Ownership When AI/Robots Do More of the Work and Earn More of the Income

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Abstract

This paper examines the likely impact of AI robotics technology on the labor market through the lens of comparative advantage. The first section reviews the success of AI in outperforming humans in chess, jeopardy, go, poker, and other strategic games, which shifts comparative advantage in some cognitive activities to machines and the potential for a portfolio of specialized computer algorithms to compete with human general intelligence in work. It presents evidence that growing robot intensity has begun to impact the job market and uses the "three laws of robo-economics" to guide thinking about how the new technologies may impact earnings and the distribution of income over time. The second section advances an ownership solution to spread the benefits of AI robot-driven automation widely via increased employee ownership, profit-sharing and gain-sharing that raises workers' stake in their firm and increased investment in pension or mutual funds and in Sovereign Wealth Funds that gives workers and citizens a greater stake in the economy writ large. The paper argues for experimenting with new policies now when human workers are critical in implementing the AI robotic technologies rather than later when the machines may be more independent and AI robotics driven automation may have added to the concentration of income and wealth that troubles many people today.

Warnings that advanced robots, artificial intelligence software, and automation threaten employment fill the media: "Robots will destroy our jobs – and we're not ready for it"; Robots Threaten Bigger Slice of Jobs in US, Other Rich Nations"; "Automation could impact 375 million jobs by 2030"; Robots will take our jobs. We'd better plan now, before it's too late"; "Will Robots take our Children's Jobs?"; "Robots can now read better than humans, putting millions of jobs at risk".[1]

Google almost any occupation and you find reports about AI robots outdoing humans at work: "AI Beats Human Lawyers at Lawyering"; "Robot barista serves coffee at Tokyo's 'Strange Café"; "AI May Soon Replace Even the Most Elite Consultants"; "Robot caregivers are saving the elderly from lives of loneliness"; "AI beats doctors at visual diagnosis, observes many times more lung cancer signals".[2]

The potential for AI robots to displace millions of human workers in repetitive and routine tasks and eventually in creative work underlies fears that the technology will massively disrupt the job market.[3] But warnings and projections of the end of human work notwithstanding, there is no sign of a technological revolution in productivity, employment, or other standard measures of labor market performance.[4] From 2000 to 2017 GDP per worker increased by 1.2% --a rate in line with that in the three preceding decades. After falling sharply in the Great Recession, the employment to population ratio recovered to relatively high rates while unemployment dropped noticeably.

Past fears that machines were destroying jobs – from the Industrial Revolution to John Henry's legendary battle with the steam-powered hammer to the technocratic explanation of the Great Depression – all fizzled out. In each period, employers developed new jobs and workers invested in new skills so that labor shifted from automating sectors to others and worker ended up with higher pay and better conditions. In response to the 1960s automation scare, President Johnson appointed the National Commission on Technology, Automation and Economic Progress, which completed its assessment just as the job market boomed in the late 1960s. Herbert Simon's 1965 analysis of the impact of automation showed that in a well-functioning market economy both labor-saving and capital-saving technology raised wages rather than destroyed jobs (Simon, 1965), leading him to conclude that "The bogeyman of automation consumes worrying capacity that should be saved for real problems", which "in this generation and the next are problems of scarcity, not of intolerable abundance".[5]

Simon's model fit the 1960s world where wages increased with productivity; income inequality held stable or fell; employment increased with economic growth; and machines substituted for workers primarily at physically onerous assembly line jobs. Collective bargaining and the growth of pension fund ownership of capital (Drucker, 1976) and Employee Stock Ownership Plan (ESOP) businesses buttressed market forces in guaranteeing that workers would benefit from advancing technology.

Today's economy and technological change, however, differ from that in the early post-world war II period. Labor's share of national income has fallen – exceptionally sharply if executive stock grants, options, and performance bonuses associated with capital income are excluded from labor compensation. Inequality of pay has increased among workers between and within occupations and among firms between and within industries. Inequality in wealth has increased. The pension fund share of equity stopped growing before it reached the levels that Drucker expected and the ESOP share of jobs stabilized at about 10% of private sector employment. With deep learning and big data from which to learn, AI has begun to substitute for humans in cognitive activities that were viewed as the exclusive domain of humans just a few years ago.

How much, if at all, do AI robotic technological advances make "this time different" for the effect of automation on jobs? Assuming that technology will not magically reverse the past several decades' increased concentration of income and wealth, what policies can best assure us that economic growth will benefit the bulk of society in the emerging coming world in which robots do more of the work and earn more of the income?

Section one of this paper applies the economic principle of comparative advantage to analyze the likely impact of AI robotics on the future of work and the time period over which this impact might plausibly occur. Weighing advances in AI automation against sluggish productivity growth and high employment, I argue that the technological data offer a better indicator of the future than the aggregate economic data. AI robot-driven automation has the potential to be sufficiently different from past automation to justify considerable "worrying capacity".

Section two presents the case that the best way to spread the benefits of AI robotic automation widely is to expand employee ownership of their firms and employees' and citizens' stake in business capital writ large. It considers policies to accomplish this goal and argues policy innovation now when firms and workers are implementing AI robotics rather than later when the machines may need little human guidance and inequality in income may be beyond that which arouses concern today.

In short, my answer to the question "Whatcha gonna do, workers, when AI Robomania runs over you?" is to spread widely ownership of capital, from AI robots to other machines and to intangible knowledge capital as well. To prosper in an economy where robots do most of the work and earn most of the income, workers and citizens have to own a larger share of capital than they do today.

1) Will the AI/robots really disrupt the labor market?

Comparative advantage – the idea that different factors of production in a market or countries in the global economy do best to specialize in the tasks that most fits their relative competency – suggests that the headline warnings of job shortages misplace the long term impact of the technology. Instead of looking for what AI/robots do to the numbers of jobs, comparative advantage says to look for what they do to wages and incomes. Comparative advantage holds that as long as AI/robots and humans differ in their attributes and costs, firms will hire humans for some jobs or tasks even if robots outperform humans in every job or task. Firms will hire humans for the work that humans do at lower cost than machines and will hire machines for the work which machines do at lower cost than humans.

