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RESEARCH

THE FUTURE OF **AUTOMATION**

RESEARCH WHITE PAPER BY

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The attached paper explores some of the broad thematic research areas upon which ARK Invest is focused today. These subjects fit squarely in the macro realm that portfolio managers should understand when analyzing investment opportunities. Like changes in economic policy, nonlinear changes in technology can have dramatic effects on industries across the globe.

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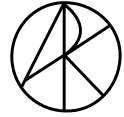
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SUMMARY

- | The History and Impact of Automation
- | The Projected Investment in Automation
- | The Impact of Automation on the Workforce

INTRODUCTION

Today, the Third Industrial Revolution is upon us, cutting across sectors to weave robots and adaptive algorithms into the fabric of our lives. As has been the case historically, automation may cause short-term dislocations. By 2035, ARK predicts roughly half of the US labor force will be replaced by automation. Ultimately, however, it will increase the value of labor per dollar output by 103%, adding \$12 trillion to overall real gross domestic product (GDP). Automation will create a virtuous cycle. The added value to real GDP will fuel progress, allow for new jobs to emerge, ensure a positive restructure of the workforce, and increase living standards meaningfully in the U.S.

HISTORY AND IMPACT OF AUTOMATION

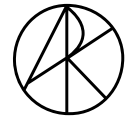
Until Blaise Pascal invented the first mechanical calculator in 1642, “computers” were rows of people performing and checking calculations. Just as the definition of “computer” has evolved during the past 400 years, so too has the employment associated with it. Developing, building, marketing, selling, servicing, and packaging computers caused a proliferation of job categories that otherwise would not have existed. The explosion in software and other applications, such as those enabled by the Internet and mobile devices, has added still more jobs. The Internet has created 2.6 jobs for every job it displaced.¹ The software industry alone has added roughly 2.5 million positions.²

Automation is defined by Merriam-Webster as “automatically controlled operation...that takes the place of human labor.”³ The focus often is on the loss of human laborers, leading to the perception that automation’s primary role is to eliminate jobs. History, however, should dispel such fears.

¹ Paul McCarthy, “The Internet has Created More Jobs But They’re Clustered in Just a Few Companies,” Business Insider, 2 January 2014. <http://www.businessinsider.com.au/the-internet-has-created-more-jobs-but-theyre-clustered-in-just-a-few-companies-2014-1>

² Robert J. Shapiro, “The U.S. Software Industry: An Engine for Economic Growth and Employment,” SIIA, 2014. <http://www.siaa.net/Admin/FileManagement.aspx/LinkClick.aspx?fileticket=ffCbUo5PyEM%3D&portalid=0>

³ Automation.” Merriam-Webster.com. Accessed May 8, 2015. <http://www.merriam-webster.com/dictionary/automation>.

