ILR Review*, Vol. 67, No. 2, 2014.
[10] David Deming, *The Growing Importance of Decision-Making on the Job*, National Bureau of Economic Research, Working Paper No. 28733, April 2021.

Automation and the Type of Work We Do

The First and Second Industrial Revolutions initially increased the demand for low-skilled labor as increased mechanization assisted individuals in getting their jobs done and mass production increased productivity.[11] With the appearance of assembly lines, for example, humans were needed to complement tasks performed by machines and often to finalize assembly. Such basic skills are often referred to as routine tasks that involve the frequent repetition of tasks and require few skills.

During those first periods of industrialization, people benefited both as workers and as consumers. Not only could low-skilled individuals find jobs, but improvements in technology also meant that they could afford things they previously could not, such as cars. Productivity rose and the standard of living improved during this time.[12] Highly-skilled craftsmen were replaced by machines operated by low-skilled laborers, but overall, more new jobs were created than old ones lost.

The Third Industrial Revolution shaped labor markets in developed countries and increased the importance of cognitive skills.[13] The rise of computers and industrial robots meant that while many roles got automated, qualified staff were needed to operate machinery, thereby complementing machines.[14] With even further automation and digitalization, the demand for skills increasingly shifted away from low-skilled labor towards high-skilled labor. However, the invention of the World Wide Web and increasing digitalization more generally meant that entire worker groups were substituted rather than complemented by machines. This type of industrialization, as compared to the previous ones, benefited low-skilled individuals only as consumers (e.g., the internet opened up new opportunities free of charge) but hurt them as workers by replacing them. Only high-skilled workers were complemented by machines, which increased the demand for skilled labor compared to those with lower routine or manual skills. The Citi GPS report *Technology at Work v6.0: The Coming of the Post-Production Society* discusses how the COVID-19 pandemic has accelerated digitalization and automation, which means low-skilled, low-income jobs are at risk of disappearing entirely in the Fourth Industrial Revolution.

There is a vast body of research that looks at how work and occupations have changed both over time and as a result of technological changes and innovations.[15] For example, Autor and Dorn (2013) found that occupations high in routine tasks, versus those high in abstract tasks, were more automatable and that the share of occupations with routine tasks is declining. Atalay et al. (2020) found that the frequency of words in job advertisements in newspapers related to routine cognitive tasks declined by more than half between 1950 and 2000.

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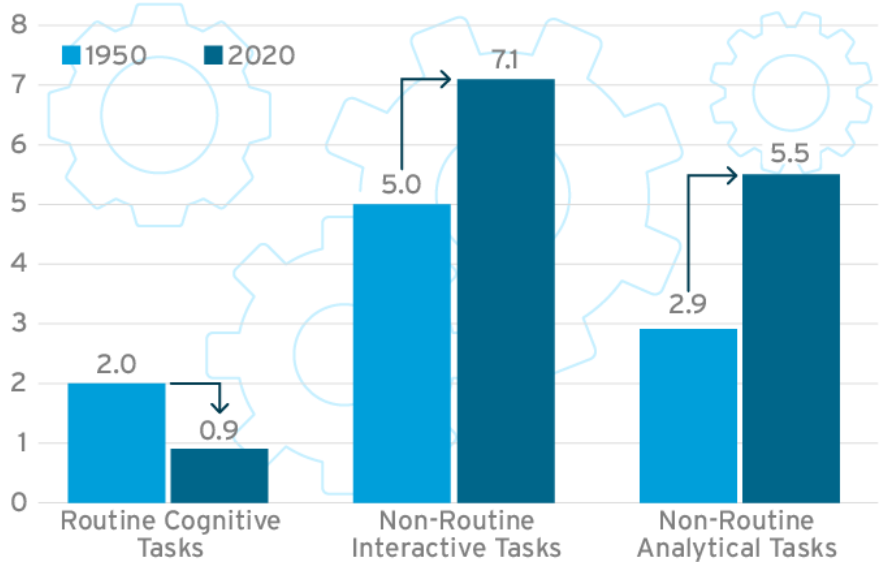
[11] Citi GPS, *Technology at Work: The Future of Innovation and Employment*, 2015.
[12] McKinsey Global Institute, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, December 2017.
[13] Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021.
[14] Citi GPS, *Technology at Work: The Future of Innovation and Employment*, 2015.
[15] David H. Autor, Frank Levy, and Richard J. Murnane, "The Skill Content of Recent Technological Change: An Empirical Exploration," *The Quarterly Journal of Economics*, Vol. 118, No. 4, November 2003; David H. Autor and David Dorn, "The Growth of Low-Skill Service Jobs and the Polarization of the U.S. Labor Market," *American Economic Review*, Vol. 103, No. 5, August 2013; Cecily Josten and Grace Lordan, "Robots at Work: Automatable and Non-Automatable Jobs," *Handbook of Labor, Human Resources and Population Economics* (Springer, 2020).

As depicted in Figure 5, the frequency dropped from 2 to 0.9 mentions per 1,000 job ad words. Routine manual task mentions declined even more. In contrast, the frequency of words related to non-routine analytic tasks increased from 2.9 to 5.5 mentions per 1,000 job ad words, while non-routine interactive tasks increased from 5 to 7.1 mentions per 1,000 words.

Figure 5. Skills Demand 1950 vs. 2020: Number of Mentions per 1,000 Job Ad Words



Source: Atalay et al. (2020), Citi Global Data Insights

Occupations and their job descriptions are changing fundamentally. Managerial jobs, for example, are becoming increasingly interactive over time, with a growing focus on teambuilding, coaching, and interactions with customers.[16]

In contrast to routine tasks that require manual and low-skill levels, occupations with tasks that require cognitive and soft skills have been highlighted as increasingly relevant for the future of work.[17] Not only is the demand for soft skills rising, but wages for these skills are also higher, affording an increase in returns to workers.[18]

[16] Enghin Atalay et al., "The Evolution of Work in the United States," *American Economic Journal: Applied Economics*, Vol. 12, No. 2, April 2020.
[17] Catherine J., Weinberger, "The Increasing Complementarity between Cognitive and Social Skills," *The Review of Economics and Statistics*, Vol. 96, No. 5, 2014; David Deming, "The Growing Importance of Social Skills in the Labor Market," *The Quarterly Journal of Economics*, Vol. 132, No. 4., November 2017; Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021.
[18] Per-Anders Edin et al., "The Rising Return to Noncognitive Skill," *American Economic Journal: Applied Economics*, Vol. 14, No. 2, April 2022; David Deming, "The Growing Importance of Social Skills in the Labor Market," *The Quarterly Journal of Economics*, Vol. 132, No. 4, November 2017.

A concrete illustration of such soft skills includes decision-making or communication skills that are increasingly important and attract large wage premiums. This points to the importance of skills that help deal with the increasing complexity and open-endedness of job tasks in today's labor market and the future. Soft skills can also be considered durable skills that are valuable irrespective of changes to the labor market.[19]

Soft skills have been shown to have positive wage returns (i.e., wage growth) when complemented with cognitive skills.[20] That is, individuals who possess both strong cognitive skills and high levels of soft skills could command a wage premium over those who only have cognitive skills. This is intuitive if you consider income generators in private equity and investment banking where strong quantitative skills are essential for entry-level positions; however, progression requires external network-building and internal leadership skills. Similarly, for roles in quantum computing or drug discovery, workers absolutely need to be able to apply very precise cognitive skills to do their jobs effectively; however, to be successful in their roles they also need high levels of soft skills to bring their teams together to decide on innovative, new applications and explorations, as well as motivate them to stay on course. A similar conclusion emerges when considering roles in a vast array of other high-paying areas of work, including artificial intelligence, civil engineering, marketing, venture capital, and entrepreneurship.

Based on the literature, soft skills alone do not garner a positive wage return currently, implying that jobs that do not have a high cognitive skill requirement, are in general poorly paid when they only demand high levels of soft skills.[21] An example would be a kindergarten teacher or receptionist. However, among lower-educated workers, wage levels and wage progression are higher in occupations requiring soft skills than in those that do not.[22] Receptionists thus benefit from higher bargaining power than cleaners, for example, especially if they work in an innovative environment, i.e., for a company that invests in innovation.

[19] Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021.
[20] Catherine J., Weinberger, "The Increasing Complementarity between Cognitive and Social Skills," *The Review of Economics and Statistics*, Vol. 96, No. 5, 2014.
[21] Cecily Josten and Grace Lordan, "Robots at Work: Automatable and Non-Automatable Jobs," *Handbook of Labor, Human Resources and Population Economics* (Springer, 2020).
[22] Philippe Aghion et al., *Soft Skills and the Wage Progression of Low-Educated Workers*, Center for Economic and Policy Research, March 2022.

What Skills Pay More?

Skills Requirement Evolution

The skills currently demanded in the labor market are being shaped by the Fourth Industrial Revolution.[23] In particular, there is evidence that employers are increasingly demanding and rewarding social skills (e.g., leadership and communication), while continuing to reward cognitive skills (e.g., decision-making and analytical).[24] However, as discussed in the previous section, demand for soft skills without cognitive skills in an occupation does not attract higher wages. As tasks are becoming more open-ended with machines performing predictable work, skills such as decision-making or artificial intelligence skills are simultaneously becoming increasingly valuable.[25]

With the current trends, labor markets are becoming more fluid and careers less linear. Between 1990 and 2016, labor markets in the U.S. and globally saw an increase in education and experience requirements in hiring according to a 2016 study from Pew Research Center. This effect was particularly evident after the Great Recession between 2007 and 2012 when worker supply rose, which led to more rigorous education and experience requirements by employers. Corporate hiring strategies often operate according to clear pre-defined criteria. For example, a bachelor's degree in business would be a prerequisite to work as an accountant or a track-record of written articles in established newspapers would be a prerequisite to become a journalist. While this is still true for many occupations and roles, we also see that degree requirements and many other clear-cut requirements are being dropped as the labor supply tightens in specific industries.[26] With the current rapid labor market developments, the trend of "degree inflation" (i.e., requiring a bachelor's degree for hiring, even for roles that did not previously require one) is being reversed.

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[23] Footnote: Carl Benedikt Frey and Michael C. Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerization?," Technological Forecasting and Social Change, Vol. 114, No. 254-280, January 2017; Jonathan Dingel and Brent Neiman, "How Many Jobs Can Be Done at Home?," Journal of Public Economics, Vol. 189, No. 104235, September 2020.; Murillo Campello, Gaurav Kankanhalli, and Pradeep Muthukrishnan, Corporate Hiring Under COVID-19: Labor Market Concentration, Downskilling, and Income Inequality, National Bureau of Economic Research, Working Paper No. 27208, May 2020.

[24] Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021; David Deming, *The Growing Importance of Decision-Making on the Job*, National Bureau of Economic Research, Working Paper No. 28733, April 2021; David Deming and Lisa Kahn, "Skill Requirements Across Firms and Labor Markets: Evidence from Job Postings for Professionals," *Journal of Labor Economics*, Vol. 36, No. S1, January 2018.

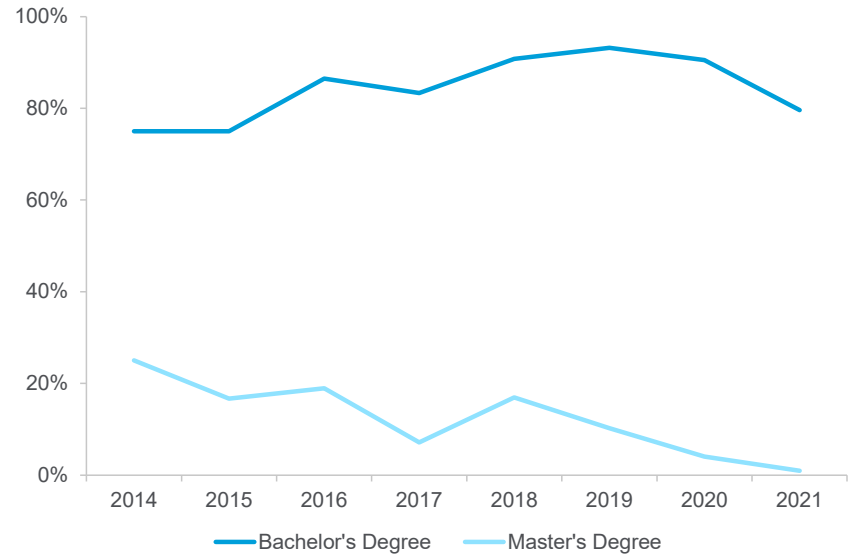
[25] Liudmila Alekseeva et al., "The Demand for AI Skills in the Labor Market," *Labour Economics*, Vol. 71, No. 102002, August 2021; David Deming, *The Growing Importance of Decision-Making on the Job*, National Bureau of Economic Research, Working Paper No. 28733, April 2021.

[26] Joseph Fuller et al., *The Emerging Degree Reset*, Burning Glass Institute, February 2022.

For example, 25% of skills requirements for jobs have changed since 2015, according to a study by the professional networking platform LinkedIn in 2022.[27] And in the specific example of journalism, the internet enables even previously unknown and unskilled writers (i.e., in terms of observable criteria such as degrees) to gain recognition as journalists or bloggers. There is a shift away from clear-cut criteria towards competency and skills more broadly.[28] Employers require a more detailed list of skills and now outline skills in job posts that would have previously been assumed when posting a degree requirement.

Indeed, based on data from LinkUp, the demand for bachelor's degrees for jobs such as editors, writers, and authors, has declined since the pandemic after generally trending upwards since 2016 as shown in Figure 6.[29] A more drastic observation is the rapid decline in demand for workers with masters degrees, especially in 2019 when 20% of job ads still demanded such a requirement but by 2022 this share dropped to effectively 0%.

Figure 6. Education Requirements in Job Postings: Editors, Writers, and Authors



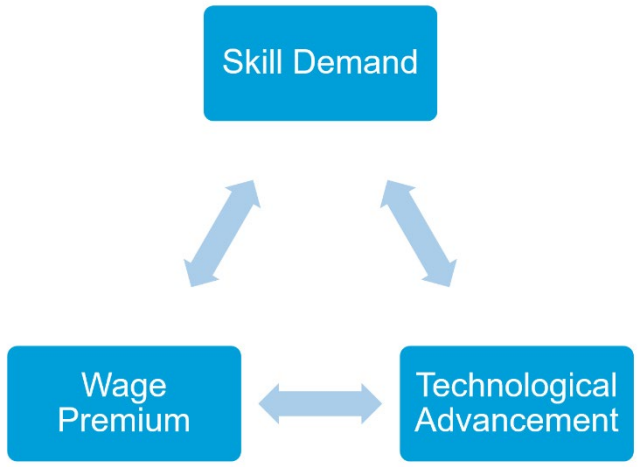
Source: LinkUp, Citi Global Data Insights

[27] Pei Ying Chua, "Why a Skills-First Approach to the World of Work Will Create More Opportunities for Both Companies and Professionals," LinkedIn Economic Graph, December 15, 2022.
[28] Joseph Fuller et al., *The Emerging Degree Reset*, Burning Glass Institute, February 2022.
[29] LinkUp is a large global job listing index of job openings. It contains job advertisements from websites of publicly traded companies to be used as input for labor market analytics. The data is continuously updated through crawling of public websites. The data contains detailed information on each advertisement including the state it was posted in, its Occupational Information Network (O*NET) occupation code, the Global Industry Classification Standard (GICS) codes at the 2-digit level, job and company attributes, and raw job descriptions and job records.

Job titles are also changing, with many roles disappearing and others appearing. An example of an occupation that has disappeared is that of a teletype operator that was no longer required by the 1980s with the introduction of the fax machine and other newer communication technologies.[30] This occupation mainly involved routine tasks and little soft skills. Other occupation groups changed in nature, such as secretarial and administrative assistants: While roles related to typing (i.e., repetitive tasks) disappeared due to the introduction of word processing technologies, roles involving interactions with people, such as secretaries and receptionists, increased.[31]

Another more recent example of an occupation under constant change is that of a social media manager, given the frequency of new platforms coming on stream. This occupation is strong on soft skills requirements such as creativity and communication. Technology-intensive occupations are also currently appearing anew, such as blockchain engineers. Those occupations require workers to be equipped with the newest cognitive skills. Over the next decades, we expect a reduction in the number of roles available for security guards, shelf stackers, drivers, and bricklayers, given the technologies coming on stream that replace the core tasks done by these workers.[32] This shows that skill demand, wage premium, and technology advancement are closely linked to each other. Technological advancements shape the skills needed, which in turn affect the wage premiums associated with such skills. Similarly, high wage premiums incentivize companies to look to technology for automation, which then affects the skill demand of such roles.

Figure 7. Linkages Among Skill, Wage, and Technology



Source: Citi Global Data Insights

It is crucial to better understand the demand for skills in the labor market over time and in particular the reward to skills as measured by earnings, while taking into account technological advancements. This helps policymakers and corporates identify the areas to focus on in terms of upskilling the workforce and talent planning for the future.

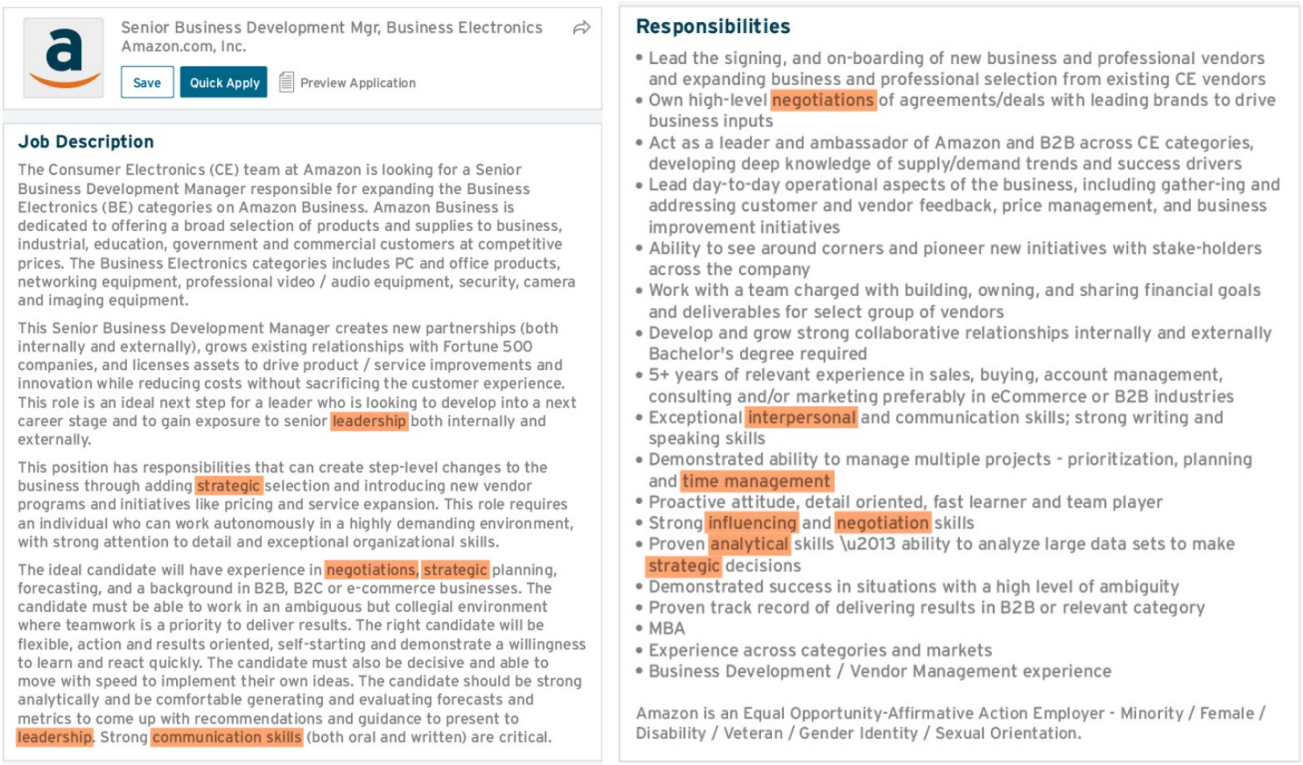
[30] Enghin Atalay et al., "The Evolution of Work in the United States," *American Economic Journal: Applied Economics*, Vol. 12, No. 2, April 2020.
[31] Ibid.
[32] Grace Lordan, "People Versus Machines in the UK: Minimum Wages, Labor Reallocation, and Automatable Jobs," *PLoS ONE*, Vol. 14, No. 12, 2019.

We extend the previously studied binary split between cognitive and soft skills to include a detailed list of the most important skill groupings and analyze their wage levels. In our work, “importance” is defined based on the frequency of times an employer states they want a particular skill in a job advert. In the next section, we describe our analysis of a large dataset of job advertisements and how we link the skills requirements in job ads to earnings.

The Context of Our Skills Analysis

In the face of a rapidly changing market for skills, we analyze how wage premiums (i.e., where a positive value indicates additional pay relative to a mean wage in our study) at the occupation level of specific skills change over two time periods. Data on the demand for skills is retrieved from LinkUp — a large platform of online job advertisements. We analyze job advertisements for companies in the U.S. captured in the MSCI USA Index. Using natural language processing techniques, we can filter out the skills requirements of each job posting (see Appendix for more details). We focus on professional occupations only, that is, occupations that require a certain level of education and experience, such as lawyers or managers.

Figure 8. Job Advertisement Example



Senior Business Development Mgr, Business Electronics
Amazon.com, Inc.

Save | Quick Apply | Preview Application

Job Description

The Consumer Electronics (CE) team at Amazon is looking for a Senior Business Development Manager responsible for expanding the Business Electronics (BE) categories on Amazon Business. Amazon Business is dedicated to offering a broad selection of products and supplies to business, industrial, education, government and commercial customers at competitive prices. The Business Electronics categories includes PC and office products, networking equipment, professional video / audio equipment, security, camera and imaging equipment.

This Senior Business Development Manager creates new partnerships (both internally and externally), grows existing relationships with Fortune 500 companies, and licenses assets to drive product / service improvements and innovation while reducing costs without sacrificing the customer experience. This role is an ideal next step for a leader who is looking to develop into a next career stage and to gain exposure to senior leadership both internally and externally.

This position has responsibilities that can create step-level changes to the business through adding strategic selection and introducing new vendor programs and initiatives like pricing and service expansion. This role requires an individual who can work autonomously in a highly demanding environment, with strong attention to detail and exceptional organizational skills.

The ideal candidate will have experience in negotiations, strategic planning, forecasting, and a background in B2B, B2C or e-commerce businesses. The candidate must be able to work in an ambiguous but collegial environment where teamwork is a priority to deliver results. The right candidate will be flexible, action and results oriented, self-starting and demonstrate a willingness to learn and react quickly. The candidate must also be decisive and able to move with speed to implement their own ideas. The candidate should be strong analytically and be comfortable generating and evaluating forecasts and metrics to come up with recommendations and guidance to present to leadership. Strong communication skills (both oral and written) are critical.

Responsibilities

- Lead the signing, and on-boarding of new business and professional vendors and expanding business and professional selection from existing CE vendors
- Own high-level negotiations of agreements/deals with leading brands to drive business inputs
- Act as a leader and ambassador of Amazon and B2B across CE categories, developing deep knowledge of supply/demand trends and success drivers
- Lead day-to-day operational aspects of the business, including gather-ing and addressing customer and vendor feedback, price management, and business improvement initiatives
- Ability to see around corners and pioneer new initiatives with stake-holders across the company
- Work with a team charged with building, owning, and sharing financial goals and deliverables for select group of vendors
- Develop and grow strong collaborative relationships internally and externally Bachelor's degree required
- 5+ years of relevant experience in sales, buying, account management, consulting and/or marketing preferably in eCommerce or B2B industries
- Exceptional interpersonal and communication skills; strong writing and speaking skills
- Demonstrated ability to manage multiple projects - prioritization, planning and time management
- Proactive attitude, detail oriented, fast learner and team player
- Strong influencing and negotiation skills
- Proven analytical skills \u2013 ability to analyze large data sets to make strategic decisions
- Demonstrated success in situations with a high level of ambiguity
- Proven track record of delivering results in B2B or relevant category
- MBA
- Experience across categories and markets
- Business Development / Vendor Management experience

Amazon is an Equal Opportunity-Affirmative Action Employer - Minority / Female / Disability / Veteran / Gender Identity / Sexual Orientation.

