When Robots Do It All and Leisure is Mandatory: Not for another 100 years

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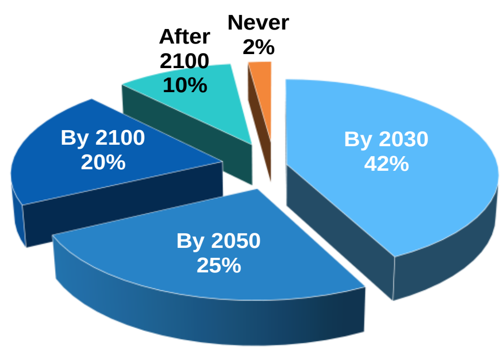
Advancements in machine learning, mobile robotics, and computing power have led to machines that are increasingly capable of performing non-routine tasks and navigating in real time. Artificial intelligence is gaining traction as an attractive investment within the tech industry. Machines are likely to take over many tasks that humans perform, but they are not likely to seize many occupations entirely. Large scale job losses are unlikely as the labor-saving impact of technological progress will be weighed against the job-creating effect, which in the past has outweighed job losses. The necessity of flexible labor retraining programs is essential due to shifts in employment between occupations and to adjustments of tasks within occupations. The major documented impact of automation on labor has been a decline in worker hours coupled with a growth in living standards.

Reality or Fiction

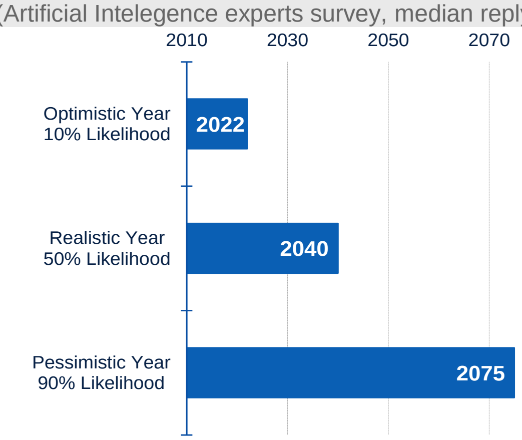
Can robots become the next Einstein, Picasso, or Mozart? What are the job prospects for us humans? Computer scientists insist that at some time within the next twenty years, computational power and processing speed will surpass the human brain's capabilities. Shortly after that, artificial intelligence machines will pass through the next step of artificial intelligence, the general intelligence phase, and reach super intelligence. Super intelligence is described as an intellect that is much smarter than the best of human brains combined in all fields – scientific, creativity, general wisdom, and social skills. At that point, humanity will cross the point of Singularity, where the first super intelligent machine will become the last invention that the humans will need to make as the computational ability of the machine will leave no room for human inventions. Prompted by super intelligent machines, economic growth will accelerate sharply because the amplified pace of improvements by machines will cascade through the economy.

Figure 1. When participants thought Artificial General Intelligence (AGI) would be achieved (Annual AGI Conference participants survey, %)



Source: BBVA Research & Barrat (2013)

Figure 2. By what year would you see a probability for Artificial General Intelligence to exist (Artificial Intelegence experts survey, median reply)



Source: BBVA Research & Müller and Bostrom (2016)

Given our adaptability to new technologies, there will be plenty jobs left for humans. The fear of technological unemployment has not materialized in the past and likely will not in the foreseeable future because the jobs lost to automation will be matched by the new jobs created by the growth-boosting effect of technological advancement. Additionally, computing power does not translate directly into human intelligence, and many domains within occupations remain genuinely human – social intelligence, creativity, new concepts and solutions, persuading, negotiating, and caring for others.

The remoteness of Super Intelligence

Today's artificial intelligence (AI) is defined as Artificial Narrow Intelligence (ANI), where each AI machine specializes in one area – playing chess, making music selections, translating languages, high frequency algorithm trading, etc. The second stage that AI machines can reach is that of Artificial General Intelligence (AGI), where an AI machine reaches and exceeds the intelligence level of a single human. In this stage, the machine would have the ability to think abstractly, reason, comprehend complex ideas, and learn from experience. The final stage of development for AI machines is that of Artificial Super Intelligence (ASI), where the machine would be smarter than all of humanity combined.[1]

The computational speed of computers grows exponentially, doubling every twelve to eighteen months, and estimates suggest that by 2030 there will be an affordable computer with a computing speed of 10^{18} floating-point operations per second (FLOPS) – equivalent to human brain speed. However, processing speed alone does not necessarily translate into human intelligence. Computers exceed the human brain in complicated computational problems but they are weak in basic human functions that we take for granted – vision, movement, manipulation, and perception. The successful emergence of ASI would have to involve neuroscientists and would most likely involve imitating the bottoms-up approach of the biological brain when creating the AI machine's software. The super intelligent machines of the future might not necessarily look like the human-like robots depicted in movies. They could be digital computers, a collective network of computers, or cultured cortical tissue.