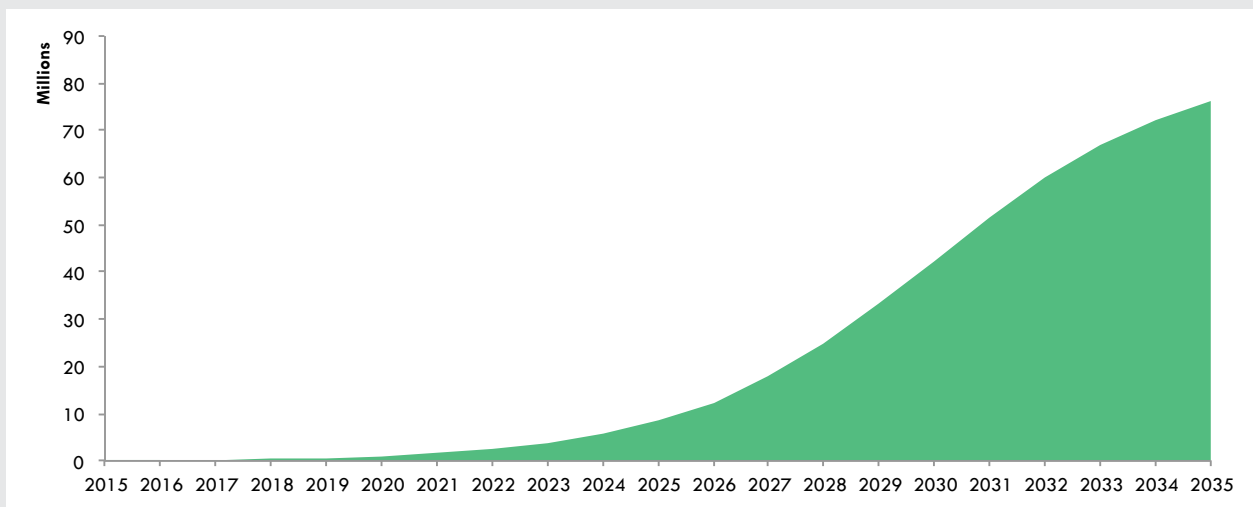


Today, the Third Industrial Revolution⁴⁴ is integrating everything from robots to artificial intelligence with adaptive algorithms. More sophisticated sensors, mechanical systems, wireless communication, computing, and cameras are enabling enhanced automation. For example, autonomous vehicles are beginning to drive, robots are vacuuming floors and fighting fires, and computers are writing the news.

Automation is an integral part of human progress. The invention of devices, processes, and technology has boosted productivity, or output per man-hour. Indeed, general-purpose technology platforms are the sources of continued innovation and an increased number of job classifications.

FIGURE 1

Projected full-time jobs automated in the US



Source: University of Oxford, ARK Original Research

A Oxford University study titled *The Future of Employment: How Susceptible are Jobs to Computerisation?*⁵ analyzes the probability that automation will usurp employment for 702 detailed occupations. Carl Benedikt Frey and Michael A. Osborne examine the underlying skills required for each job, and the likelihood that tasks will be replicated by computational and mechanical systems. Combining the probabilities in that report with United States Occupational Employment data, ARK has explored the impact of automation not only on employment, as shown below, but also on GDP growth and wealth creation.

By our calculations, automation could replace one million jobs by 2020 and 75 million – representing roughly half of the current United States labor force – by 2035. As shown below, the displacement of jobs will extend across all industries, with agriculture⁶ and food services⁷ the hardest hit.

4 The Third Industrial Revolution" The Economist, 21 April 2012. <http://www.economist.com/node/21553017>

5 Carl Benedikt Frey and Michael A. Osborne, "The Future of Employment: How Susceptible are Jobs to Computerisation?" University of Oxford, 17 September 2013. http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

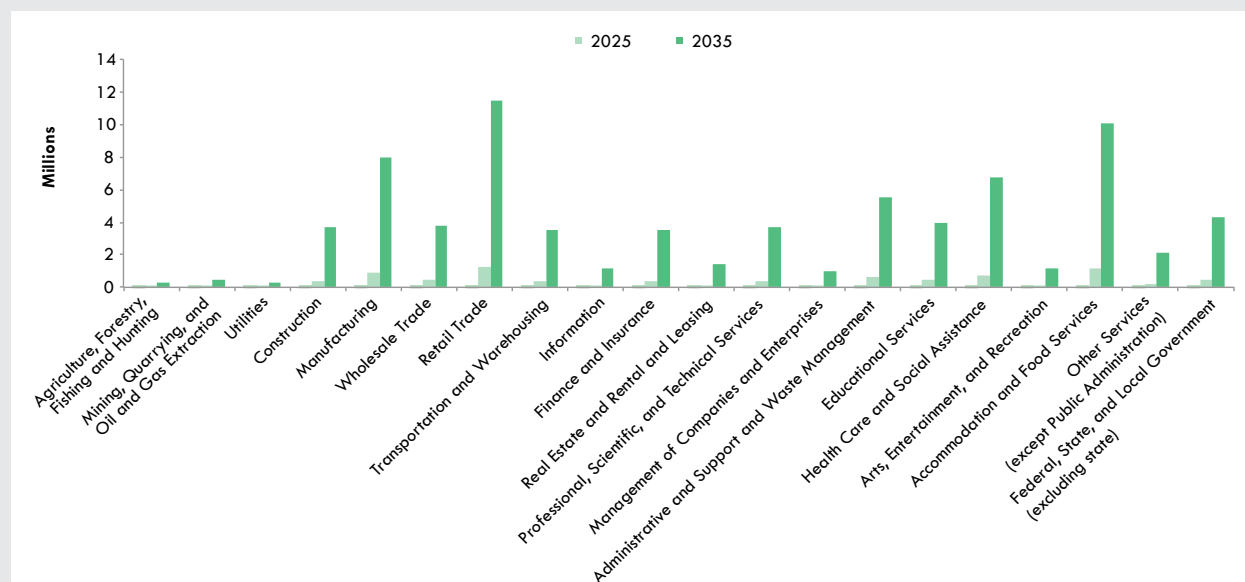
6 David Conway, "Robots will Revolutionize Agriculture and Wine Making," ARK Invest, 13 September 2014. <http://ark-invest.com/industrial-innovation/robots-will-revolutionize-agriculture-wine-making>