Source: Amazon, LinkUp

Job advertisement data is a useful source to study labor market dynamics, as it contains a large amount of data and breadth of information.[33] Furthermore, it provides a snapshot of current labor market demand and hence serves as a predictor of the future because an employee hired today will be in their role for at least the near future.[34] Job advertisement data has been used in past research to analyze the development of skills requirements in occupations. For example, one study uses online job advertisement data to analyze skills requirements after the Great Recession and finds that education and experience requirements increased — an effect that can be attributed to the increased supply of workers following layoffs during and after the recession.[35]

Our analysis focuses on the skills versus rewards relationship across two time periods: 2014-15 and 2018-1Q 2020. We choose this time frame for three reasons: (1) online job advertisement data only becomes reliable in 2014 and is very volatile in previous years; (2) March 2020 marked the outbreak of the COVID-19 pandemic that significantly disrupted hiring activities and, as such, the dynamic of the relationship in question during this period might not be representative; and (3) wage data is based on rolling averages and needs to be two years apart when analyzing time effects. We hence pool data and leave two years in between to account for bias due to rolling averages. We will examine the effects on the skills side in the pandemic period separately later in the report.

Given that wages are rarely posted in job listings, we link each job advertisement to wage data based on the state and occupation for which a job was posted. We use hourly wage estimates by occupation and U.S. state from a data source called Occupational Employment and Wage Statistics (OEWS) from the U.S. Bureau of Labor Statistics (BLS).[36] While job posting data can be seen as a proxy for the demand for skills in the labor market, linking it to actual wage outcomes informs on whether the demand for skills translates into changing "prices" or wages for specific skills at the occupational level.

Recall that we define "importance" as the number of job ads that contain a specific skill, and how often they overlap with other skills. Using this approach, we identify nine broad skill groupings that have either been mentioned in the literature or frequently highlighted as skills of the future.[37] Figure 9 shows the nine skills groups and the underlying individual keywords that define membership in each grouping.

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[33] Jason Faberman and Marianna Kudlyak, "What Does Online Job Search Tell Us About the Labor Market?" *Economic Perspectives*, Vol. 40, No. 1, 2016.

[34] Anthony P. Carnevale, Tamara Jayasundera, and Dmitri Repnikov, *Understanding Online Job Ads Data: A Technical Report*, Georgetown University Center on Education and the Workforce, April 2014.

[35] Alicia Sasser Modestino, Daniel Shoag, and Joshua Balance, "Upskilling: Do Employers Demand Greater Skill When Workers are Plentiful?" *The Review of Economics and Statistics*, Vol. 102, No. 4, 2020.

[36] The occupation information is based on six-digit Standard Occupational Classification (SOC) codes.

[37] To derive the nine skills groupings, we first chose a large pool of keywords that have either been mentioned in the literature (e.g., Deming and Kahn, 2018) or frequently highlighted in a professional context as relevant skills of the future (e.g., McKinsey, 2021). We then flag those keywords in the job ad data. This is then used as input for clustering the keywords in a meaningful way using principal components analysis.

Each individual keyword maps to the group if they are mentioned in a job posting. An example is the skills group "collaborative leadership." This skills group contains the following keywords that are mentioned in job descriptions: strategic, leadership, influence, collaborate, creativity, negotiation, and coaching. If a job ad contains one of these keywords, we flag it as requiring collaborative leadership skills. Overall, the nine skills groupings are divided as two soft skills ("collaborative leadership" and "interpersonal and organized") and seven cognitive skills ("big data", "cloud computing", "programming", "machine learning", "research", "math", and "analytical").

Figure 9. Description of the Nine Skills Groups

Non-Cognitive Skills Components		Cognitive Skills Components						
Collaborative Leadership	Interpersonal and Organized	Big Data	Cloud Computing	Analytical	Research	Programming	Machine Learning	Math
Strategic	Time management	Hadoop	Docker	Accounting	Quantitative	XML	TensorFlow	Calculus
Leadership	Competing priorities	Spark	Kubernetes	Finance	Statistics	JSON	PyTorch	Algebra
Influence	Interpersonal	Hive	Amazon Web Services	Common software, e.g., Excel	Qualitative	JavaScript	Keras	Trigonometry
Collaborate	Organized	HDFS	Terraform	Analytical	Research	SQL		Stochastic
Creativity		Scala	Azure			Git		
Negotiation		NOSql	Jenkins			API		
Coaching			Openshift					
			Containerization					
			Openstack					

Source: London School of Economics, Citi Global Data Insights

We link the nine skills groups to wages measured at the occupation level to quantify the occupation-level wage premium for each skill group. We also quantify the occupation-level wage premium for the interactions between skill groupings.

There is a large variation in how often each skill grouping appears in the job ads as seen in Figure 10 below. For example, "collaborative leadership" appears in 50.14% of job ads in 2014-15 and 61.07% in 2018-1Q 2020. In comparison, "machine learning" did not appear in job advertisements in LinkUp in the earlier time frame and only appeared in 0.19% of job advertisements in 2018-1Q 2020. The share of requests for "cloud computing" nearly tripled over the two periods. Overall, soft skills tend to be overused in job advertisements, and also across disciplines, while cognitive skills are often more specific.[38]

Figure 10. Share of Job Adverts Requesting Each of the Nine Skills Groups Across Two Time Periods (2014-15 vs. 2018-1Q 2020)

		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	50.14%	24.70%	1.63%	13.60%	N/M	1.76%	16.19%	0.19%	31.19%
	#	71,718	35,335	2,325	19,448	N/M	2,524	23,152	273	44,607
2018-1Q 2020	%	61.07%	30.85%	2.49%	13.03%	0.19%	4.88%	18.94%	0.21%	35.83%
	#	374,087	188,981	15,246	79,827	1,155	29,911	115,996	1,288	219,461

Note: Percentages do not total 100% as job ads may mention more than one skills group.

Source: LinkUp, London School of Economics, Citi Global Data Insights

[38] Federica Calanca et al., "Responsible Team Players Wanted: An Analysis of Soft Skill Requirements in Job Advertisements," *EPJ Data Science*, Vol. 8, No. 13, April 2019.

Figure 11 documents the share of job ads requesting combinations of selected skill groups over the two periods.[39] We focus on the interaction of collaborative leadership and data science skills. Overall, the share of all skills interactions increased over the two time frames. The interaction of "collaborative leadership" and "big data," for example, increased from 0.8% to 1.6%. The largest interaction both in terms of the absolute value of shares across the two time periods and the steepest increase over time is that of "collaborative leadership" and "research," which increases by 3.7 percentage points from 9.5% to 13.2%. A potential reason for this increase is that with growing automatability it becomes crucial to complement machines by both understanding what they do through broad cognitive skills such as "research" and by sharing knowledge with others through soft skills such as "collaborative leadership." For example, doctors increasingly use technology such as Clinical Decision Support Software, but they still need to understand statistics, which is a facet of research skills, alongside making final decisions drawing on their collaborative leadership skills.

Figure 11. Share of Job Adverts Requesting Select Combinations of Specific Skills (2014-15 vs. 2018-1Q 2020)

	2014-15	2018-1Q 2020
Collaborative Leadership x Big Data	0.8%	1.6%
Collaborative Leadership x Cloud Computing	1.0%	3.2%
Collaborative Leadership x Programming	6.6%	8.0%
Collaborative Leadership x Research	9.5%	13.2%
Collaborative Leadership x Machine Learning	N/M	0.1%
Big Data x Cloud Computing	0.3%	0.9%
Big Data x Programming	1.3%	2.0%
Big Data x Research	0.4%	0.8%
Big Data x Machine Learning	n/a	0.1%
Cloud Computing x Programming	1.1%	2.8%
Cloud Computing x Research	0.2%	0.6%
Cloud Computing x Machine Learning	n/a	0.0%
Programming x Research	2.6%	3.2%
Programming x Machine Learning	N/M	0.1%
Research x Machine Learning	N/M	0.1%

Source: LinkUp, London School of Economics, Citi Global Data Insights

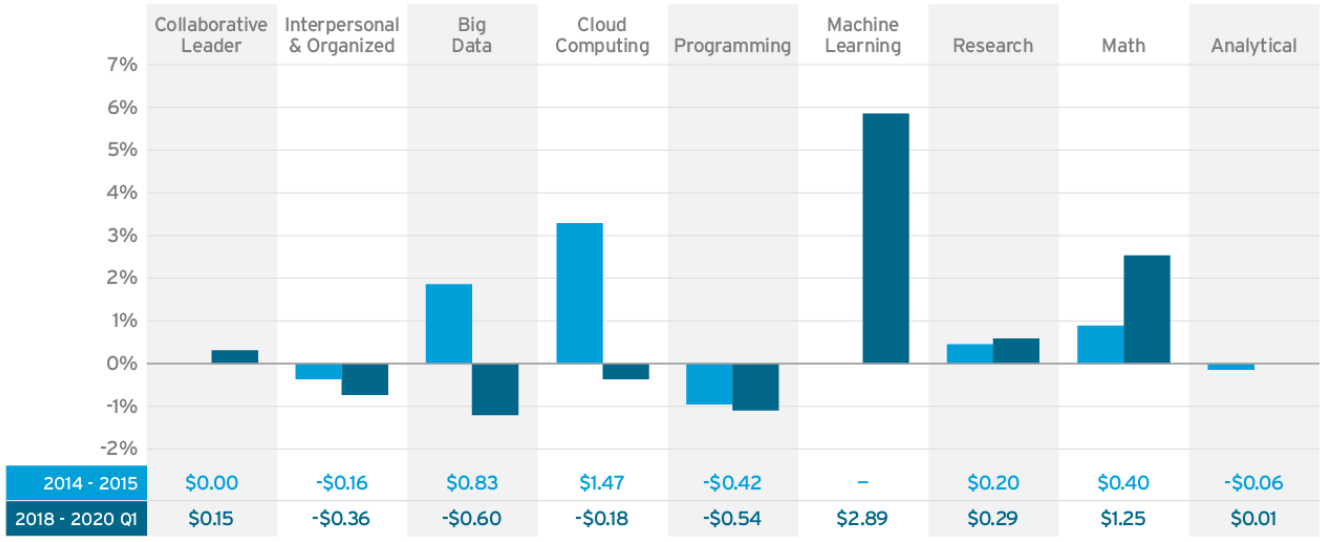
To quantify the occupation-level wage premium for each skill grouping, we run a regression of the logarithm of wages on the nine skills groups and then separately for all of their interactions. Interactions of skills groups can explain the joint effect of two skills groups on wages. For example, we can ask how much "collaborative leadership" gets rewarded when it is combined with "cloud computing."

When interpreting our regression results, we focus on changes of 10-percentage points between the two time periods, and the impact that this change has on hourly wages for the two periods. Intuitively, if demand for a skills group goes up by 10-percentage points, you would expect a positive wage premium if that skill is in short supply. In contrast, if a large subset of the population already has this skill or it is easy to acquire, the wage response could be expected to be zero or negative. Similarly, if it is possible to "bluff" having a certain skill, the wage response could also be zero or negative. "Bluffing" is most likely for soft skills where there are no easy tests of such skills. Moreover, as wages vary by occupation across each U.S. state, we can calculate state-specific effects. For instance, we can make comparisons between the cost of an occupation in New York versus Texas, in addition to shares of specific skills being demanded within specific occupations.

[39] We exclude the interactions between interpersonal and organized, analytical, and math as they are negligible in size.

Using our regression outcome, we examine the impact of a 10-percentage point increase in the respective skills group or the interaction thereof on wages in percent. We zoom in on the most interesting results in the next sections. Figure 12 shows the responses in both percent and in dollar value of wage premiums when the demand for a given skill group increases by 10-percentage points, while Figure 13 captures the demand impact on wages for a combination of skills.[40]

Figure 12. Occupational-Level Wage Response to a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups (%, $ per Hour)



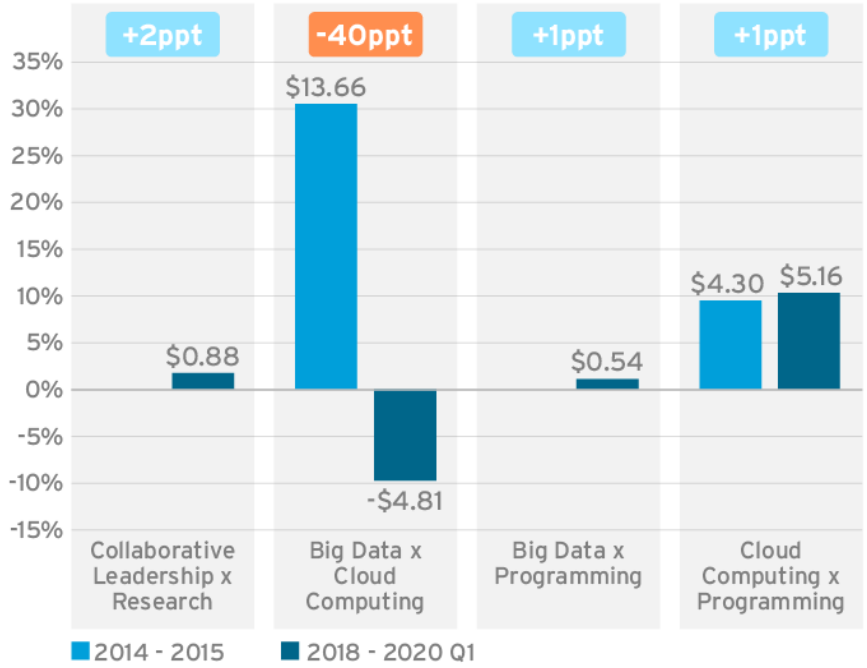
Source: LinkUp, London School of Economics, Citi Global Data Insights

As can be seen in the results above, machine learning experienced the largest increase in wage premium when such demand jumps by 10 percentage points, suggesting such skills were in short supply. Interestingly, big data and cloud computing went the other direction when these two skills groups were highly sought after in the first time period attracting good wages, but this was no longer the case in the subsequent recent period as such skills were more abundant in the labor market.

Turning our attention to the interaction of skills, Figure 13 demonstrates the largest change observed from the first time period to the second is also the product of big data and cloud computing where previously such combined skills enjoyed a $13.66 premium in pay but faced a significant decrease in the recent period. In contrast, the demand and the wages associated with a combination of cloud computing and programming skills appear to be consistent over time.

[40] We use the Lasso regression method for estimates.

Figure 13. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Select Interactions Between Skills Groups (Bars Represent %, Embedded Numbers Represent $ per Hour)



Source: Citi GPS, LinkUp, London School of Economics, Citi Global Data Insights

The Rise of the Collaborative Leader

A collaborative leader is someone who is able to think strategically and influences others but also scores high on social skills such as collaboration and negotiation. From analyzing job ads in the U.S., we find that occupations in specific states that ask for collaborative leadership skills consistently pay a positive wage premium. Overall, collaborative leadership is increasing in terms of the share of job advertisements requesting the skill between 2014-15 and 2018-1Q 2020 (see Figure 10), in addition to garnering wage premiums that are increasing over time from an effect that is not statistically different from zero in 2014-15 to a positive wage effect in 2018-1Q 2020 (see Figure 12). An increase in demand for collaborative leadership by 10-percentage points in 2018-1Q 2020 implies a 0.3% increase in wages. For the mean wage of $49.49 per hour in 2018-1Q 2020, these estimates imply a $0.15 hourly increase in wages.

If we look at the Rust Belt states, i.e., the states that used to focus on manufacturing occupations, the wage premium varies from $0.11-$0.13 (e.g., Indiana and Wisconsin with $0.11, Illinois with $0.13, and Michigan with $0.12). In comparison, areas with the largest premium are include Washington D.C. with $0.16; New Jersey with $0.15; and California and New York, each with $0.14.

Collaboration between managers and leaders is becoming essential in today's workplace. The increasing importance of collaborative leadership skills is intuitive. Facets of collaborative leadership that have been previously highlighted by academic research as valuable include creativity, negotiation, coaching, and strategic planning, in addition to collaboration and leadership.[41]

Overall, there are two main aspects of collaborative leadership that are relevant for labor markets of today and the future:

- **Occupations that require collaborative leadership are less likely to be automated**, as explained by Josten and Lordan in their 2022 study. The occupations with the highest share in leadership skills requirements all belong to management occupations (e.g., marketing managers) for which many job tasks are open-ended, making them less likely to be automated and most likely to evolve in response to technology. We find the other soft skill group, "interpersonal and organized," to have a negative wage premium that increases over time from -$0.16 in 2014-15 to -$0.36 in 2018-1Q 2020. Facets of the "interpersonal and organized" skills group like, for example, "time management" correspond with greater automation.[42] This is because such skills center around setting rules and gathering information, which are tasks that are likely to be automated as they are easily codified.

[41] Mariagrazia Squicciarini and Heike Nachtigall, *Demand for AI Skills in Jobs: Evidence from Online Job Postings,* OECD Science, Technology and Innovation Policy Papers, No. 2021/03, 2021; David Deming and Lisa Kahn, "Skill Requirements Across Firms and Labor Markets: Evidence From Job Postings for Professionals," *Journal of Labor Economics*, Vol. 36, No. S1, January 2018; McKinsey, "Defining the Skills Citizens will Need in the Future World of Work," June 25, 2021; Cecily Josten and Grace Lordan, "Robots at Work: Automatable and Non-Automatable Jobs," *Handbook of Labor, Human Resources, and Population Economics* (Springer, 2020).

[42] Cecily Josten and Grace Lordan, "Automation and the Changing Nature of Work," *PLoS ONE*, Vol. 17, No. 5, 2022.

The "interpersonal and organized" skills group also appears frequently as a requirement for occupations that have been previously highlighted to be at least partly automatable such as financial managers or lawyers.[43] The finding of differential rewards to different soft skills (i.e., "collaborative leadership" versus "interpersonal and organized") is in line with a study that found that skills related to leadership such as strategic planning are rewarded while skills related to the "interpersonal and organized" skills groups such as "time management" are punished.[44]

- **Collaborative leadership enhances individual and company performance both directly and indirectly through fostering inclusion.** Collaboration is crucial for innovation. For innovation and idea creation, working collaboratively has been shown to be paramount in combination with working independently.[45] The positive effect of collaboration on innovation and performance depends critically on the quality of the collaboration. Being a "connector" is a key trait of a collaborative leader: someone who brings people together in a way that fosters success.[46] Hence, a collaborative leader is pivotal in determining the quality of collaboration by fostering creativity, diversity of thoughts, open discussions, debates, conflicts, decision-making, amongst others. Such a leader can also create a safe space and inclusive environment for individuals to speak up about new ideas. Inclusion prevents groupthink and confirmation bias, both of which have been shown to hinder performance and innovation in a team and at the company level.[47] Inclusive leadership shares many facets with the collaborative leader skills group such as creativity, coaching and influence.[48]

[43] Grace Lordan, *Robots at Work, A Report on Automatable and Non-Automatable Employment Shares in Europe*, European Commission, Directorate-General for Employment, Social Affairs and Inclusion, 2018; Cecily Josten and Grace Lordan, "Robots at Work: Automatable and Non-Automatable Jobs," *Handbook of Labor, Human Resources and Population Economics* (Springer, 2020).
[44] Federica Calanca et al., "Responsible Team Players Wanted: An Analysis of Soft Skill Requirements in Job Advertisements," *EPJ Data Science*, Vol. 8, No. 13, April 2019.
[45] Karan Girotra, Christian Terwiesch, and Karl Ulrich, "Idea Generation and the Quality of the Best Idea," *Management Science*, Vol. 56, No. 4, April 2010.
[46] Herminia Ibarra and Morten T. Hansen, "Are You a Collaborative Leader?" *Harvard Business Review,*" July-August 2011.
[47] Groupthink is the tendency of a group of likeminded individuals to reciprocate the opinion of others and of the individual not to challenge the group. Confirmation bias is the tendency to search for information and opinions that support one's previously held beliefs.
[48] Lynn M. Shore and Beth G. Chung, "Inclusive Leadership: How Leaders Sustain or Discourage Work Group Inclusion," Group & Organization Management, Vol. 47, No. 4, 2021.

Can Collaborative Leadership Be Taught?

Our data illustrates that "collaborative leadership" is being demanded more by employers over time, and there is also a small positive wage premium for these jobs. This highlights the importance for professionals to acquire such skills. But can collaborative leadership be taught?

In a 2021 study, Josten and Lordan highlight that soft skills are more malleable than cognitive skills throughout an individual's lifespan.[49] They also highlight, however, that there is mixed evidence on the impact of soft skills training for knowledge workers. They argue that it is imperative for teaching programs to carefully design courses that are evidence-based where possible. They also call for programs to be vigorously evaluated for their effectiveness. This can be achieved in a manner that mimics randomized control trials, to allow for clear evidence on the causal effect of such courses on the desired outcomes.

Overall, when it comes to teaching soft skills, context is important. What has been shown to be effective is coaching, specific soft skills training, and leadership development.[50] Coaching is the practice of counselling individuals or a group either through teaching soft skills or through tackling specific issues in the workplace. As a learning and development activity, it is used frequently by companies and has been shown to positively affect individuals' career outcomes.[51] With regard to specific skills, coaching has been shown to improve leadership skills. One way of improving collaborative leadership skills could therefore be through coaching.

In addition, specific soft skills training can potentially be promising for improving collaborative leadership. The Inclusion Initiative at the London School of Economics carefully designed a short course, "Inclusive Leadership Through Behavioural Science," focusing on collaborative leadership with the aim of improving collaboration, decision-making, and inclusive leadership.[52] The course was created based on behavioral science evidence and shows students how to evaluate the changes they make.

Interactions Between Skills

Overall, we find complementarity between soft skills and cognitive skills. Specifically, there is a positive interaction between "collaborative leadership" and "research" in terms of wages. As shown in Figure 13 earlier, a 10-percentage point increase in the share of demand for collaborative leadership together with research increases wages by 0.01% in 2014-15 and by 1.78% in 2018-1Q 2020. The latter effect is substantially larger, resulting in a pay increase of $0.88 above mean hourly wages of 2018-1Q 2020. This pay increase is higher than the wage premiums garnered for just collaborative leadership ($0.15) and research ($0.29) during the same period.

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[49] Cecily Josten and Grace Lordan, "The Accelerated Value of Social Skills in Knowledge Work and the COVID-19 Pandemic," *LSE Public Policy Review*, Vol. 1, No. 4, May 2021.
[50] Tomas Chamorro-Premuzic, "Can You Really Train Soft Skills? Some Answers from the Science of Talent," *Forbes*, June 14, 2018.
[51] Rebecca Jones, Stephen Woods, and Yves Guillaume, "The Effectiveness of Workplace Coaching: A Meta-Analysis of Learning and Performance Outcomes from Coaching," *Journal of Occupational and Organizational Psychology*, Vol. 89, No. 2, June 2016.
[52] London School of Economics and Political Science, "Inclusive Leadership Through Behavioural Science," accessed May 4, 2023.