> "It took 40 minutes with the combined muscle of 82,944 processors in K computer [at the time of the article, the fourth fastest supercomputer in the world] to get just 1 second of biological brain processing time. While running, the simulation ate up about 1PB of system memory as each synapse was modeled individually." Whitwam (2013)

The challenges that engineers and computer scientists face within the field of robotics are real. The wide use of industrial robots was the relatively easy part of automation since robots are programmed to conduct routine tasks in a controlled environment. Despite that, the continuous improvements in Machine Learning (ML) and Mobile Robotics (MR) – where machines are increasingly capable of performing non-routine tasks and have the ability to navigate in real time – the cognition, manipulation, and interaction abilities of robots in an unstructured environment are the engineering bottleneck.

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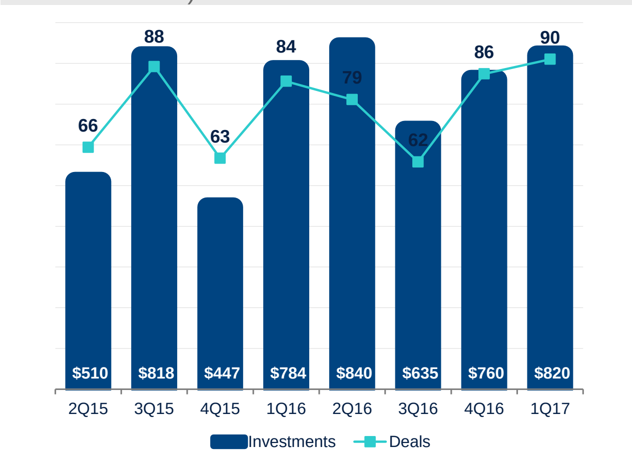
[1] Sysiak (2016)

Most importantly, similar to industrial robots, the productivity gains from intelligent robots/machines have to materialize and reach the scale where cost-benefit analysis would support independent large-scale development and production by private firms. Currently, robotics has earned the status of a “poor stepchild of every other industry” because it has repurposed technologies already developed in other industries.[2]

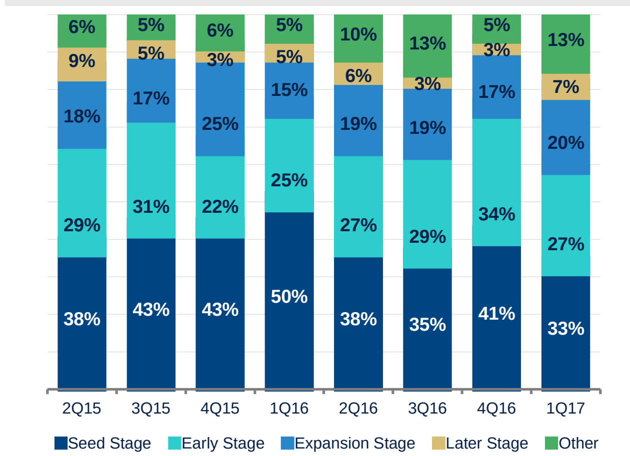
Nevertheless, AI is gaining traction as an attractive investment within the tech industry. In 2015, venture capital investments in robotics more than doubled their 2014 amount. Investments in AI are proliferating with private equity investors building portfolios of “robot investments.”[3] The first quarter of 2017 has marked the highest number of AI funding deals by venture capitalists, corporate investors, and other investors and has seen seven quarters of at least $500 million in funding.[4] AI is to become one of the hottest investment trends in the start-up scene since the launch of “big data” investments. The global robot market investments are estimated to grow to $188 billion by 2020.[5]

Figure 3. U.S. Artificial Intelligence Funding ($ Millions, number of deals)



Source: BBVA Research & PwC|CB Insights (2017)

Figure 4. U.S. Deal Share by Stage of Funding (%)