7 David Conway, "Robots Could Save the Agriculture Sector Billions," ARK Invest, 16 June 2014. <http://ark-invest.com/industrial-innovation/robots-could-save-the-agriculture-sector-billions>



FIGURE 2

Projected Number of Employees Replaced with Automation by Industry



Source: University of Oxford, ARK Original Research

IMPACT ON WORKFORCE

While automation will cause significant changes in the composition of employment, it will not cause mass unemployment. Quite the contrary, displaced workers will fill new higher-value-add jobs, and the labor force is likely to increase. The positive impact associated with the retraining of soldiers after World War II⁸ is quite instructive. The economy assimilated returning soldiers surprisingly well, boosting productivity significantly.

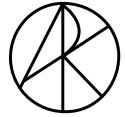
Though, as automation accelerates job turnover, the cost of friction in the labor market, which currently stands at more than \$630B per annum is expected to grow. These frictions present tremendous opportunity for companies that help firms reduce time-to-hire, provide workers with new skill-sets, and train new employees more efficiently.

In the United States today, 5.4 million jobs are unfilled because of skillset mismatches, as shown below. ARK's research indicates that recruiting and training account for over 2/3 the cost of friction in the labor market. The opportunity for recruiting and retraining has never been better.

Some companies already are responding. In 2013, corporate spending on training increased by 15%, to \$70 billion and then increased another 10% in 2014.⁹ Companies such as Cornerstone on Demand (CSOD),

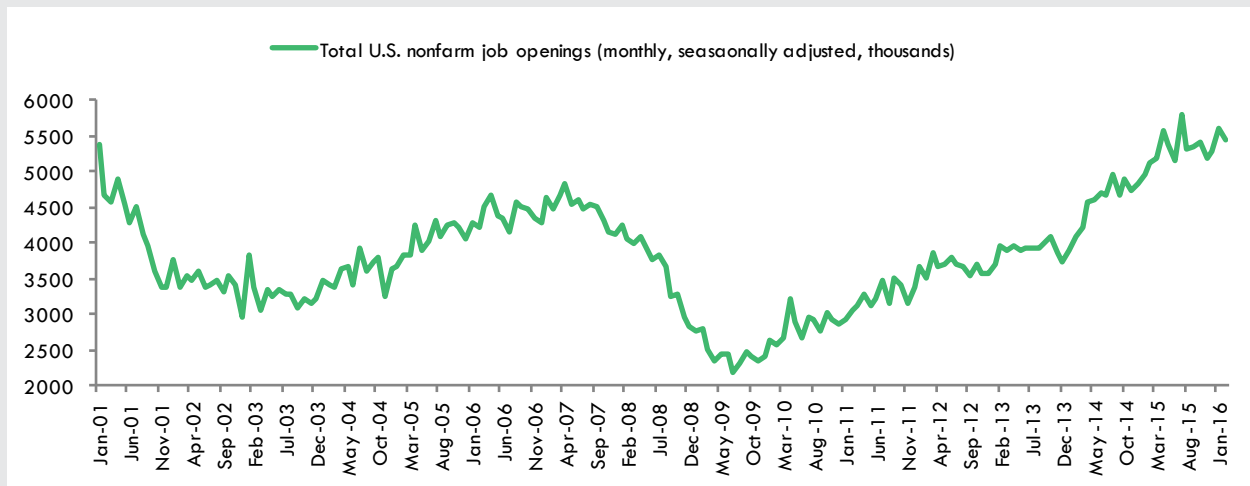
⁸ David Conway, "History Teaches Us the Workforce will Adapt to Automation," ARK Invest, 24 October 2014. <http://ark-invest.com/industrial-innovation/history-teaches-us-workforce-will-adapt-automation>

⁹ Josh Bersin "Spending on Corporate Training Soars: Employee Capabilities Now a Priority," 4 February 2014. <http://www.forbes.com/sites/joshbersin/2014/02/04/the-recovery-arrives-corporate-training-spend-skyrockets/>



Manpower (MAN), Robert Half (RHI), DeVry (DV), Adecco (AHEXY), and LinkedIn (LNKD), which acquired Lynda.com, offer career skill-building programs, and should benefit significantly as automation permeates more industries.