Past automation benefited workers because it developed machines that replaced humans at physically difficult/dangerous low wage work while creating higher value cognitive jobs. Because the machines/tools were specialized and difficult to shift from one activity to another, humans dominated work that required judgment and flexibility, particularly in novel situations. Today's AI-driven automation is different. AI creates machines competitive with humans in "brain work" as well as in physically difficult and/or routine tasks. The algorithms recognize patterns in data, select actions appropriate to different situations, and can develop novel solutions, particularly in the digital world in which much white collar work is now conducted.

Exhibit 1 is a capsule time line of the past two decades' AI advances that produced the algorithms that challenge humans in brain work. IBM's Deep Blue victory over world chess champion Garry Kasparov in 1997 brought artificial intelligence to world attention. Deep Blue's triumph was based on IBM programmers harnessing its brute force processing power to learn from human chess experience and to select the moves that gave it the best chance of winning a game.[6] Four years later IBM's Watson used machine natural language processing to beat human champions in Jeopardy, linking the Jeopardy clues/questions to a 200 million page data base of information.[7] Watson executed hundreds of language analysis algorithms simultaneously and tested solutions on its data base in a situation closer to the messy real-world of jobs, workplace, and business problems than to chess.

Go is a harder board game than chess, in part because it covers a larger space, which allows for many more possible moves. To achieve expertise, human players develop intuition about the effects of early moves on positions at game's end. Just two decades ago gaining such knowledge seemed beyond artificial intelligence. In 1997 one Go expert estimated that, "It may be a hundred years before a computer beats humans at Go – maybe even longer."[8] A hundred years? In 2016, Google's AlphaGo defeated Korean Go master Lee Sedol and went on the next year to defeat the world's top player, China's Ke Jie. AlphaGo used a Monte Carlo Tree Search to explore the landscape of winning probabilities for moves, guided by convolutional neural nets patterned after picture recognition algorithms. Its expertise came from playing games against itself than any human expert could play in a lifetime and evolving stronger strategies from this experience through reinforcement learning[9].

Since work settings are not full information board games, a skeptic might question the extent to which AI dominance in Chess and Go generalizes to workplaces. Can machines out-think humans in an incomplete information game, where players may play irrationally or bluff to deceive opponents – a game such as, say, poker?[10] In 2016, aided by a super computer that modified algorithms overnight to improve its strategy, Carnegie Mellon's Libratus defeated four humans in a three week no-limit Texas Hold'em poker tournament. In the same year the University of Alberta's Deep Stack defeated human experts by "combin(ing) recursive reasoning to handle information asymmetry, decomposition to focus computation on the relevant decision, and a form of intuition that is automatically learned from self-play using deep learning." As with the go algorithm, the poker programs learned what moves worked best from a vast catalog of example moves by humans and playing against themselves, accruing more experience than their human opponents.[11]

Still, the skeptic may note, the triumph of algorithms is limited to the particular tasks which they address – Deep Blue/chess, AlphaGo/go, Libratus and Deep Stack/poker, and so on. AI has not a clue about activities beyond its narrow skill set. You or I can beat AlphaGo at poker or Deep Stack at go. We can use our general intelligence or biological flexibility to switch from strategic thinking to cleaning an office spill to composing a memo. From this perspective, our edge is our versatility, which ought to give us comparative advantage in the non-routine work tasks that arise naturally in a dynamic economy. Updating the Irving Berlin "Anything you can do, I can do better" song from Annie Get Your Gun, the human can admit, "The one thing you can do, Robot, you can do better than me. Yes, you can. But I can do anything better than you except that one thing. Yes I can. Yes I can." [12]

There are two AI responses to human comparative advantage in versatility.

The first is that while each algorithm does only a single thing, the growing number of one-thing algorithms creates a portfolio of specialized programs/robots that can challenge humans in almost any activity. Chess? Deep Blue, ready and able. Vacuuming a house? Rumba20. Negotiating a contract? LawGeex17. Personal assistant? Cortana, Alexa, and Siri, and many more."[13] The Annie Get Your AI response to the human is "You can do more things than I can do. Yes, you can. But anything you can do, a program in my portfolio can do better than you."

The second response came on December 5, 2017, when Google's DeepMind Go-team reported that,"Starting from random play, and given no domain knowledge except the game rules, AlphaZero achieved within 24 hours a superhuman level of play", beating algorithms that had defeated the best humans in Go, chess and shogi.[14] Yikes! That a machine can learn over a weekend to dominate tasks beyond what it was designed for has profound implications for comparative advantage and the future of work. If AlphaZero can learn superhuman play in a day or so, what will Alpha20 do in the world of work in 2040 or 2050 when our babies will be on the job market? Will your employer hire Alpha20 with a direct line to massive Cloud data and quantum computer processing power or a newbie human college graduate to replace you when you retire?

Real world robots

The ability of robots to compete with humans in the off-line "real world" where we live and work has improved more slowly than in the digital world. Commenting on the AlphaGo triumph, Eleni Vasilaki, professor of computational neuroscience at Sheffield University, pointed out that while computers can beat humans at games that involve complex calculations and precision, they fall short on "tasks that are surprisingly easy for humans … Just look at the performance of a humanoid robot in everyday tasks such as walking, running and kicking a ball."[15] In the off-line world, where evolution has honed biological creatures to fit their environment humans ought to have an absolute edge over machines in some tasks as well as comparative advantage.[16] The issue is whether the pay for "walking, running, kicking a ball" will suffice to make a good living.

One way of assessing the extent to which robots have become better substitutes for humans in the off-line word is to examine the impact of the growing number of industrial robots on earnings and employment across labor markets. The growth of robots is massive: the International Federation of Robotics (IFR)[17] reported that the number of industrial robots introduced per year nearly tripled from 112,000 in 2006 to 328,000 in 2016 and projects that 1.7 million new robots will be installed in industry worldwide through 2020. Most industrial robots replace blue collar workers in routine factory work but robots have come to dominate precision welding in the highly automated automobile sector, leaving less demanding tasks to humans[18].