The past research mainly focused on the interaction of social skills and cognitive skills. Our “collaborative leadership” skills group is, however, defined at a more detailed level. While it contains aspects of social skills such as negotiation or collaboration, it also captures creativity or strategic skills, which have also been highlighted as crucial non-linear thinking skills.[53] Similarly, the “research” skills group resembles definitions classified under cognitive skills but focuses in more detail on broad cognitive skills such as the facets “quantitative” or “qualitative” rather than more niche cognitive skills related to, for example, data science. This finding is in line with the automation literature that highlights that automation increases the need for social skills alongside advanced cognitive skills like logical reasoning.[54] Logical reasoning is needed for our “research” skills group as it forms part of each facet of it like “statistics.”

Professionals require soft skills but also need to understand the implications of numerical calculations, according to the literature. So even if very advanced technologies come on stream and improve and replace human cognitive abilities, it will ultimately still be important to understand the implications of work done by such technological tools. This can be seen in LinkedIn data where, for example, more automatable cognitive skills like accounting have been decreasing over time, while less automatable skills like management have been increasing in terms of employer demand. Our finding is also in line with Josten and Lordan's 2022 study, which finds that jobs that require “people” skills together with “brain” skills are less likely to be automated.

[53] Cecily Josten and Grace Lordan, “Automation and the Changing Nature of Work,” *PLoS ONE*, Vol. 17, No. 5, 2022.
[54] McKinsey Global Institute, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, December 2017.

Data Science Is Not a Fixed Skill

Our findings also clearly demonstrate that data science is constantly evolving, with certain data science skills attracting a wage premium in one period, then losing it in the next. This is a symptom of evolving technology, which demands an evolving skill set.

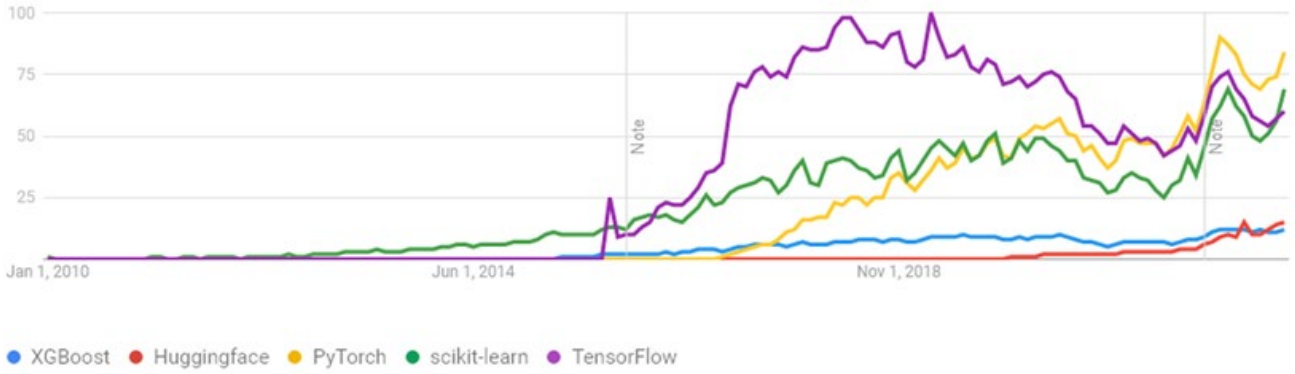
More specifically, we note that the "big data" (i.e., big data software skills such as Hadoop or Spark) and "cloud computing" skills groupings (i.e., cloud technology skills such as Docker or Kubernetes) are associated with positive returns in 2014-15 (i.e., a 10-percentage point increase in the respective skills group leads to 1.85% higher wages in big data or an extra $0.83 in big data and 3.28% higher wages or an extra $1.47 in cloud computing, which turn negative in 2018-1Q 2020 (i.e., a 10-percentage point increase in the respective skills group leads to -1.21% lower wages in big data corresponding with -$0.60, and -0.37% lower wages in cloud computing corresponding with -$0.18).

By 2018-1Q 2020 the skill grouping that increased the most relatively in share demanded and wage premium is "machine learning." This is a skill grouping that did not appear in job ads in 2014-15 and emerged in between these periods as the skills demanded of data scientists continued to evolve. In the 2018-1Q 2020 period, machine learning gained a wage premium, with a 10-percentage point increase in this skills group increasing wages by 5.83%. At professionals' mean hourly wages of $49.49 per hour in 2018-1Q 2020, this corresponds with an increase of $2.89.

Because the field of data science is constantly evolving, individuals with the right skills are in short supply and as a result enjoy high wage premiums. Those that command the highest wages over time are constantly invested in continuous upskilling. In addition, one study found that over time skills related to legacy computing skills such as software engineering and development decreased in importance as compared to newer data science skills like natural language processing.[55] There is also evidence that the economic return to university degrees changes more rapidly for applied subjects such as data science.[56] Rapidly changing applied skills are rewarded highly initially like "big data" in our analysis but turn into legacy skills over time that are not rewarded anymore as compared to more stable skills.

[55] Mariagrazia Squicciarini and Heike Nachtigall, *Demand for AI Skills in Jobs: Evidence from Online Job Postings*, OECD Science, Technology and Innovation Policy Papers, No. 2021/03, 2021.
[56] David Deming and Kadeem Noray, "Earnings Dynamics, Changing Job Skills, and STEM Careers," *The Quarterly Journal of Economics*, Vol. 135, No. 4, November 2020.

Figure 14. Data Science Skills and Tools Search Volume



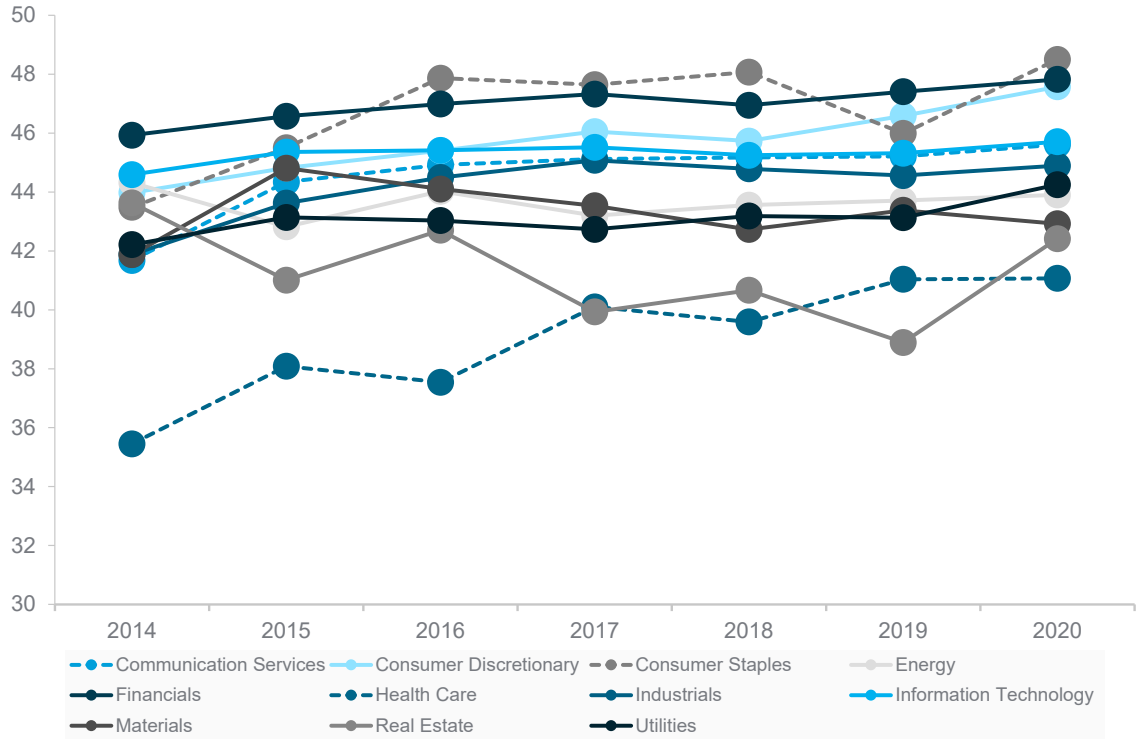
Source: Google, Citi Global Data Insights

The evolution of data science skills can be illustrated by examining Google Search trends in Figure 14. For example, Tensorflow gained significant popularity around 2017, but has since declined, and the momentum has been replaced by PyTorch. Huggingface, which is an online platform hosting a vast array of open-source pre-trained NLP models, also started gaining notable momentum from 2019 onwards. The rise and fall of the various well-known data science tools highlights the fact that the data science skill set evolves over time as new research and technologies become available and prominent in the field, complementing or replacing the existing tools.

Sector Analysis: Jobs vs. Wage Premiums

In the previous chapter, we found that "collaborative leadership" skills have become increasingly important over time. Further, we highlighted that while data science is increasing in demand, it is constantly evolving in terms of the skills required by employers. This signifies the need for data scientists to continuously upskill their offering to their employers. In this chapter, we explore the nuances and highlight differences across industries. Specifically, we document results for 11 Global Industry Classification Standard (GICS) sectors: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Healthcare, Financials, Information Technology, Communication Services, Utilities, and Real Estate. This analysis is insightful for corporates given that technology use and skill needs differ across sectors, which in turn affects the skills requirements and wages associated with them. For example, in the Industrials sector, companies are mainly adopting new digital technologies for automation purposes to increase productivity, whereas in the Information Technology sector, technology applications are more focused on innovation and individual employees are being complemented by emerging technologies which could trigger different wage responses.[57] In essence, the trend is for labor-intensive sectors and firms to employ technology to substitute workers, whereas capital-intensive sectors and firms are employing technology to complement workers' skills.

Figure 15. Wages by Sectors (Hourly Wages in $, Adjusted by CPI)



Source: London School of Economics, Citi Global Data Insights

[57] Mckinsey, *Why Industrials Should Pursue a Tech-Enabled Transformation Now*, September 2019.

Figure 15 highlights the hourly wage evolution from 2014 to 1Q 2020 in different sectors. Healthcare had the largest increase over the period examined, while Real Estate witnessed a wage decline of -2.78% for the same time period. These observations are intuitive as Healthcare requires highly specialized skills sets to perform tasks (e.g., developing new drugs, innovating medical devices, and providing hospital services), resulting in higher wages to attract the right talent. In contrast, Real Estate requires less cognitive skills and more soft skills, especially "interpersonal and organized" skills, which we earlier noted are automatable, e.g., time management skills.

Figure 16. Skill Demand (2014-15 vs. 2018-1Q 2020) Change and Wage Response to 10-Percentage Point Increase in Demand

Skill Demand	Collaborative Leader	Interpersonal & Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
Energy	⇧	⇧	⇧	⇧	⓪	⇧	⇧	⇩	⇧
Materials	⇧	⇧	⇧	⇧	⓪	⇧	⇩	⇧	⇧
Industrials	⇧	⇧	⇧	⇧	⓪	⇧	⇧	⇩	⇧
Consumer Discretionary	⇧	⇩	⇩	⇩	⓪	⇧	⇩	⇧	⇩
Consumer Staples	⇩	⇩	⇧	⇧	⓪	⇧	⇩	⇩	⇩
Healthcare	⇧	⇧	⇧	⇧	⓪	⇧	⇧	⇧	⇧
Financials	⇧	⇧	⇧	⇧	⓪	⇧	⇧	⇩	⇧
Information Technology	⇧	⇧	⇧	⇩	⓪	⇧	⇧	⇧	⇧
Comm. Services	⇧	⇧	⇧	⇧	⓪	⇧	⇧	⇧	⇧
Utilities	⇧	⇧	⇧	⇧	⓪	⇧	⇩	⇧	⇧
Real Estates	⇧	⇧	⇩	⇧	⓪	⇧	⇩	⇧	⇧

Wage Response	Collaborative Leader	Interpersonal & Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
Energy	⇩	⇩	⇩	⇧	⇔	⇧	⇧	⇧	⇧
Materials	⇧	⇧	⇧	⇧	⇩	⇧	⇩	⇧	⇩
Industrials	⇧	⇩	⇧	⇧	⇩	⇩	⇩	⇩	⇩
Consumer Discretionary	⇧	⇩	⇩	⇩	⇩	⇧	⇩	⇧	⇧
Consumer Staples	⇩	⇔	⇧	⇧	⇩	⇩	⇩	⇩	⇧
Healthcare	⇧	⇩	⇩	⇧	⇧	⇩	⇧	⇧	⇩
Financials	⇩	⇩	⇩	⇧	⇧	⇧	⇧	⇧	⇧
Information Technology	⇧	⇩	⇧	⇩	⇧	⇩	⇩	⇧	⇩
Comm. Services	⇩	⇧	⇩	⇩	⇧	⇩	⇧	⇧	⇔
Utilities	⇩	⇧	⇧	⇧	⇧	⇩	⇧	⇩	⇩
Real Estates	⇧	⇩	⇩	⇩	⇧	⇩	⇩	⇩	⇧

Note: Shaded areas indicate statistical significance at a 95% confidence level.
Source: London School of Economics, LinkUp, Citi Global Data Insights

Taking a step further, we also examine sectoral divergence in terms of how wages respond to a 10-percentage point increase in skill demand. Figure 16 summarizes the outcome of our analysis. In terms of skill demand between the two periods, apart from machine learning and cloud computing which enjoy the increased demand across the board, the trend for the other skill groups has not been universal. On the wage response to a 10-percentage point increase in demand, the picture is very mixed indeed. Even for machine learning, which was a new skill group only appearing in the second period of our analysis, the wage response is negative for 4 out of the 11 GICS sectors. This suggests that there are marked nuances within sectors for the seemingly the same skill group, which we explore further in this chapter.

Energy

According to the industry classification GICS, companies in the Energy sector are involved in exploration & production, refining & marketing, storage & transportation of oil & gas, as well as coal & consumable fuels; and oil & gas equipment and services.[58]

Within soft skills, there is a substantial increase in shares over time in the demand for collaborative leadership, in addition to interpersonal and organizational skills. Furthermore, there are increases in the shares demanded for the entire complement of data science skills: big data, programming, machine learning, and cloud computing. Notably, the steepest increase is in programming, whereas math is the only skills group that experiences a decline across the two time frames in our analysis.

These movements in skills demanded within the Energy sector mirror the changes being experienced in the industry. Over the last decade, there has been pressure on the sector to innovate towards renewable energy and such pressure only intensified further in the last five years as the younger generations have been taking strong stances against climate inactions. For energy companies to make this shift, it is crucial to have skilled research and development staff (hence the shift in demand towards research and analytical skills) and invest in new technology (hence the shift in demand towards more data skills). Intuitively, when sectors are undergoing major shifts in how business is done, collaborative leadership becomes a necessity to oversee the transition, in addition to enabling innovation. Advanced data science skills are equally important as energy companies collect a lot of data from their operations. Being able to analyze and pinpoint areas for improving operating efficiencies would benefit energy companies in terms of reducing costs, and hence increase profitability.

In terms of the impact of a 10-percentage point increase in the respective skills group on wages, we find that for this sector over time the wage premium awarded to collaborative leadership declines from a positive value (0.36%) to a negative value (-0.14%). This suggests that even though the sector is demanding *more* collaborative leaders through their job ads, they are in fact paying less for this skill over time. This observation perhaps reflects that the sector has been undergoing the transformation towards renewables for quite some time, instead of outright hiring more leaders at a premium, they would have a decent pool of home-grown leaders who have progressed through the ranks.

Consistent with previous findings, the Energy sector has evolved in the data science skills for which it is willing to pay a premium. Notably, the sector is not offering a premium for machine learning. Rather, between 2014-15 and 2018-1Q 2020 there was a shift in offering a premium to those workers skilled in big data towards workers who are experts in cloud computing, indicating a shift in focus from a workforce that can analyze big data sets on-premises (i.e., on-site) to those who are skilled in utilizing cloud environments for facilitating efficient data science work.

Due to the pressing need in the sector for research and development into renewables, it is not surprising that significant wage premiums (around 0.25%) are offered to those with expertise in research, in addition to those who are analytical.

[58] MSCI, "Global Industry Classification Standards," PDF, accessed May 4, 2023.

Materials

The Materials sector includes manufacturers of chemicals, construction materials, glass, paper, forest products and related packaging products; and metals, minerals and mining companies, including producers of steel.

The stylized facts that emerge from Figure 48 are consistent with the findings for the Energy sector. Specifically, the two soft skills we analyze — collaborative leadership, and interpersonal and organizational skills, increase in demand over time. In addition, the demand for data science skills also increases over the two time periods. Notably, demand for cloud computing in 2014-15 is very low with 0.22% of companies in the Materials sector requiring those skills in job ads, before increasing to 1.49% in 2018-1Q 2020, registering a nearly sevenfold rise in demand from the earlier period. This implies that 1.5 out of 100 jobs advertised in the sector required cloud computing in this time frame. Research skills are consistently high in demand across the two time periods, as they represent 20% (1 in 5) of all jobs advertised in this sector. Lastly, we note that analytical skills increase in demand from being requested in 36% job ads in 2014-15 to 44% in 2018-1Q 2020.

Consistent with the Energy sector, we interpret the change in demand for skills in the Materials sector as a direct reaction to the trend towards more sustainable and more environmentally-friendly mining practices. Indeed, as we transition towards net zero, raw materials will increase in demand exponentially as we move towards wind and solar power, battery-powered electric vehicles, and increased hydrogen production. This transition requires innovation in particular to satisfy growing demand, through leveraging the human and capital resources at the sector's disposal, which data and collaborative leadership skills enable.

Notably there is no significant increase in wage premium for the collaborative leadership or interpersonal and organized skills, despite their increase in demand within the sector over time. Similar to the Energy sector, the Materials sector evolves from offering a premium to those workers skilled in big data in 2014-15 (of 1.75%) towards workers who are skilled in cloud computing. Interestingly, the sector does not offer a wage premium for research or analytical skills although demand for such skills has been consistently high. The negative relationships between a hypothetical 10-percentage-point increase in skill demand and wage premium response for these two skill groups suggest that such need is largely fulfilled.

Industrials

This sector is quite broad as it includes companies that are manufacturers and distributors of capital goods in areas such as aerospace & defense, building products, and electrical equipment, among others.

Echoing our findings in the Energy and Materials sectors, requests for both collaborative leadership and interpersonal and organized skills appear frequently in job ads in the sector. In addition, the demand for these two skills increases over the two time periods in our analysis, suggesting that the Industrials sector is trying to mobilize its labor force through hiring people with more effective leadership skills. For data science skills, we see that demand in the sector increases slightly for big data and machine learning skills between the two periods, while simultaneously maintaining a consistent level of demand for programming skills (approximately 1 out of 10 of every job advertised). Consistent with Energy and Materials, demand in the Industrials sector increases significantly for cloud computing skills in job ads (from 1 in every 100 jobs advertised, to 3 in every 100 jobs advertised).

Notably, and unlike the Energy and Materials sectors, the Industrials sector does offer a small and statistically significant positive wage premium for collaborative leadership skills. The sector does not offer any additional wage premium for most data science, research, or analytical skills despite demanding these skills frequently in job ads. The notable exception is big data skills, which attract a positive wage premium of 1.70% in 2014-15, but this decreases to 1.06% in 2018-1Q 2020. We expect that the failure to reward in-demand skills within Industrials is owed to the sector's tight margins that filter through to cost containment pressures on the wage bill.[59]

Consumer Discretionary

Companies in the Consumer Discretionary sector are businesses that tend to be the most sensitive to economic cycles. The sector's manufacturing segment includes automotive, household durable goods, leisure equipment, and textiles & apparel. Its services segment includes hotels, restaurants and other leisure facilities, media production and services, and consumer retailing and services.

In terms of the demand for the nine skill groups, we see very different trends as compared to the earlier sectors, which are capital-intensive industries. Recall that for capital-intensive sectors, firms are employing technology to complement labor, while for labor-intensive sectors, firms employ technology to substitute labor. Consumer Discretionary is by and large a labor-intensive sector. It is perhaps then unsurprising that we see decreasing demand for interpersonal and organized, big data, programming, research, and analytical skills, as technological innovations and automation take over. Only demand for collaborative leadership and cloud computing increase by a considerable amount, while math remains stable. Machine learning skill demand also surfaces in the second period in our analysis, as per the other sectors.

While collaborative leadership is being requested more frequently in the sector over time (strikingly, 65% of job ads request collaborative leadership in 2018-1Q 2020), interpersonal and organized skills are being requested less in job posts in the sector over time (from 33% to 26%). This emphasizes the importance of collaborative leadership in a labor-intensive sector, while interpersonal and organized skills are automatable as mentioned in previous sections. The only cognitive skill that increases substantially in demand is cloud computing, in line with the previously-discussed sectors, cementing the importance of this discipline in our rapidly digitalizing world. Specifically for this sector, we see a nearly doubling in demand from 6 out of 100 ads in 2014-15 to 11 out of 100 ads in 2018-1Q 2020. These observations could be a reflection of the rapid rise and deployment of IoT. In addition, many SaaS (software-as-a-service) platforms have been made available to this sector, which reduce the need to have in-house programming personnel but the increased amount of data being collected strengthens the appetite for more workers skilled in cloud computing.

[59] Alberto Salamone and Grace Lordan, "Can Meaning Make Cents? Making the Meaning of Work Salient for U.S. Manufacturing Workers," *PLoS ONE*, Vol. 17, No. 7, July 8, 2022.

In terms of wage response to a change in skill demand, this sector exhibits a much more synchronized pattern than earlier sectors where stronger demand leads to larger wage premiums and vice versa for most. The only exceptions are analytical skills and machine learning where the former falls demand and yet garners a favorable wage premium response, suggesting the sector would reward the "right" or more specialized analytical skills; the latter is a relatively new skill group but a hypothetical increase of 10-percentage points in demand does not lead to positive wage premiums.

Consumer Staples

Consumer Staples is a non-cyclical sector as it includes manufacturers and distributors of food, beverages, and tobacco, as well as producers of non-durable household goods and personal products. It also consists of food & drug retailing companies, as well as hypermarkets and consumer super centers.

In terms of skill demand in this sector, contrary to earlier sectors discussed, both collaborative leadership and interpersonal and organized skills are requested less frequently in job ads in the sector from 2014-15 to 2018-1Q 2020. To be clear, demand for the former is still high, with over 60% of ads mentioning skills related to collaborative leadership. In addition, our results also show drops in demand for research and analytical skills. Notably, the demand for data science skills is relatively stable between 2014-15 and 2018-1Q 2020. These observations, in our opinion, reflect the recent evolution of automation and robotics in the sector. Technological advancements and disruptions brought about by a new breed of food and goods delivery companies disintermediate the value chain. Usage of robotics in the distribution and manufacturing of food also increased in recent years. These developments dampen the need for more specific data skills and also result in less focus on interpersonal and organized skills as they get replaced by the progress in automation.

On the wage response to a 10-percentage point increase in demand, the sector does offer pay premiums for jobs demanding big data and analytical skills that are stable over time. Programming skills also garner wage premiums in 2018-1Q 2020. Overall, the Consumer Staples sector does not follow the trend of collaborative leadership becoming increasingly relevant and legacy cognitive skills within data science decreasing, which we believe is due to the technology and innovations that have been deployed in the sector.

Healthcare

This sector consists of healthcare providers & services, companies that manufacture and distribute health care equipment & supplies, and health care technology companies. It also includes companies involved in the research, development, and production and marketing of pharmaceuticals and biotechnology products.

Healthcare is a highly specialized sector where staff can be expected to have solid education backgrounds and/or rigorous training. Unsurprisingly, both collaborative leadership and interpersonal and organized skills have been requested more frequently in job posts in the sector from 2014-15 to 2018-1Q 2020. Specifically, there is a large increase in the share of job ads seeking collaborative leadership from 37% in 2014-15 to 53% in 2018-1Q 2020. Demand for interpersonal and organized skills also grew from 22% to 27% over the two periods. These soft skills are paramount for the sector as firms need strong leaders who could collaborate and at the same time possess skills to be inclusive, hence creating an environment that fosters technological innovations and breakthroughs.