Source: BBVA Research & PwC|CB Insights (2017)

The economics of Singularity

Singularity, defined as accelerating economic growth due to rapid growth in the productivity of intelligent machines, is the economists’ perception of how far or close we are from the ASI takeover. Singularity has to be endorsed by demand side effect, supply side effect, or both. The key factor in defining the long-run map to Singularity is the substitution elasticity between digital capital, including information technologies and other conventional inputs and outputs. Demand or supply side effects should affect relative prices in such a manner that the substitution of stagnant economic inputs and outputs with high-growth and high-productivity inputs and outputs is feasible. On the demand side, the preferences of consumer spending should move increasingly towards high-productivity-growth industries to rapidly increase the share of those

2 PwC (2016)
3 Waters and Bradshaw (2016)
4 PwC (2017)
5 International Data Corporation (2017)

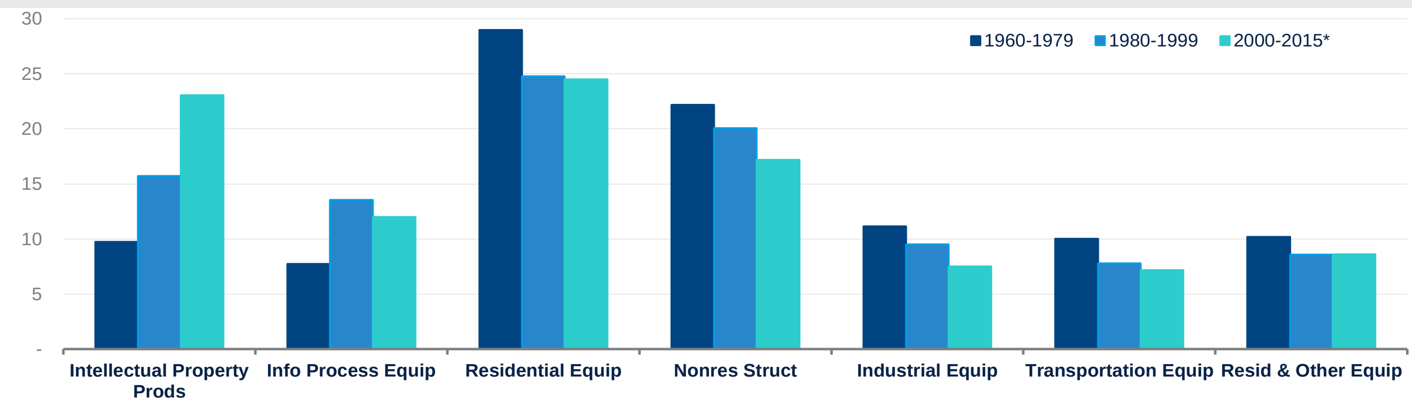
industries in consumer expenditures. On the supply side, production should have sufficient substitutability for the inputs to move towards fast improving digital capital and thus to increase the share of digital capital in the bundle of inputs.

Economist Nordhaus has formalized seven empirical tests[6] – one demand-side and six supply-side - to test the viability of Singularity. On the demand side, the key assumption for Singularity to occur is that there is elastic demand for goods in high-productivity-growth sectors. Economic theory suggests that sectors with a rapid productivity rise due to technological advancements should see a rapid price decline and should see their share within consumer expenditures increase rather than decrease. Empirical testing has shown that while prices of goods in new tech sectors are declining, there is no consistent pattern of elastic demand. On aggregate, the demand side Singularity does not hold. The shares of high and low productivity industries within consumer expenditures have hardly changed during the last two decades because the industries that have seen price decline have also experienced a decline in expenditure share.

On the supply side, the key assumption of Singularity is that there is elasticity of substitution in production. The elasticity of substitution in production of digital capital to labor should be above one, so production would move from fixed factor productivity to high-productivity-growth input, and the share of digital capital in production increases. Simulation of a standard closed economy neoclassical growth model with a Singularity assumption yields unbounded growth of output: the share of digital capital within the bundle of inputs bounds 100% as the growth rate of output accelerates. Moreover, a modest assumption of elasticity between labor and digital capital substitution also results in rapidly growing wages.

Empirical testing of supply side Singularity equates with testing several growth model simulation predictions: 1) rising labor productivity or rising total factor productivity, 2) a rising share of nominal capital in the value of inputs, eventually reaching a 100% share, 3) falling relative prices of investment and capital goods, 4) a rapidly rising real capital-output ratio, 5) the share of digital capital within total capital growing eventually towards unity, and 6) a rise in wages, under a plausible elasticity of substitution assumption between labor and capital.