Four studies have examined the relation between the increased number of industrial robots and workers by estimating how increases in robot intensity (robots per worker) across areas, industries, or occupations impact employment or earnings. Exploiting differences in robot intensity among industries and the location of industries across US *commuting zones*, Acemoglu and Restrepo (2017) estimated that changes in robot intensity from 1993 to 2007 are associated with declines in the employment to population ratio and in earnings in a commuting zone, with one additional robot per thousand workers lowering the employment to population ratio by 0.18-0.34 percentage points and lowering wages by 0.25-0.5 percentage points (see Exhibit 3). A comparable analysis across *German states* (Dauth et al. (2017)) found that robot intensity is negatively related to wages but has no clear impact on total employment, with workers in more robot-exposed industries more likely to remain employed while the industry reduces new hires. The implication is that in the German labor relations system roboticization shifts employment from younger to older workers. Examining how robot intensity impacts employment and earnings in *occupations* that involve considerable routine work[19] in the US, Nan Chen (2018) finds rising robot intensity in an industry is associated with falling wages in routine occupations, concentrated among production and material moving workers, and also reports a weaker negative relation between robotization and employment, with modest employment drops in production/material moving jobs. Finally, Graetz and Michaels' (2015) analysis of growing robot intensity among industries across *17 countries* found that robotization was associated with higher growth of industry productivity and wages and with some reduction in total hours worked for low-skilled and to a lesser extent middle-skilled workers, but with no overall impact on total employment.

These analyses are the beginning of economists' efforts to assess the impact of robots on the labor market and can be pursued in various ways.[20] But because industrial robots are deployed primarily in manufacturing, which employs less than 9 percent of the non-farm work force, studies of industrial robots must be supplemented with studies of AI robots in the service sector and white collar jobs, where most Americans work. The risk of automation in service sector jobs is from more humanoid robots while the risk in white collar work is from software programs in the digital economy. It will take a substantive data collection effort to supplement IFR robot data to give a full picture of what AI robotics are doing to work throughout the economy. Extant studies of industrial robots show enough robot effects on labor market variables to justify further work.

Three Laws of Robo-Economics

To gain insight into the potential long term effects of AI robotics on the division of work and income between humans and robots, I rely on the three laws of robo-economics.[21] Unlike Asimov's three laws of robotics, which lay out the moral rules to govern robot relations with humans, the laws of robo-economics specify the factors that allocate work tasks between the AI robots and humans (laws 1 and 2) and their consequences for the distribution of income (law 3).[22]

Law 1. ***Robots will become better substitutes for humans in work activities over time.*** The combination of artificial intelligence based on improved machine learning algorithms[23], greater computer power, big data to train the algorithms, and sensors/mechanics to interface with the off-line world, will make it easier to substitute machine for human labor. Biomicry in robotics in which engineers design and build machines based on successful biological models will help make robots increasingly able to do human work.[24] Developments in human enhancement technology that implant chips or mesh electronics into brains may create brain computer interfaces that will make it easier for humans to do AI robot work.[25] The net result will be a larger elasticity of substitution between AI robots and humans. Since the elasticity of demand for labor depends on the elasticity of substitution, this will increase the elasticity of demand for human labor[26] so that reductions in the cost of robots relative to human workers will reduce human employment more than in the past.

The strongest evidence for increased substitutability is the widening range of occupations where AI/robots undertake job tasks that have traditionally been done by humans. As noted at the beginning of this paper, virtually every week science and technology publications publish stories on new robots or AI programs that can compete with humans in particular fields. The trend of increasing substitution between the machines and labor will at some point obviate the standard capital-labor dichotomy in aggregate production functions: a machine that substitutes perfectly (nearly perfectly) for a human will increase the supply of labor just as would another worker and thus lower rather than raise wages.

Law 2. ***Technology will reduce the cost of robot substitutes for humans, driving wages down in lines of work where robots compete with humans***.

Technological advance reduces the costs of producing goods and services, including robots. In a competitive market, the reduction of cost can show up in a falling price for robots with specified skills or in a fixed or modestly increasing price for robots with markedly greater skills than earlier models. Both channels of cost reduction are found in robot prices. Using IFR price data in six major developed economies, Graetz and Michaels estimated that the price of robots fell by approximately one half in 1990-2005 and that quality-adjusted the fall was to about one fifth the 1990 level. Estimates of robot prices for the US show drops from 2005 through the mid-2010s on the order of 6% to 9% per year in real terms.[27] The Boston Consulting Group further estimates that the full cost of a robotic system of production, including project management, systems engineering, and peripherals fell from $182,000 (2005) to $155,000 (2010) to $133,000 (2104) – a drop of 3.5% per year in nominal terms and of 5.7% in real terms – and estimates that robot productivity increased substantially as well.[28]

The net impact laws of robo-economics 1 and 2 will be to shift work from humans to the robots, reducing employment and pressuring wages downward in jobs where machines can do the work of humans at lower costs.[29] Both the extensive margin of occupations where machines compete with humans and the intensive margin of tasks where a machines compete with humans in an occupationa will expand. The downward pressure on wages should, moreover, spread to occupations or tasks where humans maintain comparative advantage as workers who leave jobs highly impacted by AI robotics seek work in those occupations or tasks.

The expanding portfolio of robot substitutes for human workers could in the long run squeeze human comparative advantage into a narrow niche of work activities, reducing the income/welfare of workers, much as a country that invests in many industries can squeeze the industrial structure of a trading partner and reduce its welfare per Gomory and Baumol's (2000) model of trade. But just as a country can maintain competitiveness in desirable sectors by investing in R&D and technology, humans could maintain comparative advantage in some high value added activities by investing in skills that complement what machines do or by going cyborg with implanted chips connected to computers.