In addition, the sector significantly increases the proportion of its requests of all the data science skills we consider between 2014-15 and 2018-1Q 2020 (i.e., big data, programming, machine learning and cloud computing), in addition to research and analytical skills. In fact, this is one of the only two sectors (alongside Communication Services) out of eleven GICS sectors that have seen stronger demands across all nine skills groups.

Taken together, the changes in demand for skills over time are a testament of a sector that strives to leverage both human and technological inputs to innovate. Collaborative leadership enables firms to better leverage talent with strong research and analytical skills for essential innovations in the sector. For technological deployments, collaborative leadership, combined with excellent data skills, facilitates the effective use of innovative technologies.

The next question we want to explore is whether the Healthcare sector is incentivizing candidates to acquire these skills through offering wage premiums. In line with demand, the sector offers a pay premium of 0.40% for jobs demanding collaborative leadership in 2018-1Q 2020. Programming also garners a wage premium that increases from 0.15% in 2014-15 to 0.53% in 2018-1Q 2020 in the face of increasing demand, while the sector offers a roughly equal premium for machine learning skills, implying that they are incentivizing legacy and emerging programming skills. In addition, the sector offers a premium for math skills (even though demand for these skills is low, at around 0.1% of job ads). Interestingly, although the sector relies on strong research and analytical skills, there is no statistically significant additional wage premium beyond the wages garnered by a particular occupation title.

Financials

Companies in this sector are involved in banking, thrifts & mortgage finance, specialized finance, consumer finance, asset management and custody banks, investment banking, and brokerage & insurance.

Financials is a service-oriented, classic labor-intensive sector. Accordingly, we observe in the sector a strong rise in demand in job ads for both collaborative leadership and interpersonal and organized skills over the two periods in our analysis. Specifically, 57% of job posts sought collaborative leaderships skills in 2014-15, increasing to 69% in 2018-1Q 2020. Thirty-four percent of job ads sought interpersonal and organizational skills in the first period, rising to 48% in the second. This is a sector emphasizes heavily on teamwork and collaborations, as evidenced by our results.

In terms of cognitive skills, there are substantive increases across the data science skills category, with every data science skill increasing in demand between 2014-15 and 2018-1Q 2020. The biggest relative increases are in emerging data skills: machine learning and cloud computing. Both research and analytical skills also increase in demand, albeit to a lesser extent. These findings reflect the service-oriented nature of the sector. They also reflect that a firm's success acutely hinges on strong, collaborative leadership, as well as highly-skilled analytical workers who can truly master AI and machine learning and deploy these techniques with big data for innovation and operational excellence.

Noticeably, the demand for math skills is on the decline, which could be as a result of AI advancements and more financial products being democratized through commercially available SaaS or low-code/no-code applications. That said, this skill group still attracts the largest wage premium in response to a hypothetical 10-percentage point increase in demand in 2018-1Q 2020. These observations indicate that while the demand in general for math is decreasing, those with more specialized knowledge in certain areas — such as stochastic calculus, required in pricing exotic options, for example — would still be rewarded.

Elsewhere on the cognitive skills side, the sector offers positive wage premiums to data science skills except big data. Notably, cloud computing garners the second-largest wage premium for 2018-1Q 2020, as this skill group remains critical to elevate technology infrastructure for operational success.

In other skill groups, despite an increase in demand for collaborative leadership and interpersonal and organized skills, this does not materialize into an occupational-level wage premium in the sector. With almost 7 out of 10 jobs seeking skills for the former (which is among the highest in all GICS sectors), and nearly half of jobs seeking skills for the latter, it is fair to state that they have become skills that employers in the sector would expect candidates to possess, regardless of department or role.

Information Technology

Information Technology companies offer software and information technology services, and manufacture and distribute technology hardware and equipment including cellular phones, computers and peripherals, and semiconductors, among others.

Similar to the Financials sector, there is a rise in demand for nearly all skill groups in our analysis. The exception is programming, which registers flat demand over the two time periods studied, with almost 1 in 4 jobs requiring these skills. On the soft skills side, collaborative leadership is requested in 57% of job ads in 2014-15 increasing to 62% in 2018-1Q 2020. Interpersonal and organization skills are requested in 21% of ads in the first period, rising to 25% in the second.

There are also substantive increases across the data science skills category, with nearly every skill group increasing in demand over the two periods. In addition, consistent with the Financials sector, the biggest relative increases in skills demanded in job ads are in the emerging data science skills: machine learning, and cloud computing. In addition, both research and analytical skills also increase in demand, albeit to a lesser extent. The demand for math skills also increases significantly from 0.13% to 0.24% across the two time periods.

On the wage responses to rising skill demand front, despite an increase in demand for interpersonal and organized skills, this does not materialize into an occupational level wage premium, just like many other sectors. However, there is still a small and stable wage premium for collaborative leadership across the two time periods (around 0.1%).

The largest wage premium in the Information Technology sector is associated with job ads that require machine learning skills (0.72% in 2018-1Q 2020) and big data skills (1.2% in the first period to 4.1% in the second), which is intuitive as digitalization creates abundance of data for technology firms to analyze and innovate. Similar to the Financials sector, occupations within the Information Technology sector that require math skills garner a small wage premium (0.23%), indicating such skills have become more specialized.

Communication Services

Companies included in the Communication Services sector provide communications services primarily through a fixed-line, cellular or wireless, high bandwidth and/or fiber optic cable network.

For the two time frames examined, there is an increase in demand across all the skill groups we consider, which is consistent with patterns found in Financials and Information Technology sectors. Similar to most of other sectors, collaborative leadership also experiences a significant growth in demand in this sector from 57% of job ads in 2014-15 increasing to 69% in 2018-1Q 2020. Interpersonal and organization skills have a modest increase, being requested in 24% of ads in the first period before rising to 28% in the second.

Additionally, every data science skill — big data, programming, machine learning and cloud computing — has marked increases in demand between 2014-15 and 2018-1Q 2020. This outcome makes sense as Communication Services played a crucial role in the rise of IoT era and the resultant data collection and analytics require a labor force capable of performing such tasks. Among these skill groups, the biggest increase relates to cloud computing, with expertise in cloud computing being requested in approximately two job ads out of 100 in 2014-15, increasing to 7 job ads out of 100 in in 2018-1Q 2020. The sector has moved hand-in-hand with technologies being deployed in mobile, online streaming and app software, all of which require the data skills we track and cloud computing would allow firms to scale more economically.

In terms of wage responses to a 10-percentage point increase in demand for each of the nine skills groups, the increase in demand for interpersonal and organized skills is associated with a small occupational level wage premium of 0.27%, unlike other sectors where negative premiums are documented. For collaborative leadership skills, we find that this skill group initially has a small premium of 0.14% in 2014-15 but turns negative to -0.24% in 2018-1Q 2020.

In 2018-1Q 2020, the largest wage premiums in the Communications sector are associated with job ads that require skills in math (2.33%) and machine learning (1.54%). In addition, occupations requiring math skills garner a wage premium which is over 2% beyond what is embedded within an occupation title. The results reflect the highly desired skills amidst the technological evolution in IoT and the integral part the Communications sector plays in the Fourth Industrial Revolution.

Utilities

Companies in this sector include electric, gas, and water utilities. It also includes independent power producers and energy traders as well as companies that engage in electric generation and distribution using renewable sources.

There are increases in skills requirements in almost all nine skills groups barring research skills which witness a decline, which is consistent with the Materials sector. There are only a handful of job ads that require machine learning in the later time frame of 2018-1Q 2020. The shares and absolute numbers in the other data science skills such programming or cloud computing are also comparatively low, similar to the Materials sector and to a large extent also the Energy sector. This makes sense as the sector has been going through a transition period like the Materials and Energy sectors where sustainability is the focus, spurring the demand for modernizing sensors and promoting the further deployment of smart grids to scale the utilization of renewables.

For the wage response analysis, we find that the Utilities sector also does not reward collaborative leadership any additional premium and in fact it exhibits negative wage response in 2018-1Q 2020 of -0.15%. The skills that attract significant wage premiums are big data, programming, and research where for example a 10-percentage-point increase in big data skill demand would achieve a premium of 0.57% in 2018-1Q 2020. These skills are vital for achieving success in the transition towards renewables where data volume from sources such as sensor readings would increase dramatically. Being able to analyze large volume of data at scale, and research new technologies to improve operational efficiency would be the vital tasks for the sector.

Real Estate

Companies in this sector are real estate firms engaged in commercial and residential development and operations, and REITs (real estate investment trusts). Real estate services such as real estate agents, brokers and appraisers are also included in the sector.

Most of the nine skill groups have seen increased demand in the Real Estate sector, apart from research and math skills. The majority of job ads are spread across only three skill groups: collaborative leadership, interpersonal and organized, and analytical. Being arguably the most labor-intensive sector among all the GICS sectors, it is unsurprising that interpersonal and organized skills make up a large share of job ads compared to the other cognitive skills. Among the other skill groups, research skills dominate followed by programming skills. These results keenly reflect the service-oriented nature of the sector, being complemented by analytical skills to identify the trends and opportunities in real estate.

Similar to other sectors, digitalization has also been the main trend for the Real Estate sector. Online advertising and the collection of large amount of customer data require skilled workers who can research and analyze these sources of information, which in turn can be transformed into a firm's competitive advantage if done successfully. To be successful, as in pretty much every business, requires strong, collaborative leaders who can motivate and incentivize their teams.

In terms of wage responses to increases in skill demand, none of the skills groups' effects are significant in 2014-15. Collaborative leadership has a positive effect of 0.5% on wages in 2018-1Q 2020 in line with the increasing demand in terms of shares, while interpersonal and organized skills have a negative effect of -0.18% in the same time frame. Analytical skills are still rewarded by real estate firms, as being able to analyze market trends and understand the overarching macro environment would be vitally important for firms' success.

Industry Analysis Summary

The above sector analysis highlights to what extent the demand and the wage premiums of the nine skills groups are sensitive to industry-specific trends and developments. An example of a sector that shows very clear industry trends in its skills demand and premiums is the Healthcare sector. The Healthcare sector strives to leverage human and technological inputs to spur innovations. In that vein, collaborative leadership becomes increasingly important as firms with motivating leaders can get the best out of their employees. Further, excellent data skills also matter in this sector as they allow for innovation alongside the implementation of innovation through soft skills.

Generally speaking, there is a divide between capital-intensive and labor-intensive sectors where we find evidence of labor-intensive sectors and firms to employ technology to substitute labor through the wage premium and demand relationships, contrary to capital-intensive sectors and firms employing technology to complement labor. Within the latter, the key trend consistently observed in the Energy, Materials, and Utilities sectors stems from the increased pressure to focus on sustainability, especially the transition towards renewable energy. However, in the Energy and Utilities sectors, the demand for collaborative leadership resulting from the trends such as towards to renewable energy is not (yet) reflected in a wage premium for those skills. Overall, shedding light on industry-specific trends is crucial to better understand how sectors differ in terms of skills needs and rewards. The insights also help inform corporates of how their respective industry peers view and reward certain skill groups, which could be critical in terms of their strategic planning for the future.

What Do Other Data Sources Tell Us About Skills Demand Evolution?

As an extension to using job advertisement data to infer the rise and fall of the demand and wage premium in various skills, we have included patents data as an additional source of information to measure the rate of innovation across six of the seven cognitive skill groups and study whether there is any relationship between patents growth and the demand and wage premium for these skill groups. The underlying sense is that impactful inventions can be captured by a growth in the related patents volume; successful inventions gaining sufficient traction would eventually be incorporated and implemented in companies after a certain time lag, leading to support for further growth in R&D in those areas and amplifying increases in the corresponding patents volume.

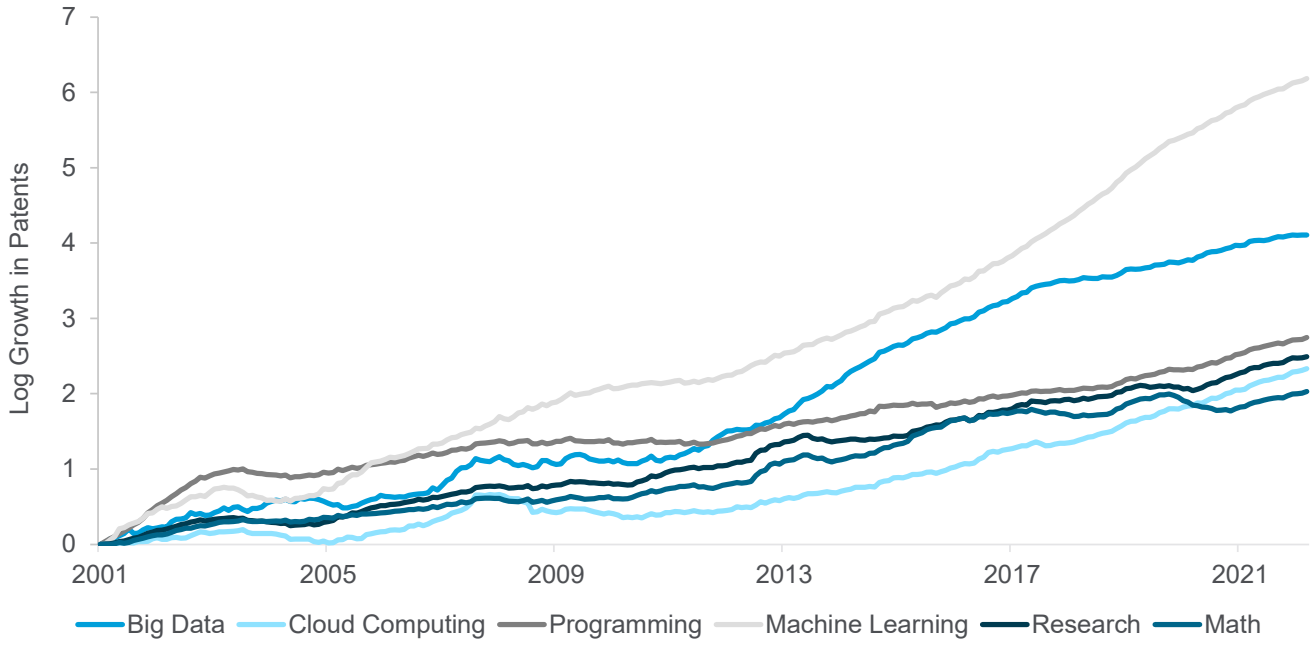
The patents data used in this analysis is sourced from a data vendor, Quant IP.[60] The geographic coverage of the patents data is global, covering over 80 patent offices, 83 million inventions in total, and on average 3 million additional applications per year. Each patent is assigned a quality score by Quant IP through its bespoke prediction algorithm, which is a function of data such as grant rate, number of citations, and geographical span of patent offices applied to. This quality score can be useful to distinguish high-quality patents with originality and innovation from low-quality patents that are potential copycats or carry little real-world impact.

In order to capture patents relevant to the six cognitive skill groups, we take the skill keywords in and search for patents that contain any of the skill keywords for each cognitive skill group within the patent body text. For example, any patent historically containing any of the keywords “tensorflow,” “pytorch,” and “keras” is considered relevant to the cognitive skills group machine learning. In this fashion, the volume of matching patents for each cognitive skills group are aggregated over monthly time frames and weighted by the quality scores to create a time series of patents growth for each cognitive skill group. The reason for excluding non-cognitive skills is intuitive: Patents typically capture advancements and breakthroughs in inventions that are closely linked to R&D areas characterized by the cognitive skills groups, whereas there is much less relevance to soft skills in patent inventions, if at all any.

Figure 17 illustrates the log patents growth, weighted by quality, for each cognitive skills group for the past 20 years. First of all, we note that the patents growth has been exponential, which is the reason the log growth instead of actual growth was shown — and even at log scale, we still observe a tremendous growth rate in patent filings. Machine learning, which recorded the largest growth in patents volume over the past 20 years, has experienced the highest growth rate post-2016. This observation coincides with the job ads analysis earlier where there were no jobs mentioning the keywords that define the skill group before 2016. Big data, ranking second in overall patents volume growth since 2002, has seen the highest growth rate between 2014 and 2017. It is interesting to note the difference in time periods in which the inflection point in growth rates were reached across the cognitive skills groups, as they mature at different times.

[60] https://quant-ip.com/

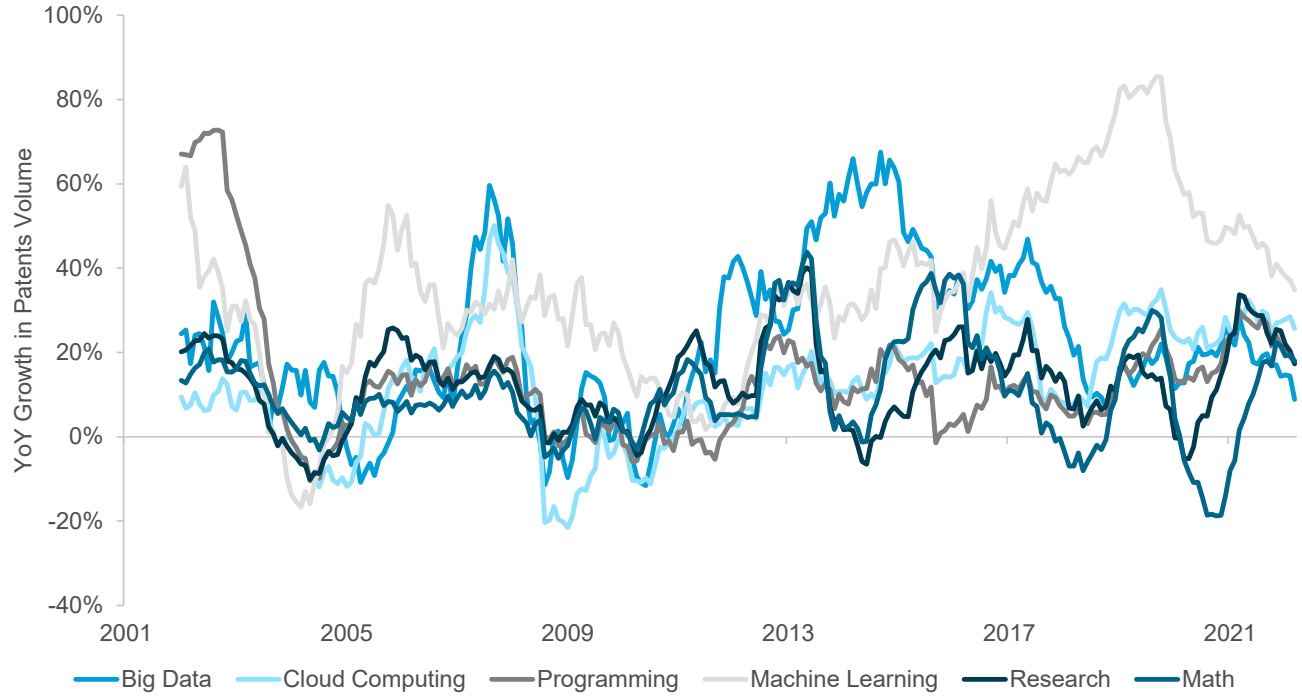
Figure 17. Patent Growth by Skill Group



Source: Quant IP, Citi Global Data Insights

To better illustrate these inflection points, we demonstrate in Figure 18 the year-on-year growth in patents volume, weighted by quality scores as derived by Quant IP.

Figure 18. Year-Over-Year Patent Growth by Skill Group



Source: Quant IP, Citi Global Data Insights

It becomes immediately clear that the rate of patents growth for machine learning reached its highest in late 2019; for big data, in late 2014; and for cloud computing, initially in 2007 and subsequently again in 2016, likely due to increased readiness and demand across various industries to adopt cloud technology for outsourcing data storage and improve computing power. It is important note that there is a lag between the time when patents are filed and the subsequent product roll-out.

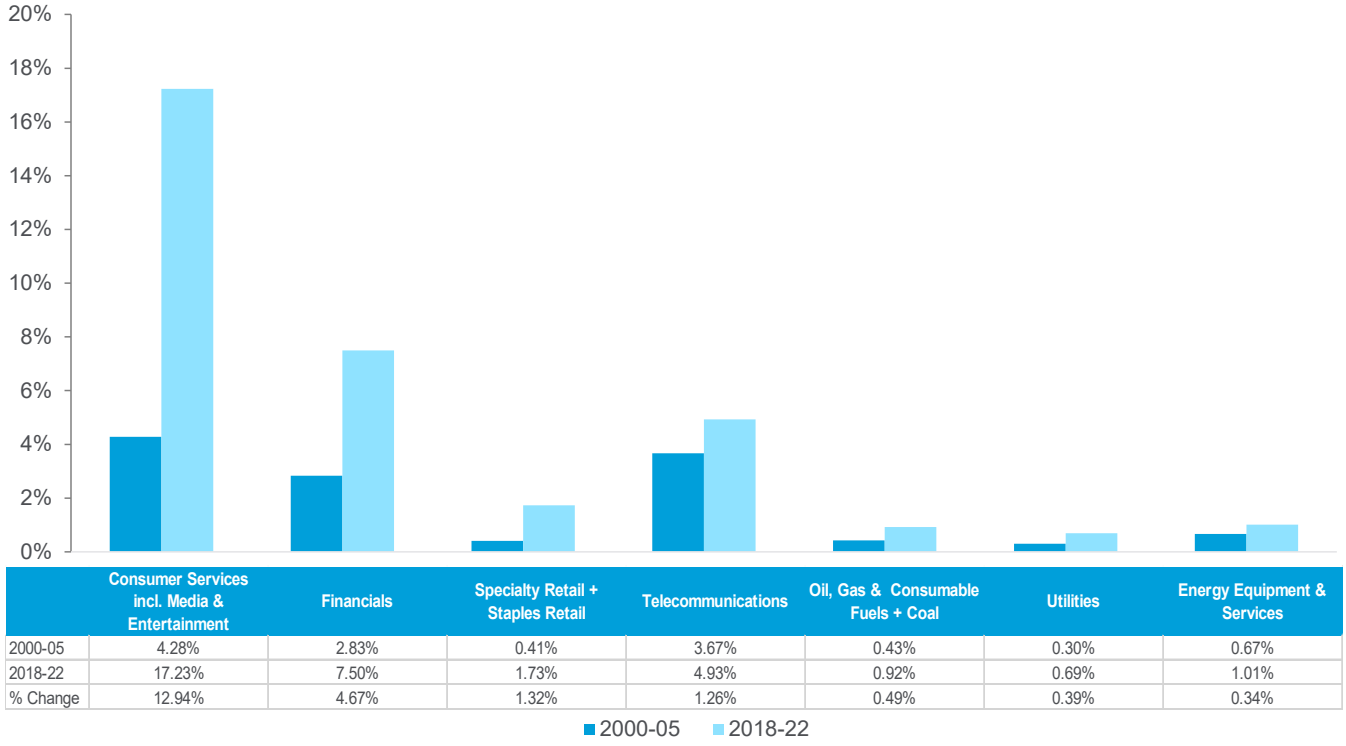
These results bode well with the findings presented in Figure 12, which shows the wage premium response to a 10-percentage point increase of each skills group share. Big data and cloud computing had the highest wage premium during 2014-15, but this premium became negative in the later 2018-1Q 2020 period — as the patents growth for these two skills groups slowed down from the highest rate of volume growth. Similarly for machine learning, the patent inventions growth rate has almost doubled from 2014-15 to 2018-1Q 2020 — which likely explain the remarkable wage premium in the later period.

Innovation by Sector

Recall in the earlier section where we examine the skill demand relationship with the wage premium responses, we highlight the importance of collaborative leadership being the most requested skills across the nine skill groups studied. In fact, the recent observations show that regardless of sector, firms expect candidates in six out of ten jobs to have such leadership skills. As also highlighted earlier, collaborative leaders have the quality of bringing the best out of their staff and being more inclusive creates an environment that foster innovations.