FIGURE 3
Total US Job Openings, Seasonally Adjusted



Source: U.S. Bureau of Labor Statistics

FIGURE 4
Cost of Friction in the Job Market



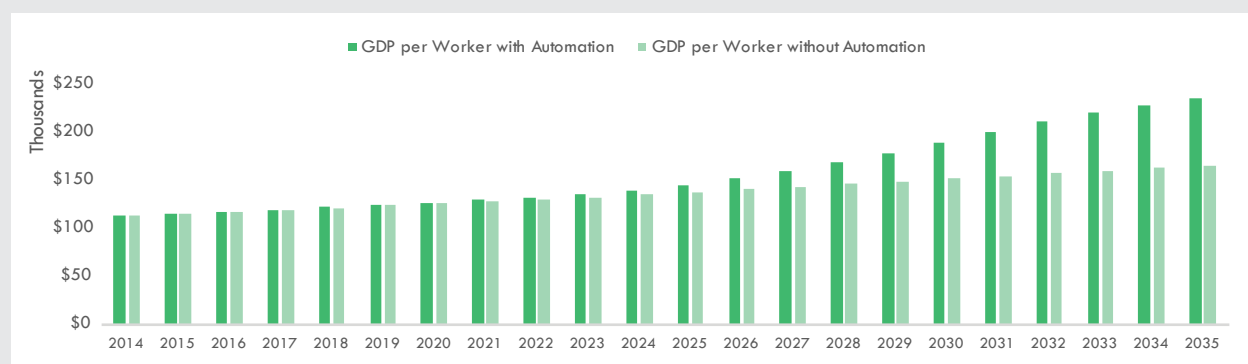
Source: Center for American Progress, U.S. Department of Labor, Bureau of Labor Statistics, Bersin by Deloitte, Association for Talent Development, ARK Investment Management LLC



The productivity associated with automation will have a profound impact on economic growth. According to ARK's research, real GDP per worker in the US will double from \$113,000 in 2013 to \$236,000 in 2035, or at an annual rate of 3.4%. Without automation, productivity would increase at roughly half that rate, or 1.8%, limiting real GDP per worker to \$167,000, as shown below. As automation proliferates, the growth of real GDP per worker will accelerate from 2.2% during the next ten years, to roughly 5% between 2025 and 2035.

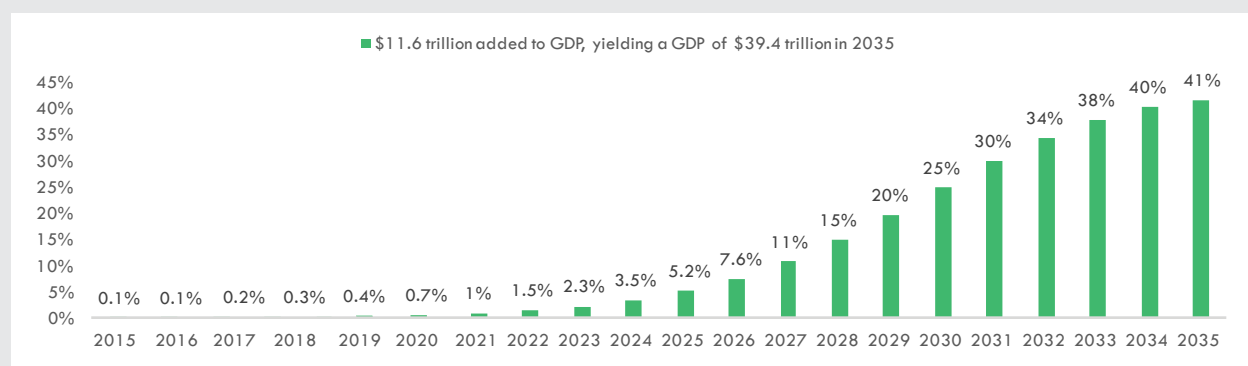
By 2035, real GDP will be 42% higher with automation than without it, as shown below. It will reach roughly \$40 trillion, or nearly \$12 trillion above the \$28 trillion that would otherwise be the case. Clearly, the extra \$12 trillion in extra GDP will bring with it many more new jobs.