It is possible, of course, that the AI robotics technology will create new tasks and occupations for humans, as have past technologies (Bessen, 2018), but to the extent that those are high wage/value added jobs, firms will have an incentive to develop and deploy AI robotics alternatives to do better and more cheaply what the human can do. There is little place to hide from a shift in comparative advantage to machines.

Near or distant future?

To determine the time period over which AI robot advances are likely to disrupt job markets requires information about the speed at which the technologies will advance and their costs decline and the ability of organizations and workers to "absorb" them.

A 2016 survey of 352 machine learning experts involved with two major machine learning conferences (Grace et al, 2017) provides insight into the *speed of technological advance*. The survey asked the experts to estimate the number of years before unaided machines in different occupations or tasks could be built to "carry out the tasks *better and more cheaply* than human workers". The survey was sent to 1,634 experts, giving a response rate of 21.5%, with no notable variation in rates of response by measurable demographic attributes. By including "more cheaply"in the wording, the survey focused AI experts on the economic as well as technological feasibility of machines replacing humans at work.

Exhibit 2 summarizes the survey results for occupations and tasks in terms of the median year at which experts expected machines to exceed humans and be cost effective and the 25th to 75th percentile range around the median. The median of the experts' expectations was that machines will outperform humans in several jobs/tasks in the decade or so following the 2016 survey, such as folding laundry (2022), winning the World Series of Poker (2020), transcribing speech (2024), translating languages (2024), writing high-school essays (2026) and driving a truck (2027). Given the success of AI in some of these areas as of 2018, the estimates seem plausible. In the area of folding laundry, Foldimate, a California start-up announced that it would introduce a folding laundry machine for $980 by late 2019. If the machine has a life span like clothes or dish washers and low maintenance cost and does what it is promises to do, it would be cost effective and possibly succeed much as the Rumba robot vacuum cleaner did a decade or so earlier.[30]

Looking further into the future, the machine learning experts expected the development of AI machines that could beat humans in retail work by 2031, writing a bestselling book by 2049, and working as a surgeon by 2053. The survey asked all participants when they expected that AI would achieve *high-level machine intelligence* defined as "when an unaided machines can accomplish every task better and more cheaply than human workers," and asked a subset when machines could be built so that we could automate all human jobs.[31] The median of expected years for high level machine intelligence to outdo humans in all tasks was 45 years, and for automating all jobs was 120 years. Around all of these medians are a wide range of variation in expert views, with AI specialists from Asia anticipating more rapid advances than specialists from North American or Europe.

Given that machine learning experts expertise lies in the technology rather than in the economic or business issues that may slow or speed the effective roll out of the machine in the economy, their assessment of when machines might do various jobs or job tasks *better* than humans is likely to be better than their assessment of when the machines will be able to do the work more cheaply. The difficulty US firms had in adapting the computer technology that motivated Solow's famous (1987) comment "You can see the computer age everywhere but in the productivity statistics" suggests that many organizations will need long periods of trial and error to make AI robot technologies work for them. And some job tasks, even in the most highly automated occupations, will almost surely remain for humans, per comparative advantage.

The Third Law: Income distribution

To the extent the AI robotic technologies create substitutes for human workers at increasingly lower costs, without offsetting creation of new high wage jobs in which AI robot substitutes for humans cannot be readily found, the distribution of income will invariably shift from workers to machines.

Law 3. ***The effect of AI robot technologies on incomes depends on who owns the technologies.***

In a world where machines do much of the work and receive much of the earnings, the economic winners are the owners of the machines while the losers are workers who compete with the machines. Workers whose activity complements the machine will enjoy increases in wages but the period of complementarity will be limited by the laws of increasing substitutability and falling costs of production. In the long run, increases in AI robots/capital will augment labor and drive down wages, seemingly validating Malthus's (1798) dystopic prediction in the Essay on the Principle of Population not because of the infinitely elastic supply of babies at subsistence incomes but because of the continual production of ever cheaper AI robot substitutes owned by someone else. If you own the robot that does your job, you benefit from the new technology. But if I own the robot that does your job, tough luck, suckah! The third law identifies *the* economic problem of a world in which AI robotics does more of the work and earns more of the income as the distribution of ownership of the AI machines and capital more broadly.

2. Employee and Citizen Ownership to the Rescue?

The natural solution to a distribution problem based on the unequal ownership of income earning AI robots and other capital assets is to expand ownership to a larger proportion of the population through increasing *employees' ownership* of their firms and *workers and citizens' ownership* of capital writ large. By ownership, I mean any of a diverse set of property rights over income-producing assets ranging from ownership of the capital, which gives employees or citizens' rights to vote on economic and management decisions, to ownership of streams of income from capital, which give persons rights to the stream but not to the capital itself.

There are many ways to structure employee ownership of capital. Employees can own part of a trust fund that has 100% ownership of a given firm, as exemplified by the UK's iconic John Lewis Partnership, whose trust fund owns the entire firm and which distributes benefits via dividends to each worker[32.] They can be part of 100% worker owned cooperative in which each worker has a vote per Spain's Mondragon worker cooperatives. They can own part of a trust that buys equity out of profits and distributes benefits as retirement income per the US's Employee Stock Ownership Plan (ESOP).

Ownership can also be organized as a start-up, funded by workers taking below market pay; as partnerships with some workers having an ownership stake while others do not; or through employee stock purchase plans that subsidize workers to buy shares as individuals (Bryson and Freeman, 2018). Stock options, which give workers the right to buy shares at a specified strike price but no ownership rights if they do not exercise the option. Workers benefit when the share price rises about the strike price and exercise their option but may cash it in quickly and thus never act as a genuine owne. Options create incentives for workers to improve company performance and raise its share price with contingent and often fleeting ownership.

Modes for paying streams of income from capital to workers range from sales commissions and piece rate forms of pay that link *individual* earnings to output to group incentive pay such as profit-sharing, gain-sharing, or bonus pay dependent on profits or meeting some cost-reduction or other target. Group incentives have surpassed individual incentive systems, presumably because production depends largely on teamwork. Profit-sharing and gain-sharing are often accompanied by participation in the workplace decisions that affect these streams but not on broader firm decisions.