Patents can be seen as a good proxy for measuring innovation. Analyzing the trends in patents filings by sector unveils the growth in the rate of innovation and also the topics of focus for firms within a given sector.

Figure 19. Patent Filing by Industry



	Consumer Services incl. Media & Entertainment	Financials	Specialty Retail + Staples Retail	Telecommunications	Oil, Gas & Consumable Fuels + Coal	Utilities	Energy Equipment & Services
2000-05	4.28%	2.83%	0.41%	3.67%	0.43%	0.30%	0.67%
2018-22	17.23%	7.50%	1.73%	4.93%	0.92%	0.69%	1.01%
% Change	12.94%	4.67%	1.32%	1.26%	0.49%	0.39%	0.34%

Source: Quant IP, Citi Global Data Insights

Figure 19 exhibits the industries within sectors that have seen the largest percentage increases in terms of the patents filed recently, compared to more than a decade ago. We choose these two time frames as developing a patent takes considerable time and by having the two periods more than a decade apart, the underlying trend would be much more apparent.

Due to the common drivers underneath some industries across sectors, we have combined certain GICS industries to show the underlying trends more explicitly. For example, the biggest jump in terms of the share in the total patents filed is in the Consumer Services space where IoT and related product & services experienced tremendous growth. This segment now accounts for 17.23% of total patents, which is only second to Financials (7.5%).

Figure 20. Top Three Topics of Patents Filing by Industry

	Topic 1	Topic 2	Topic 3
Consumer Services incl. Media & Entertainment	Electronic device, Data management	Video/image digital processing	Machine learning, Language
Financials	Automation, Equipment, Storage	Data/information processing	Machine learning, Prediction models
Specialty Retail + Staples Retail	Data processing, Storage	Image processing, Recognition	Machine learning, Model training
Telecommunications	Image storage, AI processing	Device detection/identification, Storage	Speech recognition, Voice model
Oil, Gas & Consumable Fuels + Coal	Data storage & processing, Cloud computing	Simulation and prediction models	Machine learning, Network models
Utilities	Data processing, Storage	Fault detection, Failure identification	Production optimization
Energy Equipment & Services	Control system, Device communication	Drilling fluid, Preparation	Nuclear power, Generation, Storage

Source: Quant IP, Citi Global Data Insights

Taking a step further, we also examine the main topics related to the filed patents. In Figure 20 we list the top three topics for the seven segments we identify that have the highest growth. The pattern is clear in that most of the patents cover data processing, management, and storage. With the exception of the Utilities and Energy Equipment & Services segments, machine learning is prominent in all the other segments, which echoes the findings on cognitive skills we discussed in the "Sector Analysis: Jobs vs. Wage Premiums" section. For the energy transition industries, another key observation is the importance on power generation and storage but also operational efficiencies such as fault detection and production optimization.

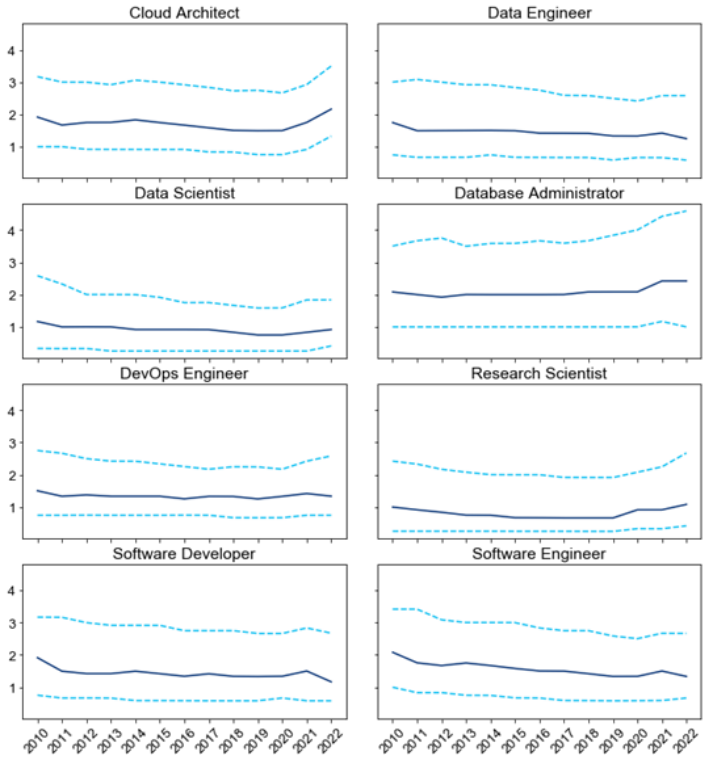
Talent Tenure

Since cognitive skills related to data and data science appear to be prominent in both job ads as well as patents filed, it is worth exploring how these roles have evolved over time from the perspective of tenure. We highlight in the earlier section that data science is not a fixed skill and working in this particular field requires constant upskilling to be kept abreast of the latest cutting-edge techniques and models. Utilizing the workforce data provided by Revelio Labs, we are able to study the nuances in the tenure of data and data science related roles.[61]

As shown in Figure 21, in general, there has been a decreasing trend in workforce tenure over the past 10 years, indicating increased career opportunities and declined employee loyalty. Data scientists have the shortest tenure, among all eight occupations relating to big data, cloud computing, programming, machine learning, and research skills. The median tenure in 2022 is in fact less than 1 year, with the third quartile tenure also being the shortest just under 2 years.

[61] https://www.reveliolabs.com

Figure 21. 1st Quartile/Median/3rd Quartile of Tenure of Data-related Roles Over Time



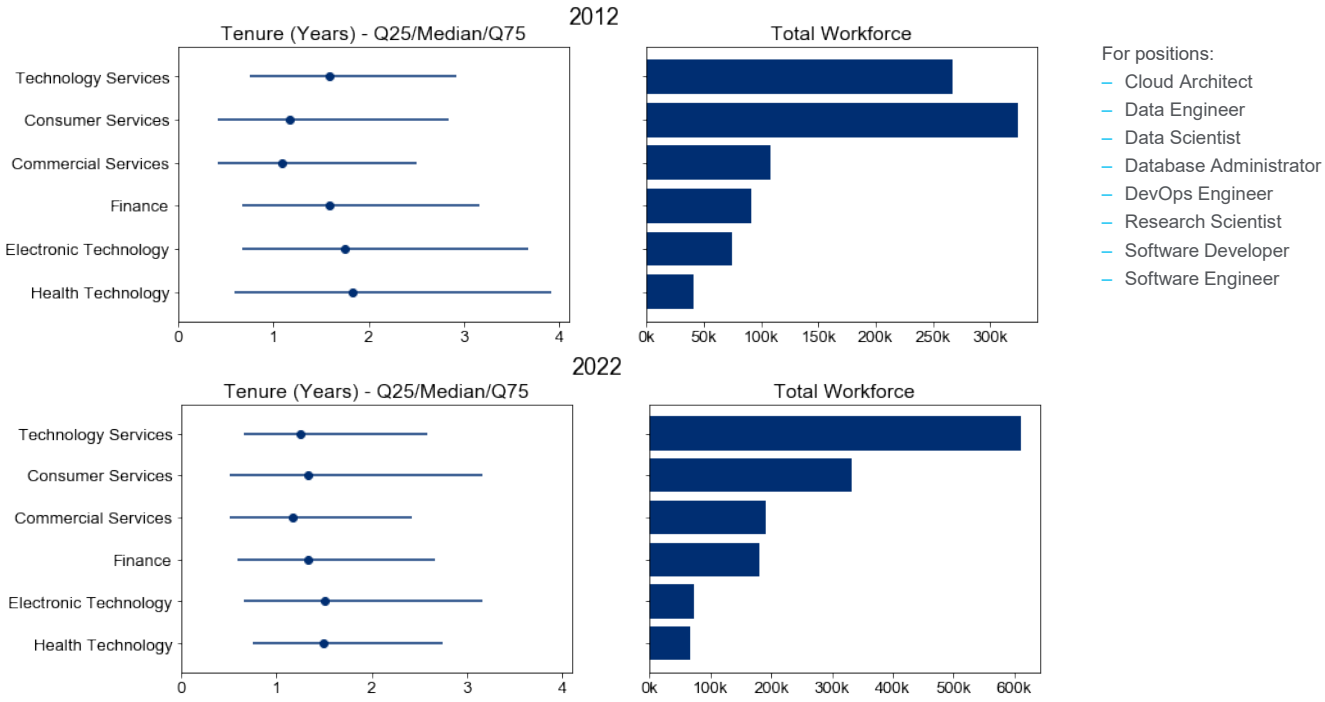
Source: Revelio Labs, Citi Global Data Insights

The median tenure has decreased for the following occupations: data engineers, DevOps engineers, software developers, and software engineers. Corporates need to pay additional attention to talent retention in these areas. In contrast, database administrators and cloud architects have the highest and still-increasing tenures, which perhaps reflect decreased career mobility due to democratization brought about by new technologies.

Tenure by Sector

Delving in deeper, we want to explore whether there is also pronounced divergence in tenure across sectors. For this analysis, we use more detailed industries within the sectors to reveal the underlying trends.

Figure 22. Workforce Tenure for Top Hiring Sectors



Source: Revelio Labs, Citi Global Data Insights

As exhibited in Figure 22, Technology Services and Consumer Services are the two top industries for hiring positions with cloud computing, big data, machine learning, research, and programming skills. When compared to 10 years ago, the steep growth in Technology Services is particularly eye-catching — its workforce size was roughly on par with that of Consumer Services in 2012, but by 2022 it was nearly double in comparison. Between 2012 and 2022, the median tenure for these positions has noticeably decreased for industries such as Technology Services, Finance, Electronic Technology, and Health Technology, suggesting more opportunities in the market and hence increased career mobility.

Recent Data Science Skills: Large Language Models

We mentioned in earlier sections of the report that data science skills are not fixed and require constant upskilling. We also established the fact that in the nine skill groups identified to be "the skills of the future," there had been significant increases in demand for the cognitive skill groups, largely related to data and data science, when analyzing the 2014–15 and 2018–1Q 2020 periods.

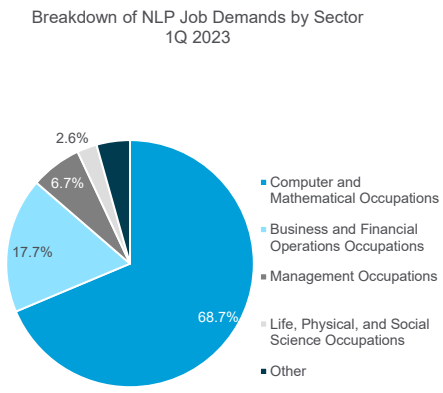
As the economy reopens after the pandemic, we continue to see tremendous growth in the AI/machine learning area, not only in hiring trends but also in patent filings, as discussed earlier. The specific strand of AI that has recently taken the world by storm is the Large Language Model (LLM), particularly ChatGPT. A large language model is a pre-trained deep learning model that understands and generates texts that mimic human responses.

As Occupational Information Network (O*NET) occupation codes consist of over 1,000 descriptions of jobs, they provide a granular read-across as to what roles demand natural language processing (NLP) skills. [62] Depicted in Figure 23, roles

[62] O*NET OnLine, "See All Occupations," accessed August 14, 2023.

requiring recent technologies such as GPT/ChatGPT and LLMs have been driven primarily by four occupation groups: (1) computer and mathematical; (2) business and financial operations; (3) management; and (4) life, physical, and social science. Among these groups, the occupation group most seeking these skills is unsurprisingly computer and mathematical occupations, which accounted for almost 70% of the total NLP roles in the first quarter of 2023. Within these occupation groups, medical scientists, financial analysts and advisors, management analysts, as well as market research analysts and marketing specialists are the roles that have experienced remarkable growth over the last four years.

Figure 23. NLP Job Demand



Occupation Description (Level 1)	Occupation Description (Level 2)	Occupation Description (Level 3)	2019	2020	2021	2022	1Q 2023	%Increase, 2019-22
Business and Financial Operations Occupations	Business Operations Specialists	Human Resources Workers	20	35	87	32	0	60.0%
		Management Analysts	629	546	1144	1510	176	140.1%
		Market Research Analysts and Marketing Specialists	430	429	852	1006	192	134.0%
		Miscellaneous Business Operations Specialists	29	12	70	41	5	41.4%
	Financial Specialists	Financial Analysts and Advisors	77	183	244	296	40	284.4%
Computer and Mathematical Occupations	Computer Occupations	Computer Support Specialists	13	17	20	41	3	215.4%
		Computer and Information Analysts	309	244	568	324	57	4.9%
		Computer and Information Research Scientists	2477	2681	5561	4799	619	93.7%
		Database and Network Administrators and Architects	46	40	89	107	11	132.6%
		Miscellaneous Computer Occupations	554	566	1078	942	148	70.0%
		Software and Web Developers, Programmers, and Testers	3650	4121	8173	6252	549	71.3%
	Mathematical Science Occupations	Data Scientists	858	765	1821	1257	227	46.5%
		Operations Research Analysts	113	50	196	94	18	-16.8%
		Statisticians	15	30	51	50	4	233.3%
Life, Physical, and Social Science Occupations	Life Scientists	Medical Scientists	76	140	301	356	55	368.4%
Management Occupations	Advertising, Marketing, Promotions, Public Relations, and Sales Managers	Marketing and Sales Managers	291	250	657	430	69	47.8%
	Operations Specialties Managers	Computer and Information Systems Managers	170	178	349	359	27	111.2%
		Financial Managers	86	33	116	174	22	102.3%
	Other Management Occupations	Miscellaneous Managers	19	23	87	59	4	210.5%
		Natural Sciences Managers	57	34	146	98	6	71.9%

Source: O*Net, LinkUp, Citi Global Data Insights

In-Depth: Competition for AI Talent

Why Are AI Skills Important?

As AI increases its value to the economy and comes closer to attaining human-level achievements, firms are seeking to invest in AI personnel as part of their corporate strategies.

Across a range of markets, the ability to recruit AI professionals is likely to be pivotal to a firm's success in this quickly changing field. According to a 2022 McKinsey survey of 1,500 companies, AI adoption plateaued after five years of steady growth.[63] The key finding for firms, as identified by McKinsey, is that the market for AI talent is tight and new specializations, often dubbed "hot jobs," are surfacing every year. The consultancy stresses that the challenge for firms is to manage AI implementation risks and build inclusive teams.

Rackspace, in their 2023 *AI and Machine Learning Research Report*, analyzed a survey of 1,420 IT managers and concluded that businesses are still struggling to find the skills necessary to identify, build, and deploy the AI tools and automation needed to resolve their skill shortages.[64] The report highlights that "*AI/ML is smart —but it isn't ready to implement itself*." While the technology's potential is vast, it is still difficult to find skilled people who can work with the technology and the data to optimize outcomes.

There are several obstacles highlighted in this report that hinder AI adoption: 67% of firms report a shortage of skilled talent, 61% point to an algorithm/model failure, 57% of firms point to the cost of AI implementation, 54% to the lack of technological infrastructure to support AI, 51% to the lack of internal skills and difficulty hiring the required roles, and 49% to technical infrastructure challenges. These headwinds largely relate to the costs and risks of talented professionals being thin on the ground, which increases the chance of failing to attain desired outcomes despite large infrastructural investments.

While the past few years have seen numerous reports and research papers discussing the shortage of AI talent, we look into the issue by gathering data on actual job advertisements to understand the specific needs of firms in the AI space.

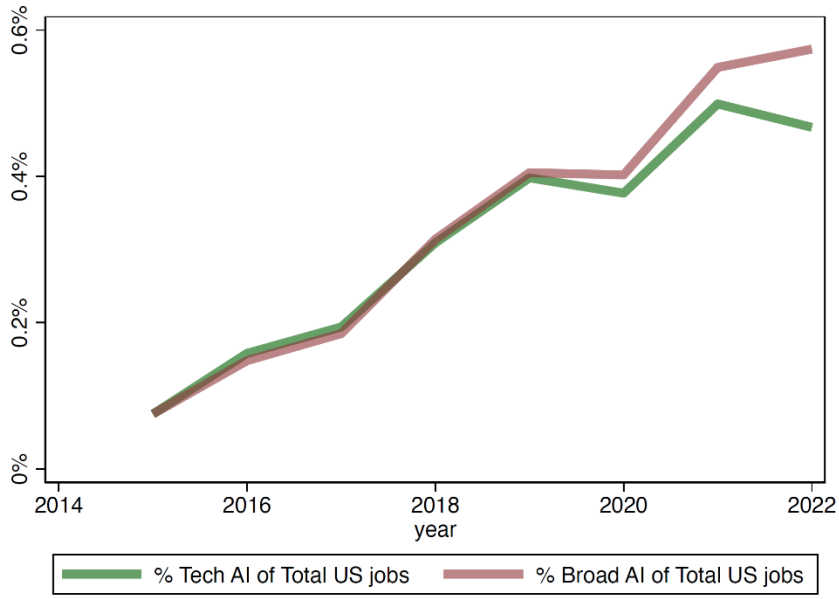
The Rise of Demand for AI Skills

The need for a workforce with more sophisticated and varied roles is growing as businesses increase their digital footprint. Traditional job titles do not portray this sufficiently. Hence, we analyzed texts from job advertisements to measure how firms' demand for AI tasks is changing. Job postings provide a useful metric because they offer real-time information and capture more nuanced changes in the labor market. For this part of the analysis, we use LinkUp Job Market Data, which curates job listings from employer websites globally.

[63] McKinsey, "New McKinsey Survey Reveals the AI Tech-Talent Landscape," January 20, 2023.
[64] Rackspace, *The 2023 AI and Machine Learning Research Report*, February 2023.

In doing so, we devised a number of different strategies to classify AI jobs and avoid overcounting through the jobs' title or undercounting by selecting too narrow a set of criteria. In addition to striving to be transparent about our identification of job postings, we divide jobs in AI in two main sectors: **Tech AI jobs**, which require the technological skills necessary to be able to "run, train and test" AI models, and **Broad AI jobs**, which necessitate an understanding of AI technologies but do not need the tech skills found in Tech AI jobs.

Figure 24. Relative Increase in the Demand for AI Skills



Source: LinkUp, Oxford Martin School, Citi Global Data Insights

The construction of these groups is central to the results that we present. The authors of similar studies often use existing classifications like those provided by the Occupational Information Network (O*NET), which are generic and fail to identify jobs that require AI skills falling outside the main classifications. If we followed this approach, we would end up overcounting the Tech AI jobs and largely excluding the Broad AI ones. Other options for categorizing jobs include the identification of specific skills (examples of this approach include the scoring mechanism outlined in a 2023 NBER Working Paper by Tania Babina et al. or Stanford University's *Artificial Intelligence Index Report 2023*), which ends up being rather restrictive for some managerial job ads.[65] The result of such an approach is a selection of "heavy" tech jobs that excludes roles that require a few AI skills or other skills that are not tech-related. A third possible option would be a naive "regular expression" approach that casts a very wide net across all jobs that simply include the terms "AI" or "ML" (i.e., machine learning), vastly overestimating the Tech AI sample but not excluding Broad AI jobs.

[65] Tania Babina et al., "Firm Investments in Artificial Intelligence Technologies and Changes in Workforce Composition," National Bureau of Economic Research Working Paper No. 31325, June 2023; Stanford University, *Artificial Intelligence Index Report 2023*, April 2023.

To mitigate the problems with these other approaches, we looked deeper into the text of each job description and considered the inclusion of one of four core skills as a prerequisite for any job ad to be considered relevant to AI. This check alone represents an improvement over the "regular expression" blanket approach. The four core skills were:

- Artificial Intelligence (AI)
- Machine Learning (ML)
- Natural Language Processing (NLP)
- Computer Vision

We then used the range of AI skills as identified by Babina et al. and their corresponding weights and added them up to construct an AI Intensity score. Each of the four core skills has a weight of 1, and other skills have weights smaller than 1. This results in a score for each job ad. Based on these scores, we construct our final sets in the following way:

- **Broad AI** job ads are for roles that refer to at least two of the core AI skills and none from the non-core ones (they can still have three or four core skills and remain in this category).
- **Tech AI** job ads are for roles that have at least one core and two non-core AI skills.

The unique thing about our classification is that a post with two key core skills will immediately count as an AI job, but if it includes a non-core one, it will move from a Broad AI to a Tech AI post. In this sense, Tech AI roles need two non-core skills plus a core one to make it to the classification, as non-core skills have a weight smaller than 1.

We first focus on the percentage of all job ads in the U.S. market that are for AI jobs. While Tech AI and Broad AI roles each made up a negligible fraction of less than 0.2% of the total market in 2015, the demand for both categories combined has increased to more than 1% of all roles (Figure 24). Until 2020, Tech AI roles and Broad AI roles saw roughly equivalent demand, but in 2020, we first observed the demand for Broad AI roles exceed that for Tech AI, a trend that kept pace until 2022 (Figure 24). In fact, this year was the first since the pandemic in which we saw a year-on-year decline in the percentage of job ads for highly technical AI roles. It is likely that this shift will persist in 2023 due to the macroeconomic situation among tech firms, which may also affect the AI job market despite its strong dynamism.

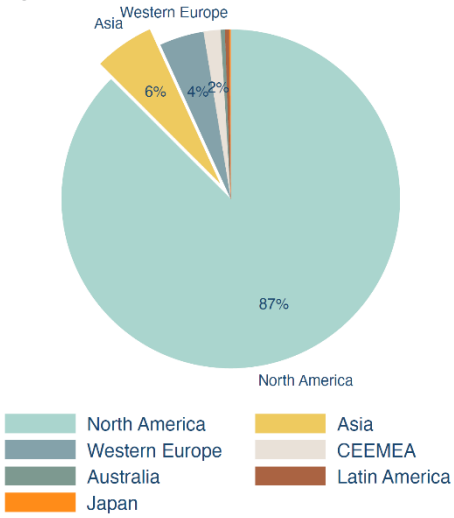
Global Demand

Between 2015 and 2021, the number of AI jobs advertised worldwide by firms grew 9 times for Tech AI jobs and 11.3 times for Broad AI ones. At the same time, the number of IT jobs advertised grew 3.7 times, and the number of total jobs advertised grew 2.7 times.

Although a large number of these jobs (more than two-thirds) are concentrated in more industrialized regions, such as North America and Western Europe, the market for AI skills is growing across all parts of the world.

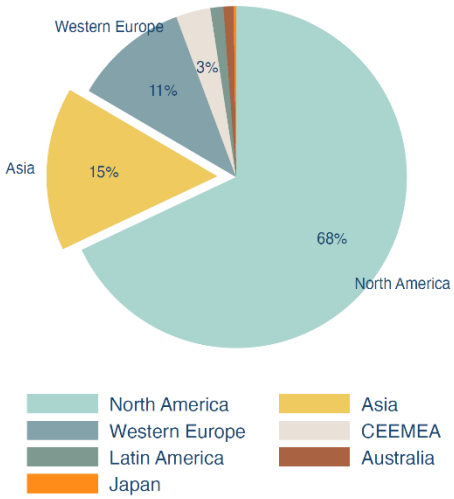
Figure 25 and Figure 26 show the changing composition of AI job postings across regions. Our job posting data covers seven regions, namely Asia; Australia; Central and Eastern Europe, Middle East, and Africa (CEEMA); Japan; Latin America; North America; and Western Europe. In 2015, 87% of these jobs were advertised in the North American market. Seven years later, only 68% of the global job postings were coming from North America.