FIGURE 5
Projected Percent Gain in GDP Per Worker with Automation

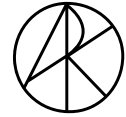


Source: University of Oxford, ARK Original Research

FIGURE 6
Projected Percent Increase in GDP with Automation



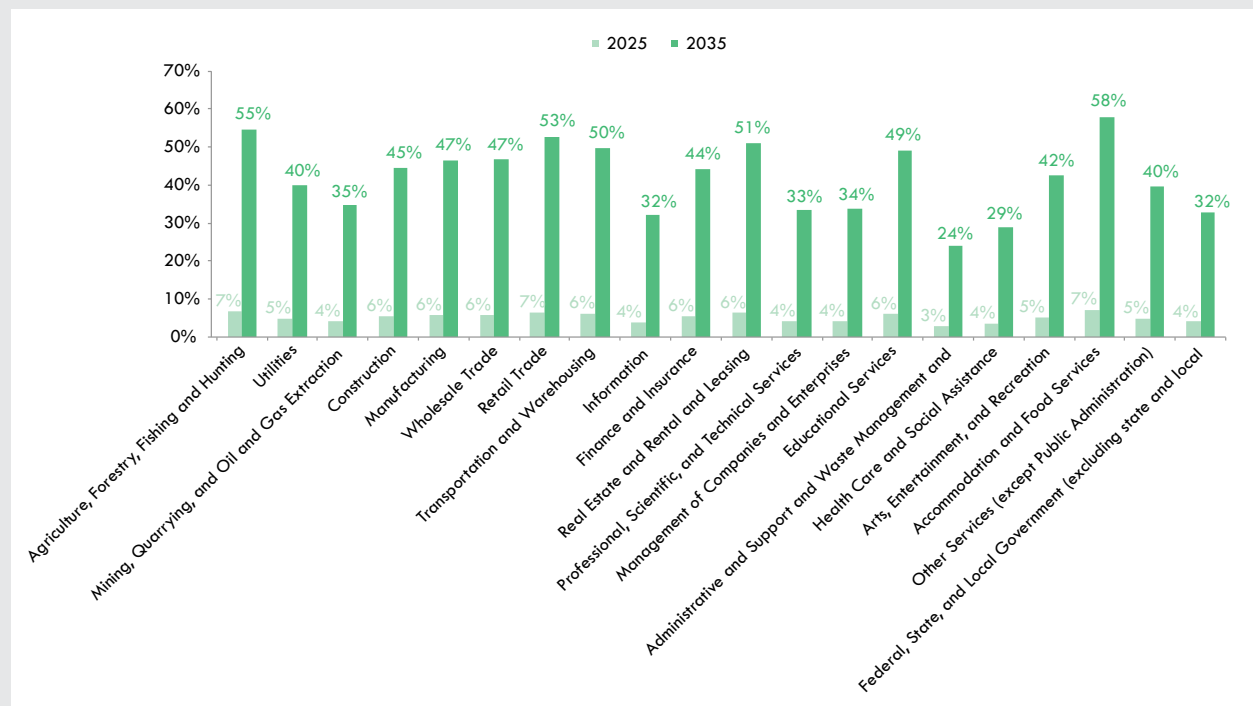
Source: University of Oxford, ARK Original Research



Robotics ecosystems will create new industries and accelerate their growth. Companies already pioneering this movement include Google (GOOG) and Tesla (TSLA) in the autonomous vehicle market, as well as AeroVironment (AVAV), Amazon (AMZN) and Elbit Systems (ESLT) in the drone space. Service robots are in their infancy, but could undergo explosive growth. Early examples include vacuum and lawnmower robots manufactured by iRobot (IRBT), medical robots by Intuitive Surgical (ISRG), and industrial robots by KUKA (KUKAY). Even more embryonic are ReWalk's¹⁰ (RWLK) robot exoskeletons enabling paraplegics to walk.¹¹ Other companies benefitting from these trends manufacture sensors, microcontrollers, cameras, batteries, computerized numerical controls, and materials required for production. Cognex (CGNX), Ambarella (AMBA), Panasonic (PCRFY), Fanuc (FANUY), and Rockwell Automation (ROK) will be prime beneficiaries.

Automation will permeate every sector of the economy, with accommodation and food services, agriculture, and retail trade garnering the biggest boosts to productivity. By 2035, GDP per worker will increase by 58% in the accommodation and food services sector, 55% in agriculture, and 53% in retail trade, as depicted below.