The different forms of ownership have advantages and drawbacks that makes them more or less suitable for particular companies and workers and for motivating workers in the short run and in the long run. Many firms choose a mixture of systems: ownership shares to assure workers commitment over the long run and profit-sharing or bonuses that pay off in the short run. Countries have used both the business tax system and labor relations laws to encourage different forms. The United Kingdom tax system favors employee stock purchases. The US gives tax breaks to ESOP firms. Many European countries mandate works councils that participate in decisions about workplace conditions and other establishment-level decisions without having an ownership stake or explicit profit or gain-sharing program. Germany's co-determination laws place workers on company boards of directors, also without workers having share ownership. France mandates profit-sharing. [33]

The US has arguably the most vibrant employee ownership of capital and capital income in the world, which gives the country a good base from which to adopt policies for increasing workers' ownership as AI robots produce more of GDP. In 2015 15.5 million US workers worked for 9,910 firms with ESOP or ESOP-like plans, constituting 11% of 2015 employment and 13% of private sector employment. Millions more workers have financial stakes in their firms through buying shares in a employee stock purchase plans or through stock options; or stakes in their firm's stream of revenues via profit-sharing or gain-sharing. The ESOP-like companies were valued at $1.4 trillion dollars of which employee ownership had $286.3 billion dollars – an ownership stake of roughly one-fifth.[34]

Overall in 2014 45% of workers in the private sector reported that they either owned shares in their employing firm, had stock options or participated in profit-sharing or gain-sharing modes of compensation. The proportions having profit sharing or gain-sharing exceeding the proportion owning stock or having options (see exhibit 4). The mean amounts of ownership and of profit or gain-sharing are about four times the median amounts, due in part to the greater ownership stake of managers and high paid professionals than other workers in firms that have these systems. The value of stock ownership relative to salary is 95% at the mean and 23% at the median. These figures imply that if the stock value increases at 5% a year, the additional income from ownership is comparable to a 5% higher salary in every year at the mean to a 1% higher salary at the median[35]. Profit-sharing and gain-sharing adds 4-5% to the earnings of the median worker receiving those benefits.

Employee ownership works

The chief economic selling point of employee ownership as that it improves productivity by motivating workers to do more while at the same time spreading income within a firm more evenly. Under the right conditions, the improved productivity pays for the higher earnings of workers and raises return to capital, which can benefit non-employee stakeholders as well as workers. Underlying these generalizations is a substantial empirical literature that has analyzed the effects of ownership on the firm and on workers in the US and other countries.

On the firm side, studies find that firms with ownership or other sharing modes of pay average higher output per worker, higher total factor productivity, and higher return on assets than otherwise comparable firms without such programs. Blasi, Freeman and Kruse (2016) reported that among US firms that entered Fortune's annual Great Places to Work in America competition, return on equity was higher for those with greater employee ownership. Using confidential British Census files, Oxera (2007) found that ownership in the UK, which generally takes the form of employee stock purchases, increased value added per worker by ~ 2.5%. O'Boyle, Pankaj, and Gonzalez-Mulé (2016)'s meta-analysis of econometric studies reported "a small, but positive and statistically significant relation (of ownership) to firm performance (r=0.04)"; and found that the estimated effect among firms that shifted from non-employee ownership to employee ownership was of similar magnitude as between firms with/without employee ownership in a particular time period. The meta-analysis further found evidence that "the effect of employee ownership on performance has increased … over time" and was stronger outside the USA[36] (possibly because ownership is less common outside the US). The National Center for Employee Ownership's review of major studies through the mid-2010s shows the range of data sets and techniques behind studies that provide the base for meta analyses.[37] In addition, employee ownership reduces the chance of a firm going bankrupt or laying off large numbers of workers in a recession.[38]

Workers benefit from ownership by gaining higher incomes via shares or profit-related bonuses and by participating more in workplace decisions. Developing greater trust/loyalty to their firm, workers are more likely to stay with their employer than otherwise comparable workers without such plans and are more likely to monitor co-workers to keep productivity high (see chapters in Kruse, Freeman, and Blasi 2010). Indicative of work conditions at employee-owned firms, a disproportionate proportion of firms selected as Great Places to Work are employee-owned, usually with an ESOP or have broad-based stock options (Blasi, Freeman and Kruse 2016). In the General Social Surveys of 2002, 2006, 2010, and 2014 the average layoff rate for workers with employment ownership was 2.3% compared to 9.9% of workers in firms with no ownership.[39] Consistent with this Kurtulus and Kruse (2016) report that workers in ESOP firms benefited from greater job security in the Great Recession and preceding business cycle downturn.[40]

Critics of employee ownership often stress that workers in employee owned firms may hold too much of their wealth in their employer, risking job and capital if the firm runs into economic trouble. Many ESOP firms deal with the risk problem by having separate 401k or other pension vehicles for workers to own shares outside of the firm. Many workers with stock options cash in on their shares when the shares are “in the money” and many with stock grants sell them quickly as well, so as not to bear too much risk. Blasi, Kruse, and Markowitz (2010) estimate that workers with plausible risk preferences should hold no more than 10-15% of their assets in own firm. But the lower risk of bankruptcy and layoffs in ESOP firms suggests that this estimate may be too conservative.

That firms and their workers that chose ownership or profit-sharing in the past benefited from this choice does not, of course, guarantee that incentivizing other firms to follow suit will generate similar gains. To the extent that firms choose their form rationally, the productivity benefits of ownership are likely to be greater for early adopters who chose the form with limited tax breaks than for late-comers induced by additional tax or other incentives to go employee owned. Measured gains are also likely to fall as the share of firms with ownership grows.