Figure 25. Regional Demand (2015)



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Figure 26. Regional Demand (2022)



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

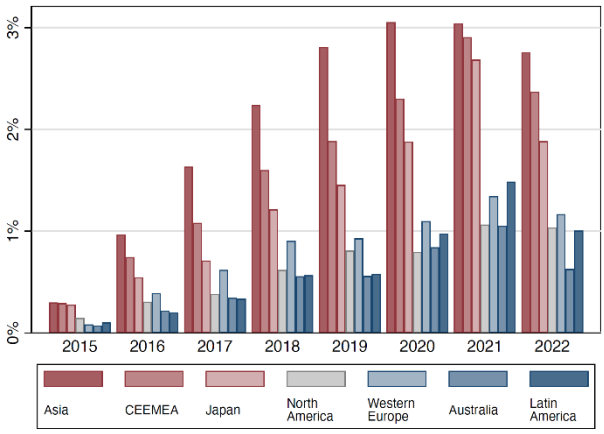
Asia has diverged further from Western Europe to emerge as the second-largest market for AI skills.

Asia (15%) grew much larger than Western Europe (11%) and emerged as the second-largest market for AI skills. Part of the increased share of other regions could also reflect a broader pattern of digital transformation, leading companies to post more jobs online. But the pattern remains the same if we focus on the relative demand growth over the last five years.

Figure 27 shows the AI job postings for each region normalized by the total number of job postings. While North America represents the largest market, the composition of job postings in other regions is skewed towards IT jobs, resulting in much higher percentages for Asia, the CEEMEA region, and Japan. In these markets, AI roles grew from less than 0.3% of the total advertised to more than 2.5%, whereas in North America, Western Europe, and Latin America, these values reached 1% of total jobs in 2022.

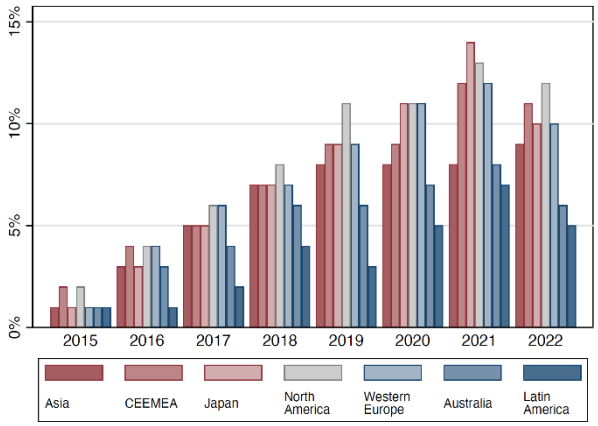
Figure 28 repeats this exercise with the AI job postings for each region normalized by the total number of IT job postings to alleviate the theme-specific skewness. In this setting, most regions grow at a steadier pace, with North America leading in this metric in 2022, closely followed by the CEEMEA region, Japan, and Western Europe. Latin America and Australia trail behind, with almost half their AI jobs in the IT market.

Figure 27. Relative Increase in the Demand for AI Jobs Against All Other Jobs



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Figure 28. Relative Increase in the Demand for AI Against All IT Jobs



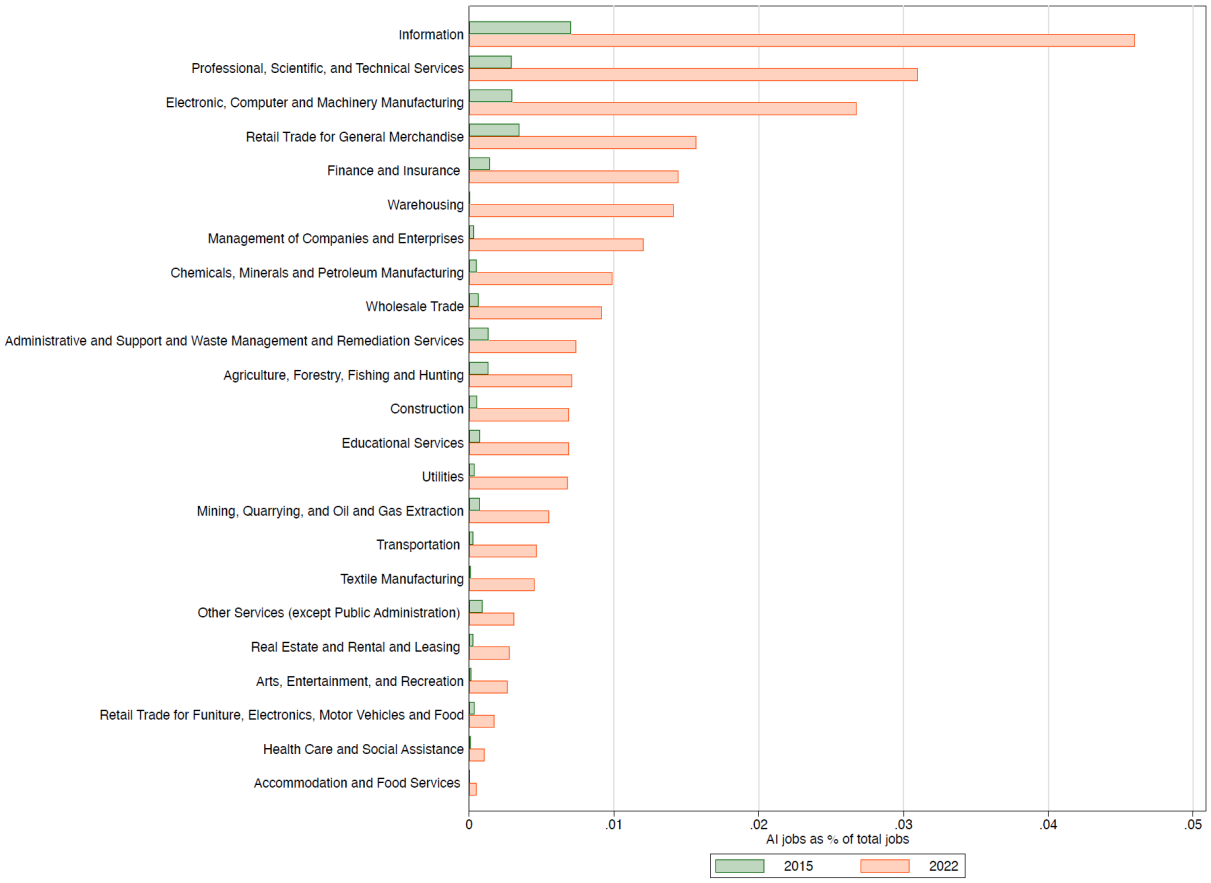
Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Industry-Specific Demand

Across different industries, three sectors accounted for more than 90% of the AI job postings in 2022 (Figure 29). The largest share of AI demand versus all other job types comes from Information (4.6%), followed by Professional, Scientific, and Technical Services (3.2%) and Electronic, Computer, and Machinery Manufacturing (2.7%). Among the remaining sectors, AI roles in Retail Trade account for more than 1.6%.

Figure 29 shows the pattern of demand growth across all sectors between 2015 and 2022. During this period, the average share of AI job postings out of all job postings in the industry grew from 0.11% to 1%, which amounts to a nine-fold increase. The fastest-growing sectors were Manufacturing, with a 39-fold increase; Management of Companies and Enterprises, with a 34-fold increase; and Warehousing, with a 32-fold increase over this period. These striking figures are clearly driven by the scarcity of AI-related jobs in these sectors in 2015, but even when we investigate the same patterns starting in 2017, the changes are spectacular: Manufacturing saw a seven-fold increase in five years, Management saw a five-fold increase, and Warehousing saw a 21-fold increase. These sectors have notably seen the introduction of AI tools in their business processes — for example, Warehousing and Manufacturing are leveraging automation and robotics and computer vision technologies, while Management's increase in AI uptake likely reflects the technology's white-collar applications and our decision to separate Broad AI and Tech AI roles. The group of industries showing the next-largest increases in AI demand include Professional, Scientific, and Technical Services; Finance and Insurance; Health Care and Social Assistance; and Utilities.

Figure 29. Industry-Specific Demand for AI Skills



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Aside from demand growth rates, the nominal values of AI skills matter a lot for the compositional effects of automation technologies in each industry. A prominent sector that lags behind almost all others in AI skill demand is Healthcare and Social Assistance, with less than 0.1% of all jobs in 2022 requiring Tech AI or Broad AI skills. Given AI's potential to improve efficiency in diagnostic tools and patient-support systems, it is striking that the demand for AI talent in healthcare is five times less than the cross-industry average. In a series of reports, Citi has highlighted the significant opportunity for AI in healthcare, and while there are reasons for optimism about the potential for transformation, we also see arguments for a measured view, including: long leads times to make sure drugs or devices are safe and effective, high levels of regulation, conservative providers, the difficultly of changing reimbursement economics, and the importance of human connection.[66]

[66] One report in this series is form Adam Spielman and Wenyan Fei, *Smart Thinking on AI in Healthcare Part 4: Biopharma*, Citi Global Insights, June 23, 2023.

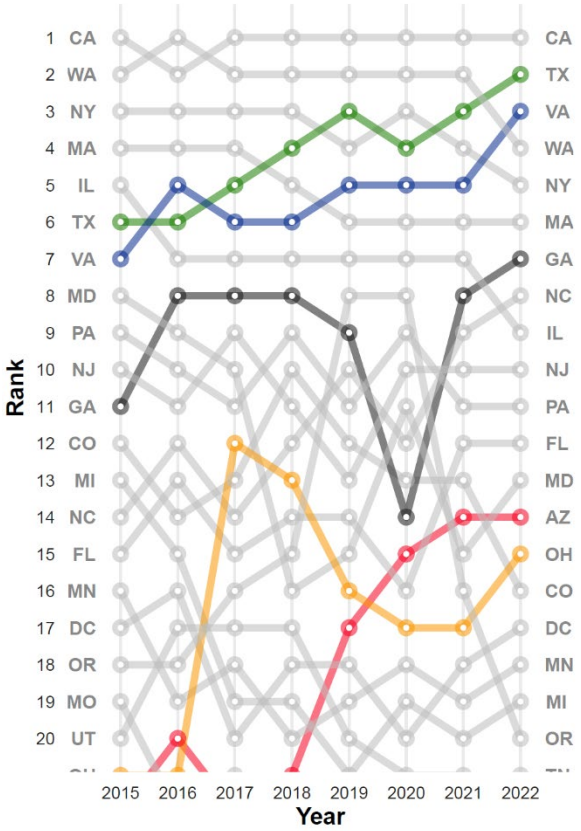
Demand Across Locations

As demand grows across different industries, the geographic market of AI skills could also change. Businesses choose their locations based on agglomeration benefits and the cost of production. As the use of AI applications grows over time, employers might favor different locations for hiring AI talent. Businesses could also relocate based on their cost of doing business or the availability of skilled workers. In this section, we examine the U.S. market closely to understand how the demand for AI skills varies across geographies. In a subsequent section, we take into account the supply side by examining the location of AI professionals.

The concentration of AI job postings across the U.S. in 2022 is clearly skewed toward a handful of states. We first look at Broad AI roles. In this category, California comes in at the top with 16.8% of all postings, consistent with the density of established firms and startups in the region. Texas, with 8.3% of all postings, comes in second, closely followed by Virginia with 8.1% of U.S. demand. Washington comes in fourth with 7% of all job ads for Broad AI professionals, and New York is fifth with 6.9%.

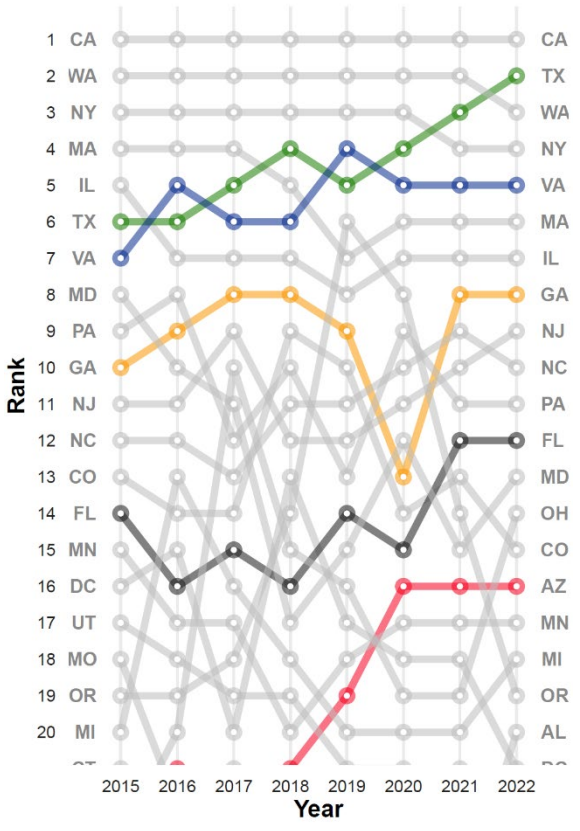
For Tech AI professionals, the demand follows a similar pattern. California comes in first with 18.5% of all ads, Texas second with 8.6%, Washington third with 7.5%, New York fourth with 6.9%, and Virginia fifth with 6.6%. We observe that some regions are more focused on peripheral AI roles (Virginia and Washington), whereas others are more concentrated in tech-heavy ones (California).

Figure 30. States Ranked by Total Job Ads in Broad AI



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Figure 31. States Ranked by Total Job Ads in Tech AI



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Figure 30 shows the full dynamics across U.S. states over the last seven years in Broad AI demand. The vertical axis shows the ranking of each U.S. state based on its shares of Broad AI job postings at the start and end of the period. Out of the top five states in 2015, Illinois, New York, and Massachusetts have declined in the rankings. This could reflect rising real estate costs in these metro areas forcing firms and workers to reconsider their locations. The emerging locations of Broad AI demand are highlighted in color. Texas and Virginia are the most notable among them. These are now the second- and third-largest markets in the demand for Broad AI skills. Georgia, Ohio, and Arizona have also moved ahead in the rankings, gaining three, six, and eight spots respectively.

Figure 31 shows the same rankings by state for Tech AI roles. Texas is also a clear winner in this domain, along with Virginia, Georgia, Florida, and Arizona. California takes the top spot, while demand for Tech AI roles in Washington and New York has not been as high as in the top two states.

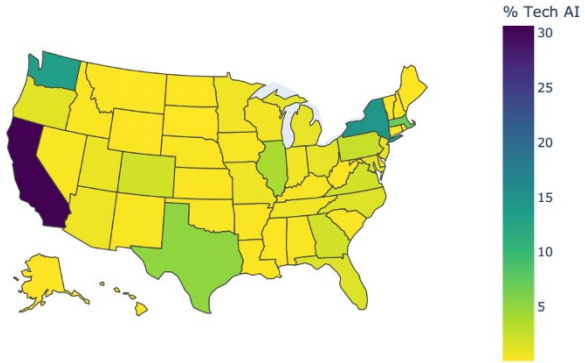
Supply of AI Professionals

We next turn our focus to the supply side of Tech AI and Broad AI skills, assessing the availability of AI professionals in the U.S. to understand how the supply of these skills is distributed across space. A rich dataset extracted from LinkedIn profiles of workers helps us gain insights about their location choices and other characteristics.

Location and Characteristics of AI Professionals

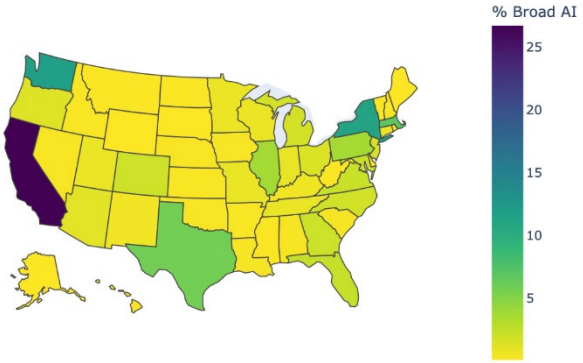
The distribution of AI skills is very heterogeneous across the U.S. Almost one-third of AI professionals are located in California, which contains 30.67% of Tech AI and 26.7% of Broad AI professionals based on 2022 locational information from user profiles. New York is home to 14.55% of Tech AI and 11.14% of Broad AI talent, while Washington hosts 13.4% of Tech AI and 11.61% of Broad AI workers. Texas and Virginia, which rank very highly in demand for these hard-to-find skills, seemingly struggle to attract workers who have them, as these states contain only around 5% and 2%, respectively, of all U.S. AI professionals. This distribution of professionals represents a challenge for firms in states far from California, New York, or Washington, as they will need to leverage remote or other hybrid work arrangements to find adequately skilled personnel (Figure 32 and Figure 33).

Figure 32. Spatial Distribution of Tech AI Professionals



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

Figure 33. Spatial Distribution of Broad AI Professionals



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

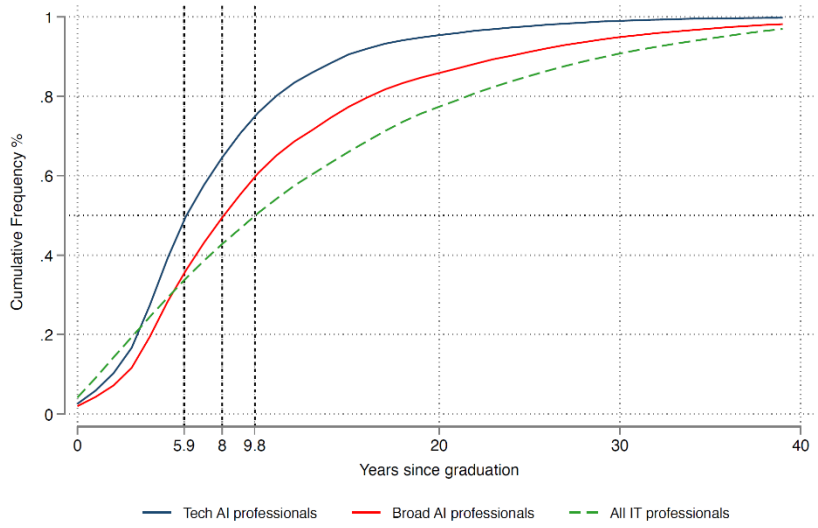
In this section, we also look at the characteristics of AI professionals and specifically calculate the years of experience of Broad AI and Tech AI workers. We evaluate the differences between AI professionals and IT professionals in terms of the distribution of years of experience. Figure 30 shows cumulative percentages of workers in Broad AI, Tech AI, and IT by years of experience, measured by the number of years since their graduation.

The median Tech AI professional has 5.9 years of experience, meaning that 50% of Tech AI professionals have less than six years of experience. For Broad AI professionals, the median is 8 years of experience. The figure for IT professionals is 9.8 — 1.7 times more than Tech AI and 1.2 times more than Broad AI. This shows that the AI-skilled workforce is relatively young. Only 9% of the Tech AI and 22% of the Broad AI workforce has at least fifteen years of experience, whereas 33% of IT professionals have this level of experience. For workers with twenty-plus years of experience, the gap is even larger — only 4% of the Tech AI and 13% of the Broad AI workforce has at least twenty years of experience, while 22% of the IT workforce does.

One implication of having a relatively younger workforce with AI skills is that there are fewer workers available who could assume senior roles requiring these skills, especially the more tech-heavy ones, which often change quickly. As we discuss in the previous section, in recent years, we have seen a surge in demand for AI skills outside IT and other technical roles.

The Tech AI workforce is particularly young, with only half of these professionals having at least six years of experience.

Figure 34. Cumulative Distribution of Years of Experience



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

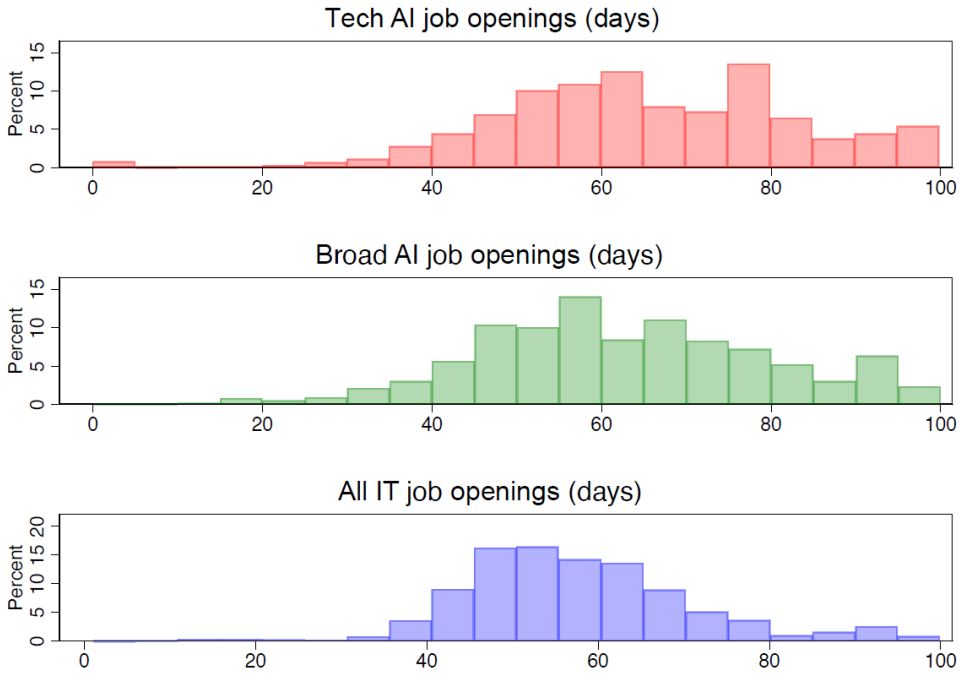
Recruiting Difficulties

In this section, we explore the implications of firms' competing with each other to acquire much-needed AI skills. If rising demand outpaces the supply of AI skills, it will take longer for firms to fill vacancies, or some vacancies will remain unfilled. We check two indicators to understand the nature of AI skill shortages. Our first measure looks into the duration of job advertisements to understand whether it takes especially long to recruit AI professionals. Our second measure examines location-specific delays that can illustrate how acute the skill shortage is across markets.

Tech AI and Broad AI Job Opening Times

We calculate the number of days for which a job is advertised. We refer to this period as "job opening duration." Figure 35 shows the distributions of mean job opening duration for large U.S. cities. The average job opening time is 47 days for all IT job postings, whereas it is around 56 days for Tech AI job postings and 55 days for Broad AI job postings. Although the averages are in the same range, the distributions of Tech AI and Broad AI have a longer right tail, meaning that there are some job postings with longer opening duration than usual. The 90th percentile is 84 days for Tech AI job postings, 83 days for Broad AI, and 74 days for IT job postings.