Figure 5. Investment in Private Fixed Assets by Type Share of Total (%)



Source: BBVA Research & BEA

[6] Nordhaus (2015)

The empirical estimates do not exhibit acceleration in multi-factor and/or labor productivity, in the rate of decline of capital prices relative to wages, in capital-output ratio growth, nor in wage growth (1, 3, 4, and 6). At the same time, there are signs of acceleration in the trend of the income share of capital and the digital capital share in capital stock (2 and 5). Thus the supply-side Singularity is plausible but the extrapolation of estimated trends suggests that the time at which it could be reached is in 100 years or more.

There will be plenty jobs left for humans

The awareness that automation and digitization is penetrating the domain of truly human tasks such as reasoning and sensing have revived the fear that new technologies will displace workers and give rise to technological unemployment. The concern of technological unemployment threat is not new. The similar concern in 1950s and 1960s had led to the establishment of the "Blue-Ribbon National Commission on Technology, Automation, and Economic Progress." In the 1960s, economists were witnessing rapidly rising productivity and worried that productivity growth could surpass the demand of labor. The threat was taken seriously enough that the Commission recommended "a guaranteed minimum income for each family; using the government as the employer of last resort for the hard cored jobless; two years of free education in either community or vocational colleges; a fully administered federal employment service."[7]

Yet, in the 2010s, despite the rapid growth in information communication technologies, digitization, machine learning and mobile robotics, economists are puzzled by consistently low productivity growth, strong payroll growth, and an unemployment rate that has declined to its historic low. While technological unemployment is hard to quantify, structural unemployment, defined as unemployment due to structural shifts in the economy's industry makeups combined with frictional unemployment, has corrected itself to a low of 4.4% (estimated as the natural rate of unemployment), a rate so low that it hasn't been since the 1950s.

Meanwhile, the advancements in computational power, artificial intelligence, and mobile robotics have redefined the capabilities of machines and have yielded high estimates of how many jobs would be lost to robots. A ground breaking study by Frey and Osborne has estimated that as much as 47% of all U.S. occupations will be lost to automation within the next 10 to 20 years.[8] Nonetheless, there are two crucial caveats to that estimate.

First, the estimated percentage of occupations that have a high probability of being automated is based on the survey that evaluates the automation probability of tasks performed in the core seventy occupations. There is a significant likelihood that the assessment of these probabilities could overstate the technological capabilities and pace of technology utilization. More importantly, the automation of tasks within the evaluated occupations does not necessarily translate into automation of the occupation itself. Occupations consist of a bundle of tasks and not all of these tasks may be easily automatable. Many occupations that would be considered to be highly automatable incorporate tasks such as face-to-face interaction,

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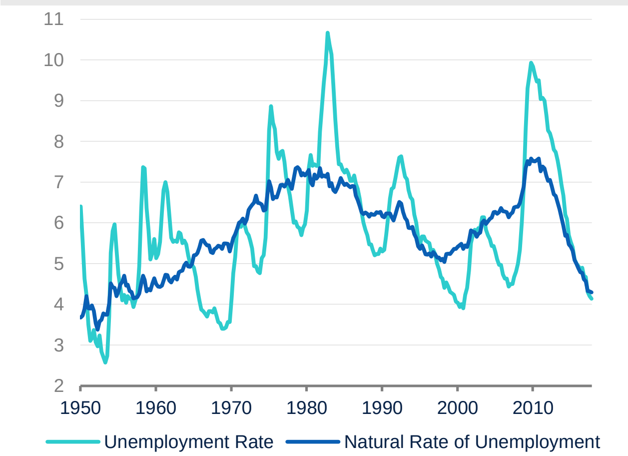
[7] Autor (2015)
[8] Frey & Osborne (2017)

flexibility, judgment, and common sense, which are hard to automate. Alternatively, a task based approach has estimated a much lower percentage - 9% of all occupations that have a high probability of being automated.[9]

Secondly, while it is possible to derive estimates of how many jobs would be lost to automation, it is impossible to estimate how many new jobs would be created due to automation. Robots will have to coexist with humans. Thus smart machines will improve the productivity of labor but not necessarily displace it. Moreover, robots are still in the process of learning to perform basic routine tasks in an unstructured environment – tasks that people don't usually put on their resumes such as walking down the hallway without bumping into people, orienting themselves, and taking the elevator.