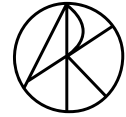
FIGURE 7
Projected Percent Gain in GDP per Worker with Automation by Industry



Source: University of Oxford, ARK Original Research

¹⁰ <http://rewalk.com>

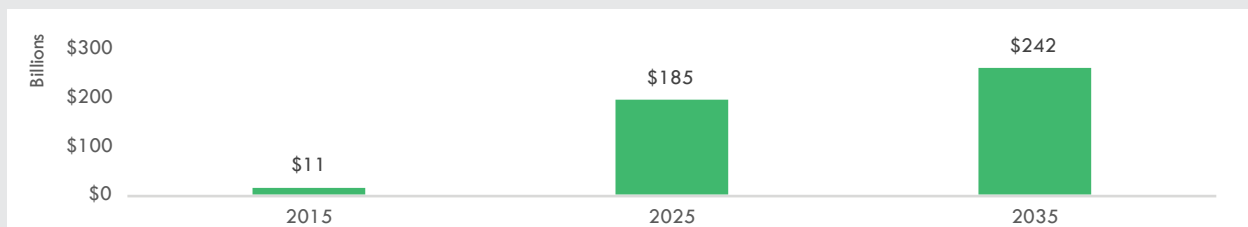
¹¹ David Conway, "Can Robot Exoskeletons Overcome Price Barriers?" ARK Invest, 17 December 2014.
<http://ark-invest.com/industrial-innovation/can-robot-exoskeletons-overcome-price-barriers>



Spending on automation is poised to soar orders of magnitude above current investment levels. Cumulatively, it will increase by roughly \$3.8 trillion through 2035. As artificial intelligence solves increasingly complex problems, the return on investment from “smarter” robots, drones, and automation will drive adoption. Between 2015 and 2035, annual investment in automation could increase at a 16.5% annual growth rate from \$11 billion to \$242 billion, as illustrated below. During the next decade it should compound at a 33% annual rate. Given the declining cost curves in technology, unit growth rates could be even higher.

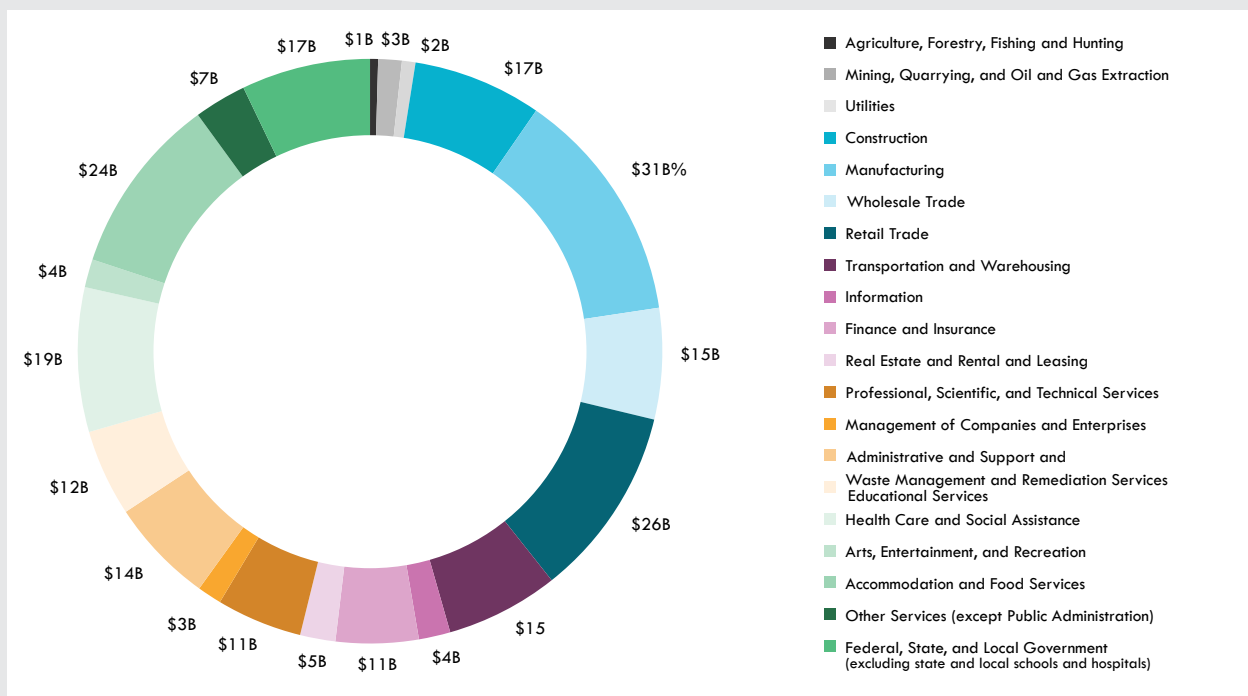
Several sectors will spend disproportionately on automation to boost productivity. In 2035, manufacturing will account for the largest percentage, 13% of the total, or \$31 billion. Spearheaded by companies like