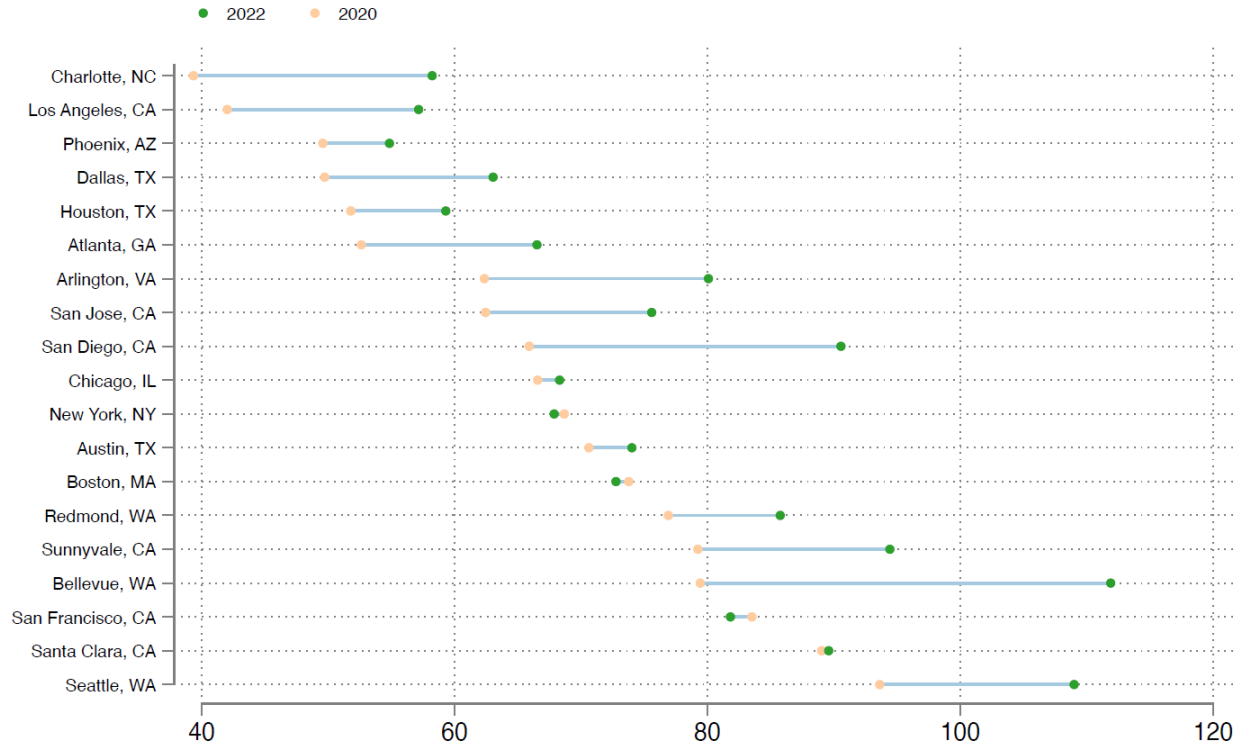
Figure 35. Job Opening Duration



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

We next compare all U.S. markets at the city level to identify the places where it is harder to recruit Tech AI and Broad AI professionals. In Figure 36, we plot the differences in job opening duration between 2020 and 2022 for Broad AI talent across all U.S. cities, with cities ordered by the time taken in 2020. The figure shows that in Seattle and Bellevue, WA, the opening times exceeded 100 days in 2022, making these two of the hardest cities to recruit these professionals. Both cities had very strong increases since 2020 as well. There are six cities with average job opening times of more than 80 days to recruit Broad AI professionals: Santa Clara, San Francisco, Sunnyvale, and San Diego — all in California — along with Redmond in Washington and Arlington in Virginia. In three cases — San Francisco, New York, and Boston — we observe a decline in the days required to recruit these professionals, which might reflect a changing spatial distribution, both in terms of supply (professionals relocating outside large metro areas) and demand (firms moving outside large cities). This is an interesting trend that might be related to the remote and hybrid work arrangements introduced during the pandemic. The rest of the cities all show a higher average than the Broad AI mean of 55 days, with increasing delays over the period 2020-2022.

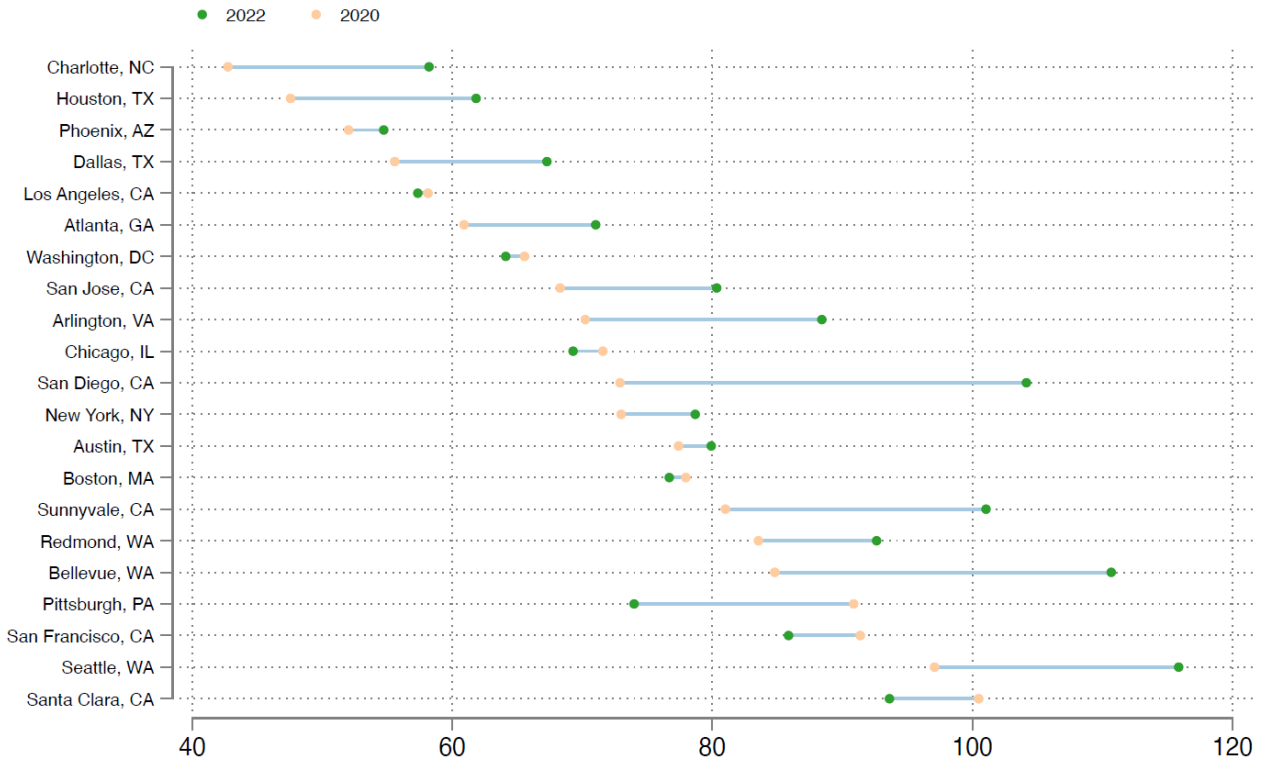
Figure 36. Change in Days to Recruit Broad AI Talent by Area: 2022 vs. 2020



Source: Oxford Martin School, Citi Global Data Insights, LinkUp

We also assess the Tech AI segment of professionals, comparing U.S. markets at the city level to identify the places where it is harder to recruit workers. In Figure 37, we plot the difference in job opening duration between 2020 and 2022 for Tech AI talent across all U.S. cities, with cities ordered by the time taken to fill jobs in 2020. Again, we see that Seattle and Bellevue, WA take the top spots, but this time, they are also joined by two cities in California, Sunnyvale and San Diego, in the over-100-days group. In the over-80-days group, we find Santa Clara, San Francisco, Redmond, Austin, Arlington, and San Jose. All of the states these cities are located in were notably in top spots in the state rankings of demand for Tech AI professionals (Figure 31). In Figure 36, we also see several cities that experienced a decline in opening times: Santa Clara, San Francisco, Pittsburgh, Boston, Chicago, Washington, and Los Angeles. This finding also aligns with the previous findings for Broad AI waiting times in large metro areas. The rest of the cities all show a higher mean than the Tech AI mean of 56 days, with increasing delays over the period 2020-2022.

Figure 37. Change in Days to Recruit Tech AI Talent by Area: 2022 vs. 2020

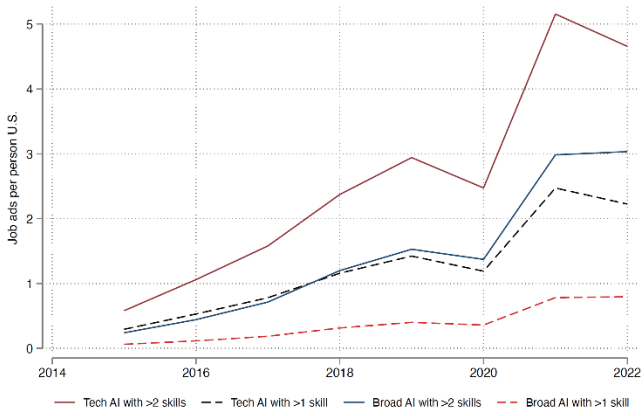


Source: Oxford Martin School, Citi Global Data Insights, LinkUp

Does the Supply Match the Demand?

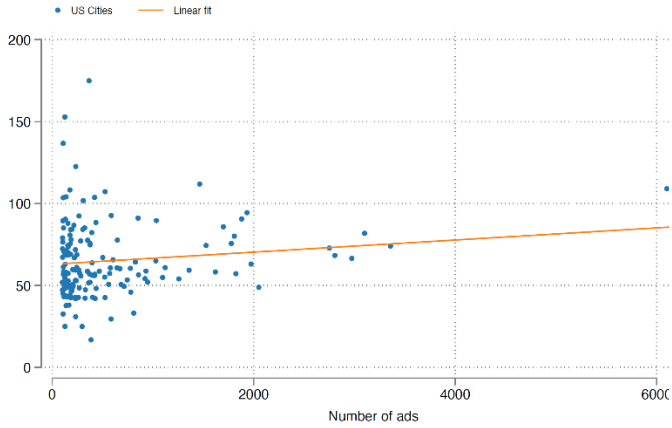
We compare the demand for AI skills over the period from 2015-2022 — as measured by the number of Tech AI and Broad AI job postings — with the supply of AI professionals. The average U.S. state has 4.7 Tech AI job postings per professional and three Broad AI job postings per professional. Figure 38 shows how the ratio of job postings per AI worker varies across the U.S. as a whole. For this chart, we relax the assumptions for the type of skills required for Tech AI and Broad AI professionals by including the "potential" pool of candidates that can be recruited conditional on upskilling or reskilling. In this context, there are still 2.2 job ads per Tech AI professional, which is remarkable given this includes underskilled supply. Broad AI professionals are much easier to recruit in this setting, with 0.8 job ads per professional.

Figure 38. Supply of AI Professionals to Demand for AI Skills (U.S.)



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

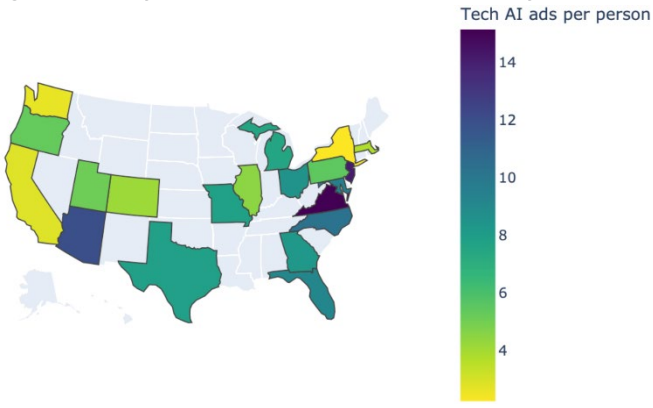
Figure 39. Days to Recruit AI Talent vs. U.S. Cities by Market Size



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

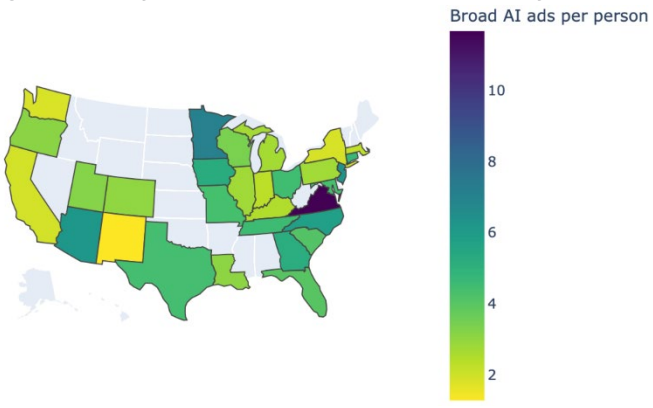
In Figure 40 and Figure 41, the states shown in blue or dark blue report the highest numbers of job postings per Tech AI or Broad AI professional. Among these locations, Virginia, Arizona, and New Jersey stand out, as there are few Tech AI and Broad AI professionals residing there. In Virginia, there are 15 job ads per person for tech-heavy roles and 11.7 per person for Broad AI roles in 2022; in Arizona these figures are 12 for Tech AI and 6.1 for Broad AI, and in New Jersey they are 14.1 and 6.3, respectively. The time taken to fill a position in these states is also high, standing at 64 days in Arizona and New Jersey and 62 days in Virginia, which is 13%-16% higher than the mean days to recruit Broad AI and Tech AI professionals in the U.S. In Figure 39, we plotted the number of days taken to recruit AI professionals across all the cities reported in the job ad data. We did not observe any significant correlation between the number of ads in a given city and average days to recruit, apart from a weak positive association in some larger markets like California and Washington.

Figure 40. Supply of Tech AI Professionals vs. Demand, by U.S. State



Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

Figure 41. Supply of Broad AI Professionals vs. Demand, by U.S. State



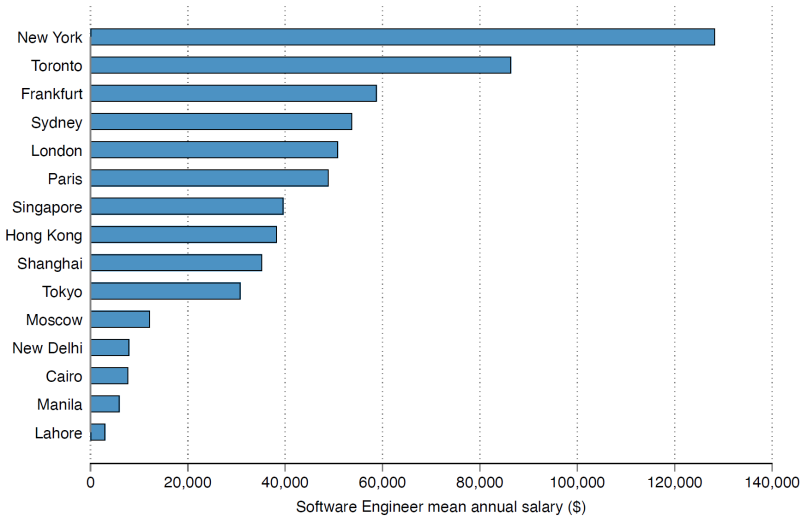
Source: Oxford Martin School, Citi Global Data Insights, Revelio Labs

The largest markets exhibit the least scarcity of AI talent, e.g., California has 2.8 job ads for each professional in Tech AI roles and 1.9 ads per person in Broad AI. The time to recruit AI professionals in California is among the longest in the country at 84 days, second behind Washington with 105 days. In Texas, whose ranking in the top AI destinations has risen significantly in recent years, the job ads per professional in Tech AI and Broad AI have increased to 7.8 and 4.4, respectively, with 66 days to recruit these professionals.

In New York, there are many more AI professionals to recruit, with 2.2 Tech AI ads and 1.9 Broad AI ads per professional and 70-day waiting times. One possible explanation for the range in numbers is that many AI professionals might not report their skills in detail on their online profiles, which would naturally change some of our findings significantly. For more mature markets (e.g., California, Texas, and New York), we do not expect underreporting of skills to be the case, so our rough estimates of the scarcity of AI talent, which are based on weighted averages across states, would possibly drop, but not significantly. This also supports our choice to provide more lenient estimates for the job ads per person with fewer skill requirements in Figure 38.

Given the difficulties of recruiting local AI talent in certain states, we also consider the potential for wage arbitrage through remote or hybrid work. To take a broader look at the tech industry as a whole, we collected city data to compare the mean annual salaries of software engineers across the world (Figure 42). In New York, salaries are 10-40 times higher than in regions like Pakistan, the Philippines, Egypt, India, and Russia. They are also more than 2-4 times higher than in most European countries, Australia, Japan, Singapore, Hong Kong, China, and the UK. These differences suggest that remote and hybrid work might represent an attractive way for firms to navigate the AI talent scarcity, as they present opportunities for wage arbitrage.

Figure 42. Mean Annual Salary of Software Engineers by City Around the World



Source: Oxford Martin School

In this chapter, we reviewed two indicators — Tech-AI and Broad-AI — to assess the impact of rising demand for AI skills. We found that in the U.S., the recruiting time for AI jobs, as reflected in job opening duration, is 10% higher than for IT jobs overall. Rising markets in Asia might explain the even higher difficulty of recruiting AI professionals.

Across the U.S. market, we do not find any systematic pattern to suggest that larger markets face more difficulties in hiring workers with the necessary skills (Figure 39). Our second indicator, the demand-supply ratio, shows that some growing markets (e.g., Virginia and Arizona) have acute skill shortages, while other large markets (e.g., Texas, California, and New York) have smaller but still meaningful skill shortages. In general, businesses demand more AI skills than can be filled by the current pool of workers across the U.S.

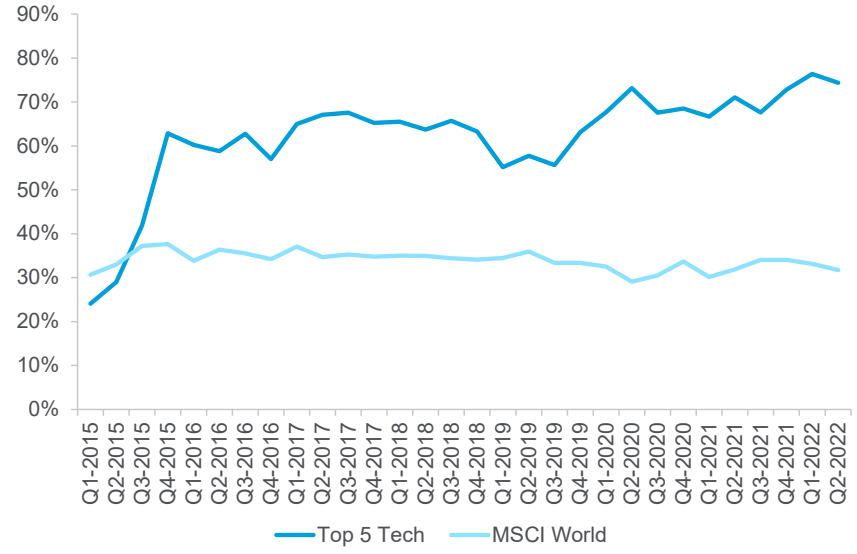
Cognitive Skills: Implications for Corporates and Investors

So far in this report, we have examined the relationship between skills demand and wage premiums and how they differ in certain sectors while being similar in some other clusters underpinned by certain trends. Soft skills such as collaborative leadership have been on the rise and dominated in job ads where on average 6 out of 10 request it, seen as (almost) must-have skills. At the same time, we show that cognitive skills have a profound effect on innovations as proxied by patents filings for the seven skills groups studied.

Taking it one level down from overall skill groups, we want to explore what tangible benefits these cognitive skills bring for companies and whether they are useful indicators for investors consider. In order to understand their effects on company performance, we analyze the improvements through the lens of innovation and stock returns.

Firstly, we select five world-leading tech firms and aggregate their job ads that fall into the seven cognitive skills categories — big data, cloud computing, analytical, research, programming, machine learning, and math — then calculate the proportion of these jobs versus the total over time. As a benchmark, we repeat the same calculation for the constituents within MSCI World index. As can be seen in Figure 43, the share of cognitive skill hires relative to the total has consistently hovered around the 30%-35% range. In contrast, the top five tech companies we selected had a significant jump in their hires with cognitive skills including data, research, and analytical skills, reaching 60% within two quarters in 2015 amidst the start of big data and AI booms. Since the pandemic, the share of these skill groups has gone up to mid-70%, as the outbreak and subsequent lockdowns accelerated the shift to digital technology and boosted the need for a workforce with such skill sets.

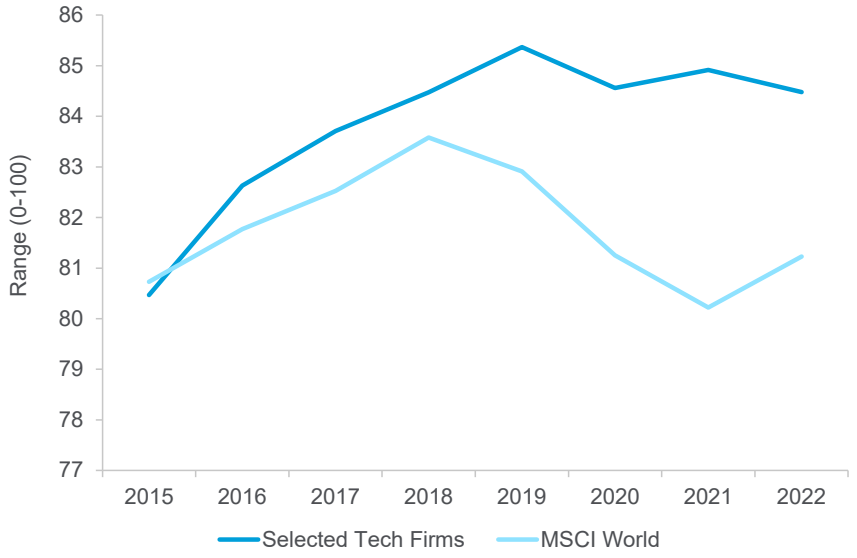
Figure 43. Cognitive Skills Hires vs. Total Hires (%)



Source: LinkUp, Citi Global Data Insights

How does the higher proportion of cognitive skill hires reflect in the rate of innovation? As shown in the earlier sections, patents can be seen as a good proxy for how much a company focuses on R&D and innovation through not only the volume of the filing but also the quality. We use Quant IP's multi-dimensional patent quality score that combines Grant, Market, and Citation Scores, providing a general assessment of patent quality.[67]

Figure 44. Patents Quality (Median)



Source: QuantIP, LinkUp, Citi Global Data Insights

It is evident from the chart above that patents filed by the five world-leading tech companies have significantly higher quality than companies in the MSCI World universe and are also more consistent in maintaining quality.[68]

Did Companies With More Cognitive Skill Hires Generate Higher Returns?

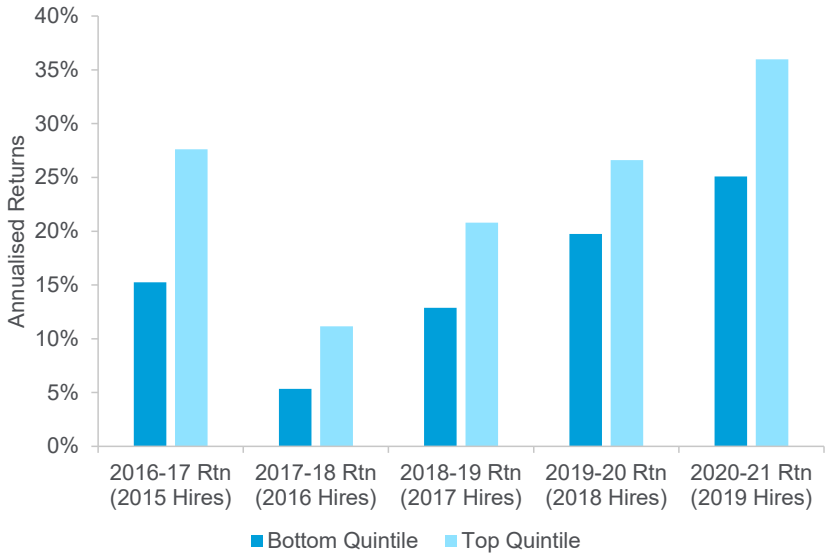
The above analysis shows that the top five tech companies in the world have higher proportions of hires with cognitive skills than average and these firms tend to have a higher rate of innovation as proxied by patents. Looking at company performance from a more traditional angle, would companies seeking these skills also attract better stock returns?

To answer this question, we conduct a simple analysis where we rank companies in the MSCI USA Index universe by the proportion of cognitive skills hires and divide them into quintiles where top quintile consists of companies with the highest share of such hires and vice versa. Intuitively, it would take some time for talents hired to make noticeable impact to companies' bottom line as they integrate, contribute, and innovate over time. Consequently, we use a lead-lag window of a 1-year minimum to account for such a gap, i.e., we rank companies based on the hires who join in

[67] See Quant IP's website. A high Citation Score signifies increased citation likelihood by other companies; a high Market Score indicates a greater predicted market coverage 5 years after filing; and a high Grant Score represents a higher probability of patent grant.
[68] As measured in the standard deviation of the patent scores.

year *t*, divide into quintiles, and then calculate the quintile annual return from year *t+1* to year *t+2*.