Attitudes

Polls show that a majority of Americans look favorably on employee ownership, which reflects the widespread desire of Americans to have their own business or work for themselves[41]. The first line of exhibit 5 gives the difference between the proportion of persons who view employee ownership positively and the proportion who view it negatively in a 2016 poll. Far more persons of every ideological bent and party preference favor the ownership “concept” than oppose it, though very liberal persons or Democrats had a greater preference for employee ownership than very conservative persons or Republicans. Line 2 shows that a majority of respondents in all groups except those with very conservative views would support legislation favoring ownership. Neither survey question is ideal. The line 1 question had a framing line “so that all the workers in a company share in its success” without pointing out that workers also share in the company's failure. The legislation question does not reference existing legislation favoring ESOP firms nor give any specific legislation or alternative way boost workers or their firm. Still, the poll documents the basic fact that employee ownership has a positive connotation to the majority of Americans.

Lines 3 and 4 of exhibit 5 give the results of questions that go beyond “apple pie”. They put some money figures on the preference for ownership. Line 3 shows that 52% say they would not pay more for a product produced by an employee owned firm, while 48% say they would, with 21% saying they would pay up to 10% more and the other 27% going higher in their willingness to pay more. But it is hard to assess these responses without knowing the price of the product nor the product. People are likely to be more willing to pay 10% extra for something that costs $5.00 than something that costs

$50,000. They may also be more willing to pay more for furniture from an employee owned firm than for pornography from an employee owned firm. Still, the survey results are similar to those from studies that ask persons about their willingness to pay more for goods made under fair labor conditions, whose responses have been validated by experiments.[42] Enough people who say they would pay more for a product made under desirable work conditions actually do so as to make the survey responses believable. Finally, line 4 shows that more persons say they would be moved to buy a product with an Employee Owned label than say they would be moved to buy products with a fair trade label, a great place to work label, or certified B corporation label. That more would shun a product with the certified B label probably reflects the fact that few know what a B corporation is or does.

By contrast, Americans have less favorable views toward a universal basic income (UBI) to deal with the possible adverse effects of AI robotics on workers. In 2017 Gallup asked whether someone supported or opposed"a universal basic income program as a way to help Americans who lose their jobs because of advances in artificial intelligence?" A small majority (52% to 48%) opposed the policy with Republicans strongly opposed and Democrats favoring the UBI.[43] Differences between the sampling design and structure of questions about employee ownership and the UBI muddy any comparison, but the results suggest a leeriness toward UBI as a solution to income problems generated by AI robotics that contrasts with a receptiveness to employee ownership. Finland's 2018 decision to end its two year experiment with a basic income guarantee in 2019 and to make some benefits contingent on the unemployed taking training or having some work activity suggests that the UBI may be an unrealistic path for the US.[44]

Policy Options

If a government were to seek an ownership route of responding to the challenge of AI robotics to the distribution of income, what are the policy options?

Given that tax advantages sparked the initial growth of ESOP companies and that reductions in tax benefits stabilized the ESOP share of employment in the 1980s, one way to encourage greater ownership would be to raise its associated tax benefits, either restoring some benefits that were eliminated to lower the federal deficit or introducing new ones.[45] Another way to make ownership more financially attractive would be to include employee-owned firms among those getting preferential treatment in bidding for public contracts (small businesses, businesses with underrepresented minority or female ownership). The federal government or states could also try to spread knowledge about the advantages and opportunities for firms to choose an employee ownership structure. They could give grants to regional/state centers to develop information, training and policies to facilitate private sector firms considering share ownership. The U.S. Department of Labor, which regulates ESOPs under the ERISA law could ease some regulations to reduce the administrative burden on running an ESOP. Last but not least, government leaders could use their "bully pulpit" to draw attention to employee owned firms. Pro ownership tweets, anyone?

But expansion of employee ownership alone is unlikely to increase worker incomes enough to offset shifts in the distribution of income to machines if AI robots manage to do even half of what machine learning experts expect, much less to arrest the trend toward greater concentration of wealth or income. The exhibit 4 figures that show how much extra income workers earn from profit or gain sharing and stock ownership suggest that extending these forms of compensation more widely might add 5% or so to median income, which is fine if wages are rising but not if the new technologies produce stagnant or falling labor earnings. To assure workers have rising standards of living requires an increase in workers' stake in business capital not only in their own firm but in the entire economy.

Pension fund "socialism" and Sovereign Funds to fill the gap?

Capital income is more unequally distributed than labor income. The top 1% wealth holders have 35% of total wealth, which is about 3 times the share of the top 1% labor income earners in total labor income. Inequality in capital income has also increased more rapidly than inequality in labor income. [46] To the extent that AI robot automation raises capital's share of income, it will add to inequality and accelerate the rising trend in inequality.

To spread ownership of business capital beyond an employees' own firm requires pension funds that invest in business assets broadly and sovereign funds that hold capital in the name of citizens' and distribute the returns to them as well as individual purchases of shares.

Peter Drucker's (1976) The Unseen Revolution: How Pension Fund Socialism Came to America heralded the rising proportion of capital owned by pension funds as a revolution in capitalism that made the US “the first truly socialist country.” Drucker estimated that workers in business firms owned about 25 per cent of equity capital and workers in the public sector, non-profit enterprises or self-employed owned another 10 percent. He predicted that by 1985 workers would own at least 50 percent of equity capital. But the proportion of US equity held by pension funds did not incease as he expected, stabilizing just a bit above his 35% estimate for the early 1970s. Defined contribution plans and IRAs grew at the expense of the defined benefit plans that he saw as the future.[47] The private pension business ended up in the control of a small number of Wall Street firms. In 2016 ten private equity firms had nearly 60% of the 50 largest firms' $1.5 trillion of pension.

President George Bush tried in 2005 to convince Congress and citizens to privatize part of social security in a way that would have boosted pension fund ownership and validated part of Drucker's vision. But Bush's plan foundered for both economic and political reasons, leaving tax-funded Social Security the mainstay of US pensions. A decade earlier Sweden found a more successful way to increase pension fund ownership of capital, by *supplementing* social security through a 2.5% surcharge that workers were obligated to invest in private investment funds.[48] By supplementing its public pension system through the tax surcharge (which the US seemed unwilling to do), Sweden maintained existing benefits while augmenting citizens' ownership of capital. Still, the fact that retirement accounts are accessible only to retirees, such a system would not provide the capital income during the working years that may be needed to supplement labor income in the age of AI robots.