FIGURE 8
Projected Annual Investment in Automation, Select Years

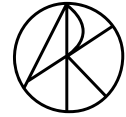


Source: University of Oxford, ARK Original Research

FIGURE 9
Projected Investment in Automation in 2035, by sector



Source: University of Oxford, ARK Original Research



Amazon (AMZN), the retail sector will spend roughly \$26 billion, or 11% of the total investment. In 2014, Amazon boosted the number of Kiva robots in its global distribution centers from 1,000 to 15,000, a fifteen fold increase in one year, and then doubled its Kiva install base to 30,000 in 2015. Game on! Closely related to retail, the accommodation and food services category is set to spend \$24 billion as shown in figure 9.

CONCLUSION

Consumers, corporations, and robot manufacturers will enjoy benefits beyond productivity with automation. Robots, for example, do not steal or call in sick¹², two of the biggest detractors from profits in the retail industry. In the fast-food industry, robots improve quality and consistency while reducing costs¹³. In the health care industry, robots aide nurses¹⁴, allowing them to direct attention to more pressing medical problems.

Demand for robots will grow significantly, improving margins for businesses, and potentially lowering costs to consumers. The benefits of automation, however, will be even more profound than the 42%, or \$12 trillion, increase in incremental GDP. Automation will save lives and prevent tragedies by improving the accuracy and consistency of work and removing humans from dangerous environments. Perhaps most importantly, automation will enable people to pursue higher-level careers that will spur future innovations and progress, and further human fulfillment.

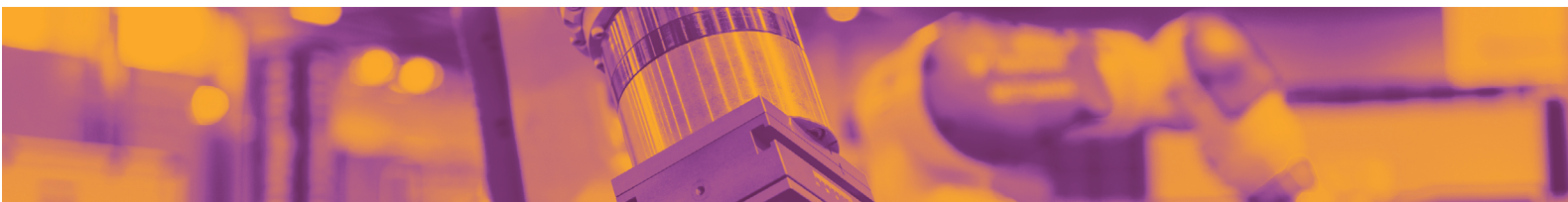
THE PRODUCTIVITY ASSOCIATED WITH AUTOMATION WILL HAVE A PROFOUND IMPACT ON ECONOMIC GROWTH. ACCORDING TO ARK'S RESEARCH, **REAL GDP PER WORKER IN THE US WILL DOUBLE FROM \$113,000 IN 2013 TO \$236,000 IN 2035**, OR AT AN ANNUAL RATE OF 3.4%

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¹² David Conway, "Robots in Grocery Stores May Double Margins and Reduce Food Prices for Consumers," ARK Invest, 3 April 2014.
<http://ark-invest.com/industrial-innovation/robots-grocery-stores-may-double-margin-reduce-food-prices-consumers>

¹³ David Conway, "Robots will Save Manufacturing Billions," ARK Invest, 8 August 2014.
<http://ark-invest.com/industrial-innovation/robots-will-save-manufacturing-billions>

¹⁴ David Conway, "Nurse Assistant Robots Offer a Win-Win for the Health Care System," 28 May 2014.
<http://ark-invest.com/industrial-innovation/nurse-assistant-robots>



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