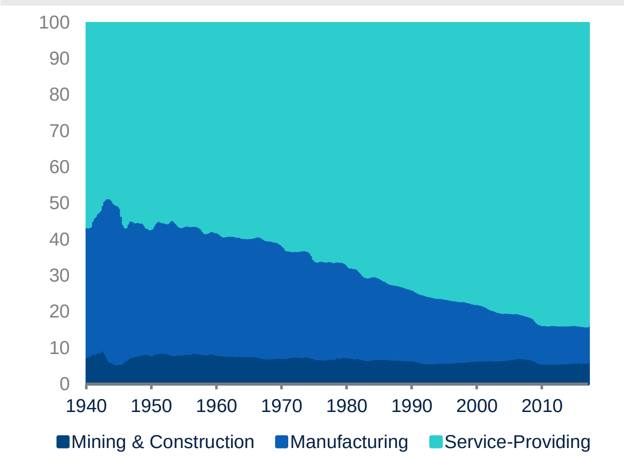
Even as automation has moved from the manufacturing sector into the service sector, the automation of mundane skills allows employees to refocus on other customer service tasks – tasks that require higher skills and human interaction. For example, the introduction of Wally, which is the room-delivery service robot in the Los-Angeles Residence Inn Marriott hotel that independently navigates the hotel to deliver orders, has not resulted in less employees hired but has allowed hotel management to widen the range of room-delivery items, shorten the room-delivery time, and provide a higher level of service at the front desk.[10]

Figure 6. Unemployment Rate (%)



Source: BBVA Research & BLS

Figure 7. Payroll Employment Share of Total Private (%)



Source: BBVA Research & BLS

What the future holds: economic impact

Robust advancement across all domains is moving the robotics ecosystem forward and the pace at which technological innovations are being utilized within industries and offered for general consumption is expected to accelerate.

Large scale job losses are unlikely as the labor-saving impact of technological progress will be weighed against the economic feedback mechanisms that should increase the demand for labor. A positive labor demand shock could arise

[9] Arntz & Zierahn (2016)
[10] Wood (2016)

from industries producing new technologies, and industries that will face higher product demand as their competitiveness will get a boost from the infusion of new technologies. The major documented impact of automation on labor has been the decline in worker hours coupled with growth in living standards. Taking advantage of automation may slowly lower the standard 40 hour work week.

At the same time, economists expect large shifts in employment between industries and occupations, as well as adjustments of tasks within occupations. What both occupational and task based economic studies on automation and job-replacement agree on is that the jobs under threat to be lost are low-skilled and low-income jobs. The probability of the occupation being replaced by machines declines with higher educational attainment and higher income. As the tasks complimenting machines are expected to become increasingly complex, job prospects for a certain segment of the labor force that lacks necessary, education, skills and/or training will deteriorate. Thus, automation and digitization are at the core of the widening gap in wage inequality and wage polarization as low-wage and low-skill workers are to bear the economic cost of automation and are the most disadvantaged in preparedness for the jobs of the future.

Additionally, the reach of monetary policy is likely to be restrained by a low inflation environment since advancements in information communication technologies, digitization, machine learning, and mobile robotics have also resulted in a new normal, subdued inflation. Automation and information communication technologies put downward pressure on wage growth with heightened competition for jobs from both machines and offshoring. Moreover, automation and digitization continue to put downward pressure on the price of capital, as the prospect for digital capital is to grow into a resource that is abundant, has low marginal costs, and is fundamental for all industries.

In the environment where economic growth could accelerate as the amplified pace of improvements by machines would cascade through the economy, the long-run trends of demographics and growing income inequality will continue to pose restraints. Thus, government policies targeted towards education and workforce training, innovation, deepening information and communication technologies infrastructure, and promotion of both private and public capital investment can have a high impact on future living standards. The necessity of flexible labor retraining programs is essential and on the rise, where both private and public training could accommodate the ever-changing labor market environment.

Overall, future of productivity growth, labor market conditions and wage growth are largely determined by the ability of the U.S. to form a long-term human capital investment strategic plan for producing skills that compliment rather than substitute smart machines – social intelligence, problem-solving, creativity, coordination, and the ability to cope with the uncertainty of rapidly changing technology.

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