Sovereign funds – state owned investment vehicles that invest public moneys based largely on taxes and royalties from publicly owned natural resources such as oil and gas in real and financial assets – offer a different mechanism to spread capital wealth. Sovereign funds have spread worldwide from their initial creation in Texas, growing in the 21st century to exceed over 7 trillion dollars in assets. Norway has the largest single fund, valued in 2017 at $1.03 trillion or $193,000 per person. It uses its funds primarily to support government spending. Many Mid-Eastern oil countries have also capitalized on their natural resources to create sovereign funds while China, Singapore, Korea, and Australia among other countries have developed such funds from other flows of public moneys.[49]

Texas originated its sovereign fund in 1854 when it created the Permanent School Fund to invest income from public lands/natural resources to support primary and secondary schools. In 2017 the Fund had 41.4 billion dollars and spent $1.06 billion on elementary and secondary schools in the state and provided guarantees for school district bonds that allowed the schools to obtain lower interest rates.[50] In 1876 Texas developed the Permanent University Fund to benefit universities, which has grown into, and allocates five percent of the fund to the University of Texas and Texas A&M for educational spending. Other US states with oil or land resources also established such funds, devoting the moneys to particular social purposes.

Sovereign wealth funds give citizens' a stake in capital wealth that could supplement other incomes, though the only fund that regularly distributes assets to residents is the US's Alaska Permanent Fund. Based on a sizable flow of economic rent from taxes and royalties on state owned oil land, the Alaska Permanent Fund has given each Alaska resident regardless of age a yearly cash dividend, which has ranged from $331 in 1984 to $3,269 in 2008.[51] In the 2010s dividends were on the order of $2,000 per year until 2016 when the governor vetoed half of the allocations passed by the state legislature to use the moneys to reduce a large state budget deficit.[52] Viewing the Alaska Permanent Fund as a universal permanent cash transfer, Jones and Marinescu (2018) found that the dividend had no effect on employment while increasing part-time work and thus worked well as an income transfer. The Alaska experience suggests that Sovereign Funds could play a substantial role in distributing the benefits of economic growth from AI robotics technology in the future, though the funds would presumably have to be financed from public resources beyond land and natural resources.

Given the dependence of modern economies on the stock of scientific and technical knowledge, which derives from government R&D spending on basic science and technology, it may be worthwhile to consider ways to monetize that knowledge base to develop a new Sovereign Fund.

Conclusion

AI robotics create substitutes for humans in brain work as well as in physical labor – a development that suggests that AI robot automation will differ from past automation experiences. To the extent that technology increases substitution between AI robots and humans while the costs of producing machines falls, the new technologies will change the comparative advantage of machines relative to people and are likely to raise the income earned by machines relative to human workers. Studies of the deployment of industrial robots suggests that the technologies are beginning to affect employment and earnings.

Increased ownership of capital offers a potentially fruitful way to spread the benefits of AI robotic technologies widely. Employee ownership has worked well in the US and might gain considerable public support as a response to the challenge of AI robotics technology. But broad ownership of capital outside of an employing firm is also likely to be needed to spread the benefits of that technology to the bulk of workers and citizens. Widening the who in “who owns the robots rules the world” inside and outside the firm deserves serious attention as we approach an economy in which technology could banish scarcity and attain tolerable abundance for all, if its benefits were appropriately distributed.

References

Acemoglu, D. and Restrepo, P. (2017), "Robots and jobs: Evidence from US labor markets", NBER Working Paper No. 23285 (March), Cambridge, MA, available at: http://www.nber.org/papers/w23285 (accessed 1 May 2018).

Autor, D.H. (2013), "The 'task approach' to labor markets: an overview", *Journal Labour Market Research*, Vol. 46, Iss. 3, September, pp. 185-199, available at: http://dx.doi.org/10.1007/s12651-013-0128-z (accessed 1 May 2018).

Autor, D.H. (2015), "Why are there still so many jobs? The history and future of workplace automation", *Journal of Economic Perspectives*, Vol. 29, No. 3, Summer, pp. 3-30, available at: http://www.jstor.org/stable/43550118 (accessed 1 May 2018).

Autor, D.H., Levy, F., and Murnane, R.J. (2003), "The skill content of recent technological change: An empirical exploration", *The Quarterly Journal of Economics*, Vol. 118, Iss. 4, pp. 1279–1333, November.

Arntz, M., Gregory, T. and Zierahn, U. (2016), "The risk of automation for jobs in OECD countries: A comparative analysis", OECD Social, Employment and Migration Working Papers, No. 189, OECD Publishing, Paris, France, available at: http://dx.doi.org/10.1787/5jlz9h56dvq7-en (accessed 1 May 2018)

Bessen, J. (2018), "Automation and jobs: When technology boosts employment", Law and Economics Research Paper No. 17-09, Boston University School of Law, last revised: 28 Mar 2018, https://www.bu.edu/law/working-papers/automation-and-jobs-when-technology-boosts-employment/ (accessed 1 May 2018).

Blasi, J., Freeman, R. and Kruse, D. (2016), "Do broad-based employee ownership, profit sharing and stock options help the best firms do even better?" *British Journal of Industrial Relations*, Vol. 54, Iss. 1, March, pp. 55-82, available at: https://onlinelibrary.wiley.com/toc/14678543/54/1 (accessed 1 May 2018).

Blasi, J.R., Kruse, D.L. and Markowitz, H.M. (2010), "Risk and Lack of Diversification under Employee Ownership and Shared Capitalism," in Kruse, D., Freeman, R. and Blasi, J. (Eds.), *Shared Capitalism at Work: Employee Ownership, Profit and Gain Sharing, and Broad-based Stock Options*, University of Chicago Press for NBER, Chicago, IL, available at: http://papers.nber.org/books/krus08-1 (accessed 1 May 2018).