Figure 45. Quintile Returns: Top and Bottom Quintiles



Source: LinkUp, Citi Global Data Insights

As shown in Figure 45, the top quintile baskets formed from 2015 to 2019 consistently outperform the bottom quintiles every year in the following 12-month period after the formation of the quintiles based on hiring activities. This analysis suggests that, at least historically, companies that most seek these cognitive skills in their hiring tend to outperform those that place less emphasis on such skills.

In summary, the seven cognitive skill groups — consisting of data science-related skills, as well as research, analytics, and math — are the key to companies' quest for innovations as well as improved financial performance. These findings provide insights for corporates to consider in their own hiring activities versus peers, and for investors to take into account the importance of cognitive skills for their potential investee companies, as historically the divergence in stock returns of the most versus the least is stark.

Conclusion and Policy Recommendations

The insights from this report are useful in a number of contexts. In the face of rapidly changing labor markets due to the Fourth Industrial Revolution, understanding the demand and reward for skills is crucial for firms. Hiring has evolved from very specific education and experience criteria towards detailed skills requirements.[69] Job titles are also changing with automation increasingly substituting for humans in occupations. Examples are bricklayers who can be replaced by bricklaying robots, concierges that can be replaced by robotic butlers or customer service agents by chatbots, and accountants by accounting software.[70] In contrast, machines also have the potential to be powerful complements to humans in the workplace. Examples include managers who use video conferencing tools to work globally, doctors who use Clinical Decision Support Software to make better decisions, statisticians who can use machine learning and AI to analyze ever larger data sets, and teachers who have access to online teaching tools. At the same time, new occupations are coming on stream that require different skills sets as compared to those jobs that are being destroyed. Examples here are blockchain engineers or information security engineers that have been classified as new and emerging occupations by O*NET in the U.S.[71] In the future, we can expect additional jobs to be created that are beyond our imagination today.

In this report, we quantified the changing demand and "price" of nine skills groups. These are two soft skills (collaborative leadership, and interpersonal and organized) and seven cognitive skills (big data, cloud computing, programming, machine learning, research, math, and analytical). In our work "importance" was defined based on the frequency of times an employer states they want a particular skill in a job advert. We focused on professional occupations only.

Overall, we found that collaborative leadership increased in importance over time in terms of demand and hourly wages. This shift can be explained with the lower automatability of occupations that require such skills. It can also be explained by the fact that in professional workplaces, collaboration has increased in importance, requiring leaders to master this important soft skill. Collaborative leadership also fosters individual and company performance both directly and indirectly through fostering inclusion. That is, a leader that has collaborative leadership skills such as negotiation skills or creativity also closely resembles an inclusive leader that determines the quality of collaboration by fostering these skills in others and creating an inclusive environment where individuals feel safe to speak up about new ideas. In this report, we highlight that collaborative leadership soft skills can be taught if the program (i.e., coaching or a course) is carefully designed with a focus on evidence-based design.

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[69] Joseph Fuller et al., *The Emerging Degree Reset*, Burning Glass Institute, February 2022.

[70] Grace Lordan, "People Versus Machines in the UK: Minimum Wages, Labor Reallocation, and Automatable Jobs," *PLoS ONE*, Vol. 14, No. 12, 2019; Alana Semuels, "Millions of Americans Have Lost Jobs in the Pandemic — And Robots and AI Are Replacing Them Faster Than Ever, *Time*, August 6, 2020; Daron Acemoglu and Pascual Restrepo, "Automation and New Tasks: How Technology Displaces and Reinstates Labor," *Journal of Economic Perspectives*, Vol. 33, No. 2, Spring 2019.

[71] O*NET OnLine, "Browse Bright Outlook Occupations," accessed May 4, 2024.

Our findings also demonstrate that data science is constantly evolving, causing certain data science skills to attract a wage premium in one period, then lose it in the next. Technology is constantly evolving and hence demanding an evolving skill set. This underlines the importance of continuous learning for professional data scientists. Concretely, this report finds that "big data" shifts from having positive returns in the 2014-15 time frame to having negative returns in the later 2018-1Q 2020 time frame, while more recent technologies, such as machine learning, gained a wage premium in 2018-1Q 2020. Because the field of data science is constantly evolving, individuals with the right skills are in short supply and as a result enjoy high wage premiums. Upskilling becomes particularly crucial in the data science world.

We further find a complementarity between soft skills and cognitive skills; concretely between collaborative leadership and research skills. This finding is in line with past research that focused on the interaction of social skills and cognitive skills and the fact that non-linear thinking becomes key for the future of work.[72] Professionals in particular require soft skills but also need to understand the implications of numerical calculations.[73]

In the report we also take a deep dive into the demand and supply of AI skills over the period 2015-22. To achieve this, we use global job ad data along with skills of the existing workforce. We first at the demand for AI-jobs and break the AI job ad data into two groups: Tech-AI jobs, relating to technological skills necessary to "run, train and test" AI models and Broad-AI jobs, requiring an understanding of AI technologies but not the "hard" tech-skills found in Tech-AI jobs. Since 2015 we observe a five-fold increase in the demand for these groups as a percent of all U.S. jobs. Globally, AI jobs grew 9 times for Tech-AI jobs and 11.3 times for Broad-AI ones, while IT sector jobs rose 3.7 times and the number of total jobs advertised grew 2.7 times. Asia stands out as the region with the highest growth over this period, surpassing Northern Europe.

The rising demand for AI skills has several asymmetric repercussions. The industries most affected by these skills have experienced spectacular increases in the demand for AI talent since 2017: Manufacturing had a 7-fold increase in 5 years, Management a 5-fold increase, and Warehousing a 21-fold increase. On the other end, it is striking that Healthcare AI-talent recruitment is 5-times smaller than the cross-industry average, posing a huge investment opportunity. During this period new tech-hubs have been formed in the U.S. with Texas and Virginia rising to the top spots for AI demand surpassing New York and Washington.

The supply of these hard-to-find professionals is also skewed across the U.S. with California hosting almost a third of the country's total. Candidates with next to no experience being hired for senior roles —more than half of the Tech-AI professionals have less than 6 years of experience compared to an average of 10 years for all IT jobs — due to high demand for their skills. Recruiting AI professionals is harder than IT ones (47 days for IT, 56 days for Tech-AI jobs, and 55 days for Broad-AI) but the real struggle is for the top AI talent (90th percentile) which takes almost 3 months for both Tech-AI and Broad-AI roles. With some states having more than 10 job ads per AI professional, wage implications are also important, making the quest for talent a global endeavor that builds on remote and hybrid arrangements. Casting a wide net for AI professionals increases the pool of

[72] Cecily Josten and Grace Lordan, "Automation and the Changing Nature of Work," *PLoS ONE*, Vol. 17, No. 5, 2022.
[73] McKinsey Global Institute, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, December 2017.

candidates and significantly reduces cost making it a viable and often necessary option.

Our findings are useful for several reasons. They provide information to firms on the skills that are valuable in today's labor market such as collaborative leadership, both on its own in or in combination with broad cognitive research skills, and up-to-date data science skills. This is useful in terms of planning, training, and upskilling corporate workers for their daily tasks, but it is equally useful for attracting and retaining talent. In the advent of the Fourth Industrial Revolution, addressing talent needs has come to the top of the agenda of many companies. Corporates are increasingly focusing on skills-based hiring, which can help them close prevalent skills gaps and labor shortages, and also retain talent.[74]

With a larger focus on skills-based hiring, which reduces the focus on degrees, companies might hire more diversely and inclusively by broadening their talent pool to skilled non-degree holders. Companies can invest in task-based assessments that focus on the skills they need and those that have been highlighted as relevant in this report. Knowing which specific skills to hire and to invest in is hence key as demonstrated in this report.

Further, companies can invest in upskilling their workforce. In the Citi GPS report *Education: Learning for Life*, we emphasized that employee aspirations for reskilling and upskilling opportunities, combined with the ongoing skills gap, mean lifelong learning is an imperative for most organizations. Employers who fail to provide the necessary learning and development opportunities are likely to face a variety of financial repercussions. In this report, we also demonstrate the impact on innovation and ultimately the financial performance through the lens of investors.

This report highlights that upskilling is particularly crucial in the field of data science as it rapidly evolves. Examples for upskilling in data science are data coding bootcamps or short courses in data science. Such upskilling tools have been on the rise, which shows that "lifelong learning" is already at the top of the agenda for many companies and individuals. Upskilling also helps tackle skills shortages.[75] From this report, employers also learn that labor shortages are not necessarily about a shortage in workers but about a shortage in job-relevant skills. That is, while employees who are skilled in legacy data science skills might lack job-relevant skills, they may still be able to upgrade their skill set to job-relevant skills that are paid well. Our work provides information to firms on the volatility of prices for specific skills.

Finally, our work also provides a new lens through which investors can view firms. That is, they can analyze the skills being demanded by a company they are contemplating investing in and determine if this company is seeking the skills that are most relevant in today's economy for a specific occupation as a pulse point for their innovation and future readiness. We demonstrate the impact of such activities could have on the financial performance of companies including share price performance.

[74] Joseph Fuller et al., *The Emerging Degree Reset*, Burning Glass Institute, February 2022.

[75] David Deming and Kadeem Noray, "Earnings Dynamics, Changing Job Skills, and STEM Careers," *The Quarterly Journal of Economics*, Vol. 135, No. 4, November 2020.

Appendix

Figure 46. Share of Job Adverts from the Energy Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

ENERGY		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	42.04%	27.50%	0.14%	6.80%	N/M	0.22%	12.81%	1.09%	37.19%
	#	581	380	2	94	N/M	3	177	15	514
2018-1Q 2020	%	61.07%	30.85%	2.49%	13.03%	0.19%	4.88%	18.94%	0.21%	35.83%
	#	5,661	4,053	142	1,110	20	300	1,684	73	3,819

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 47. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Energy Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.36%	-0.14%	$0.16	-$0.07
Interpersonal and Organized	-0.10%	-0.05%	-$0.05	-$0.02
Big Data	0.40%	-0.94%	$0.18	-$0.45
Cloud Computing	-1.89%	0.80%	-$0.86	$0.39
Programming	0.15%	0.08%	$0.07	$0.04
Machine Learning	N/M	0.00%	N/M	$0.00
Research	-0.26%	0.22%	-$0.12	$0.11
Math	-0.86%	0.46%	-$0.39	$0.22
Analytical	-0.05%	0.28%	-$0.02	$0.14

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 48. Share of Job Adverts in the Materials Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

MATERIALS		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	61.63%	28.27%	0.15%	3.74%	N/M	0.22%	20.34%	0.37%	36.35%
	#	824	378	2	50	N/M	3	272	5	486
2018-1Q 2020	%	65.17%	34.21%	0.28%	5.19%	0.03%	1.49%	19.56%	0.47%	43.93%
	#	5,603	2,941	24	446	3	128	1,682	40	3,777

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 49. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Materials Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.08%	0.05%	$0.03	$0.02
Interpersonal and Organized	-0.05%	0.03%	-$0.02	$0.01
Big Data	1.75%	0.30%	$0.76	$0.14
Cloud Computing	-1.01%	0.19%	-$0.44	$0.09
Programming	-0.06%	0.30%	-$0.03	$0.14
Machine Learning	N/M	-2.23%	N/M	-$1.02
Research	0.05%	-0.13%	$0.02	-$0.06
Math	-0.64%	1.02%	-$0.28	$0.47
Analytical	-0.04%	-0.04%	-$0.02	-$0.02

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 50. Share of Job Adverts in the Industrials Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

INDUSTRIALS		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	43.08%	18.80%	0.85%	10.27%	N/M	0.99%	13.97%	0.27%	28.92%
	#	10,436	4,554	205	2,488	N/M	241	3,383	65	7,006
2018-1Q 2020	%	56.37%	26.55%	1.21%	10.56%	0.10%	2.80%	16.48%	0.24%	32.99%
	#	56,818	26,765	1,216	10,647	97	2,827	16,608	243	33,252

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 51. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Industrials Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.14%	26.00%	$0.07	$0.13
Interpersonal and Organized	0.07%	-0.07%	$0.03	-$0.03
Big Data	1.70%	1.06%	$0.80	$0.51
Cloud Computing	0.21%	-0.06%	$0.10	-$0.03
Programming	0.28%	0.06%	$0.13	$0.03
Machine Learning	N/M	-2.90%	N/M	-$1.40
Research	0.06%	-0.27%	$0.03	-$0.13
Math	-0.14%	-0.50%	-$0.07	-$0.24
Analytical	-0.22%	-0.21%	-$0.10	-$0.10

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 52. Share of Job Adverts in the Consumer Discretionary Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

CONSUMER DISCRETIONARY		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	58.79%	32.71%	2.77%	25.74%	N/M	5.88%	20.16%	0.11%	40.75%
	#	7,620	4,240	359	3,336	N/M	762	2,613	14	5,282
2018-1Q 2020	%	65.34%	25.93%	2.36%	11.69%	0.15%	11.38%	17.66%	0.17%	30.21%
	#	32,303	12,821	1,168	5,777	72	5,624	8,729	83	14,935

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 53. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Consumer Discretionary Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.00%	0.25%	$0.00	$0.13
Interpersonal and Organized	-0.37%	-0.41%	-$0.17	-$0.21
Big Data	2.17%	-0.27%	$1.02	-$0.14
Cloud Computing	1.03%	0.46%	$0.48	$0.24
Programming	-0.40%	-1.32%	-$0.19	$0.69
Machine Learning	N/M	-0.86%	N/M	-$0.45
Research	-0.09%	-0.07%	-$0.04	-$0.04
Math	1.35%	0.06%	$0.63	$0.03
Analytical	-0.08%	0.43%	-$0.04	$0.22

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 54. Share of Job Adverts in the Consumer Staples Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020

CONSUMER STAPLES		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	65.12%	24.42%	2.01%	7.56%	N/M	1.09%	19.34%	0.17%	43.56%
	#	1,973	740	61	229	N/M	33	586	5	1,320
2018-1Q 2020	%	62.11%	21.69%	2.90%	8.08%	0.20%	2.05%	17.71%	0.07%	39.63%
	#	13,529	4,724	631	1,761	43	446	3,857	15	8,632

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 55. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Consumer - Staples Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	-0.10%	-0.17%	-$0.05	-$0.09
Interpersonal and Organized	-0.06%	0.00%	-$0.03	$0.00
Big Data	1.87%	1.94%	$0.86	$0.98
Cloud Computing	-0.49%	-0.67%	-$0.23	-$0.34
Programming	-0.06%	0.68%	-$0.03	$0.35
Machine Learning	N/M	-1.00%	N/M	-$0.50
Research	-0.30%	-0.23%	-$0.14	-$0.12
Math	1.23%	-0.76%	$0.57	-$0.38
Analytical	0.14%	0.15%	$0.06	$0.08

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 56. Share of Job Adverts in the Healthcare Sector Requesting Each of the Nine Skills Groups (2014-15 vs 2018-1Q 2020

HEALTHCARE		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	37.14%	21.61%	0.18%	3.39%	N/M	0.14%	14.49%	0.10%	18.67%
	#	12,614	7,338	62	1,150	N/M	46	4,920	34	6,339
2018-1Q 2020	%	53.17%	26.59%	0.83%	5.35%	0.06%	1.24%	18.98%	0.12%	28.92%
	#	77,428	38,724	1,208	7,795	85	1,808	27,632	172	42,120

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 57. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Healthcare Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.05%	0.40%	$0.02	$0.17
Interpersonal and Organized	-0.17%	-0.54%	-$0.06	-$0.23
Big Data	-1.69%	-0.35%	-$0.62	-$0.15
Cloud Computing	-0.03%	-0.39%	-$0.01	-$0.17
Programming	0.15%	0.53%	$0.05	$0.23
Machine Learning	N/M	0.49%	N/M	$0.21
Research	0.07%	0.01%	$0.03	$0.00
Math	0.43%	0.83%	$0.16	$0.36
Analytical	-0.05%	-0.14%	-$0.02	-$0.06

Note: Statistically significant values highlighted in yellow

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 58. Share of Job Adverts in the Financials Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

FINANCIALS		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	57.44%	34.44%	1.31%	14.82%	N/M	0.65%	20.25%	0.28%	49.86%
	#	13,953	8,367	319	3,599	N/M	158	4,918	67	12,111
2018-1Q 2020	%	68.67%	47.68%	3.75%	17.47%	0.17%	4.27%	22.10%	0.19%	51.83%
	#	79,709	55,340	4,358	20,273	198	4,960	25,650	223	60,163

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 59. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Financials Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.05%	-0.28%	$0.02	-$0.15
Interpersonal and Organized	-0.17%	-0.04%	-$0.08	-$0.02
Big Data	-1.69%	-1.10%	-$0.84	-$0.58
Cloud Computing	-0.03%	1.27%	-$0.01	$0.67
Programming	0.15%	0.39%	$0.07	$0.21
Machine Learning	N/M	0.04%	N/M	$0.02
Research	0.07%	1.13%	$0.03	$0.59
Math	0.43%	2.95%	$0.21	$1.56
Analytical	-0.05%	0.18%	-$0.02	$0.09

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 60. Share of Job Adverts in the Information Technology Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

INFORMATION TECHNOLOGY		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	57.04%	21.05%	3.12%	22.68%	N/M	3.75%	12.72%	0.13%	24.01%
	#	16,708	6,165	915	6,645	N/M	1,099	3,726	38	7,034
2018-1Q 2020	%	61.91%	24.85%	4.13%	22.20%	0.45%	10.07%	16.48%	0.24%	28.47%
	#	64,906	26,049	4,332	23,273	474	10,556	17,274	255	29,844

Source: LinkUp, London School of Economics, Citi Global Data Insights

Figure 61. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Technology Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.09%	0.11%	$0.04	$0.06
Interpersonal and Organized	0.18%	-0.24%	$0.09	-$0.13
Big Data	1.20%	4.10%	$0.59	$2.18
Cloud Computing	0.67%	-1.31%	$0.33	-$0.70
Programming	-0.77%	-0.58%	-$0.38	-$0.31
Machine Learning	N/M	0.72%	N/M	$0.38
Research	-0.14%	-0.04%	-$0.07	-$0.02
Math	-3.30%	0.23%	-$1.68	$0.12
Analytical	-0.20%	-0.58%	-$0.10	-$0.31

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 62. Share of Job Adverts in the Communications Services Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

COMMUNICATION SERVICES		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	56.74%	23.47%	3.92%	17.23%	N/M	1.72%	20.08%	0.14%	33.42%
	#	5,751	2,379	397	1,746	N/M	174	2,035	14	3,387
2018-1Q 2020	%	69.07%	28.41%	4.89%	18.41%	0.36%	7.15%	23.85%	0.24%	37.68%
	#	29,654	12,198	2,098	7,903	156	3,071	10,239	101	16,175

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 63. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Communication Services Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.14%	-0.24%	$0.07	-$0.13
Interpersonal and Organized	-0.24%	0.27%	-$0.11	$0.14
Big Data	1.20%	-0.40%	$0.56	-$0.21
Cloud Computing	-0.11%	-1.05%	-$0.05	-$0.56
Programming	-0.27%	-0.10%	-$0.13	-$0.05
Machine Learning	N/M	1.54%	N/M	$0.81
Research	-0.41%	0.40%	-$0.19	$0.21
Math	2.09%	2.33%	$0.98	$1.23
Analytical	0.00%	0.00%	$0.00	$0.00

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 64. Share of Job Adverts in the Utilities Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

UTILITIES		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	51.66%	30.46%	0.15%	4.83%	N/M	0.20%	22.56%	0.60%	45.72%
	#	1,026	605	3	96	N/M	4	448	12	908
2018-1Q 2020	%	61.76%	34.41%	0.59%	7.33%	0.04%	1.44%	21.00%	0.79%	46.33%
	#	5,676	3,162	54	674	4	132	1,930	73	4,258

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 65. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Utilities Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	-0.02%	-0.15%	-$0.01	-$0.07
Interpersonal and Organized	-0.05%	0.03%	-$0.02	$0.01
Big Data	0.76%	0.57%	$0.33	$0.26
Cloud Computing	-1.05%	-0.33%	-$0.45	-$0.15
Programming	0.13%	0.24%	$0.06	$0.11
Machine Learning	N/M	0.23%	N/M	$0.11
Research	-0.06%	0.09%	-$0.03	$0.04
Math	0.64%	-0.06%	$0.28	-$0.03
Analytical	0.20%	-0.04%	$0.09	-$0.02

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 66. Share of Job Adverts in the Real Estate Sector Requesting Each of the Nine Skills Groups (2014-15 vs. 2018-1Q 2020)

REAL ESTATE		Collaborative Leadership	Interpersonal and Organized	Big Data	Programming	Machine Learning	Cloud Computing	Research	Math	Analytical
2014-15	%	53.09%	43.25%	N/M	3.42%	N/M	0.23%	16.93%	0.92%	50.34%
	#	232	189	N/M	15	N/M	1	74	4	220
2018-1Q 2020	%	62.89%	49.51%	0.34%	3.77%	0.07%	1.37%	15.97%	0.22%	55.84%
	#	2,800	2,204	15	168	3	61	711	10	2,486

Source: LinkUp, London School of Economics, Citi Global Data Insight

Figure 67. Occupational Level Wage Response of a 10-Percentage Point Increase in Demand for Each of the Nine Skills Groups, Real Estate Sector

	10pp Effect on Wages (% Chg)		10pp Effect on Wages/Hour ($)	
	2014-15	2018-1Q 2020	2014-15	2018-1Q 2020
Collaborative Leadership	0.12%	0.50%	$0.05	$0.23
Interpersonal and Organized	0.23%	-0.18%	$0.10	-$0.08
Big Data	N/A	-0.10%	N/M	-$0.05
Cloud Computing	-0.63%	-0.83%	-$0.27	-$0.37
Programming	0.35%	-0.62%	$0.15	-$0.28
Machine Learning	N/M	2.14%	N/A	$0.97
Research	-0.24%	-0.05%	-$0.10	-$0.02
Math	1.17%	-0.14%	$0.51	-$0.06
Analytical	-0.16%	0.22%	-$0.07	$0.10

Note: Statistically significant values highlighted in yellow.

Source: LinkUp, London School of Economics, Citi Global Data Insight

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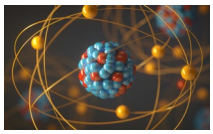

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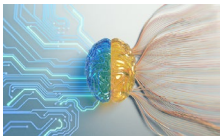

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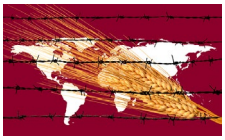

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IMPORTANT DISCLOSURES

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Key Insights Regarding the Future of Skills That Pay

HUMAN CAPITAL

Global labor markets are currently in transition, with rising automation and technological innovation increasingly leading to the replacement of humans in the workplace by machines. / In contrast to routine tasks that require manual and low-skill levels, occupations with tasks that require cognitive and soft skills have been highlighted as increasingly relevant for the future of work.

LABOR MARKET

Labor markets are becoming more fluid and careers less linear. While pre-defined hiring criteria still exist, we also see that degree and other clear-cut requirements are being dropped as the labor supply tightens in specific industries. / Collaborative leadership fosters inclusive environments that benefit innovation. Earlier research shows occupations with the highest share in leadership skills requirements are in management, often with open-ended tasks that are less likely to be automated.

TECHNOLOGY

Certain data science skills in our analysis like "big data" are rewarded highly initially but turn into legacy skills over time that are not rewarded anymore as compared to more stable skills. / Demand for machine learning, a more recent technology, gained a wage premium in the second period of our analysis, showing rapid change in talent needs within data science as the field constantly evolves.