Brown N. and Sandholm, T. (2018), "Superhuman AI for heads-up no-limit poker: Libratus beats top professionals", *Science*, Vol. 359, Iss. 6374, 26 January, pp. 418-424, available at: DOI: 10.1126/science.aao1733 (accessed 1 May 2018).

Brynjolffson, E. and McAfee, A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a time of Brilliant Technologies,* W. W. Norton & Company, New York, NY.

Chen, Nan (2018), "Are robots replacing routine jobs?" Harvard College Thesis, Applied Mathematics, 30 March.

Dauth, W., Findeisen S., Sudekum, J., Wobner, N. (2017), "German robots – The Impact of Industrial Robots on Workers," IAB-Discussion Paper 30/2017, Institute for Employment Research, Articles on labour market issues, available at: http://doku.iab.de/discussionpapers/2017/dp3017.pdf (accessed 1 May 2018).

Deming, D.J. (2017), "The growing importance of social skills in the labor market," Working Paper No. 21473, NBER, Cambridge, MA, June, available at: http://www.nber.org/papers/w21473 (accessed 1 May 2018).

Drucker, P. (1976), *The Unseen Revolution: How Pension Fund Socialism Came to America*, Harper & Row, New York, NY.

Frey, C.B. and Osborne, M. (2013), "The future of employment: How susceptible are jobs to computerisation?" Working Paper, Oxford Martin Programme on Technology and Employment, University of Oxford, September, available at: https://www.oxfordmartin.ox.ac.uk/publications/view/1314 (accessed 1 May 2018).

Gownder, J.P., Koetzle, L., Condon, C., McNabb, K., Voce, C., Bartels, A., Goetz, M., Hoar, A., Garberg, C., and Lynch, D. (2017), "The future of jobs, 2027: Working side by side with robots", Forrester, 3 April, available at: https://www.forrester.com/report/The+Future+Of+Jobs+2027+Working+Side+By+Side+With+Robots/-/E-RES119861 (accessed 1 May 2018).

Gomory, R.E. and Baumol, W.J. (2000), *Global Trade and Conflicting National Interests*, MIT Press, Cambridge, MA.

Goldsmith, S. (2010), "The Alaska Permanent Fund dividend: A case study in implementation of a Basic Income Guarantee", presented at 13th Basic Income Earth Network Congress, July, University of Sao Paulo, Sao Paulo, Brazil, available at: http://www.iser.uaa.alaska.edu/Publications/bien_xiii_ak_pfd_lessons.pdf (accessed 1 May 2018).

Grace, K., Salvatier, J., Dafoe, A., Zhang B. and Evans, O. (2017), "When will AI exceed human performance? Evidence from AI experts", 30 May, available at: arXiv:1705.08807v2 (accessed 1 May 2018).

Graetz, G. and Michaels, G. (2015), "Robots as work", Discussion Paper No. 1335, CEP, March, available at: http://cep.lse.ac.uk/pubs/download/dp1335.pdf (accessed 1 May 2018).

Hong, G., Zhou, T., Schuhmann, T., Viveros, R., Lieber, C. (2018) "Mesh electronics: a new paradigm for tissue-like brain probes" *Current Opinion in Neurobiology,* Vol. 50, June, pp. 33-41, available at https://www.sciencedirect.com/science/article/pii/S0959438817301952?via%3Dihub (accessed 1 May 2018).

International Federation of Robotics (2016), "World Robotics: Industrial Robots 2016", Report.

Jones, D. and Marinescu, I. (2018). “The labor market impacts of Universal and Permanent Cash Transfers: Evidence from the Alaska Permanent Fund”, Working Paper No. 24312, NBER, Cambridge, MA, February, available at: http://www.nber.org/papers/w24312 (accessed 1 May 2018).

Kruse, D., Freeman, R. and Blasi, J. (2010). *Shared Capitalism at Work: Employee Ownership, Profit and Gain Sharing, and Broad-based Stock Options*, University of Chicago Press for NBER, Chicago, IL, available at: http://papers.nber.org/books/krus08-1 (accessed 1 May 2018).

Kurtulus, F.A. and Kruse, D.L. (2017), “How did Employee Ownership Firms weather the last two recessions?: Employee Ownership, employment stability, and firm survival in the United States: 1999-2011”, W.E. Upjohn Institute for Employment Research, Kalamazoo, MI, available at https://doi.org/10.17848/9780880995276 (accessed 1 May 2018).

Mishel, L. and Bivens, J. (2017), “The zombie robot argument lurches on: There is no evidence that automation leads to joblessness or inequality”, Economic Policy Institute Report, Washington, DC, 24 May, available at: https://www.epi.org/publication/the-zombie-robot-argument-lurches-on-there-is-no-evidence-that-automation-leads-to-joblessness-or-inequality/ (accessed 1 May 2018)

Manyika, J., Lunda, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., Ko, R., Sanghvi, S. (2017), “Jobs lost, jobs gained: Workforce transitions in a time of automation”, Executive Summary (December), McKinsey Global Institute. Available at: https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Future%20of%20Organizations/What%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/MGI-Jobs-Lost-Jobs-Gained-Report-December-6-2017.ashx (accessed 1 May 2018).

Moravčík, M., Schmid, M., Burch, N., Lisý, V., Morrill, D., Bard, N., Davis, T., Waugh, K., Johanson, M., Bowling, M., (2017), “DeepStack: Expert-level artificial intelligence in heads-up no-limit poker”, *Science*, Vol. 356, Iss. 6337, (May 5), pp. 508-513, available at: http://science.sciencemag.org/content/356/6337/508.full (accessed 1 May 2018).

Nedelkoska, L. and Quintini, G. (2018), "Automation, skills use and training", OECD Social, Employment and Migration Working Papers, No. 202, OECD Publishing, Paris, available at: http://dx.doi.org/10.1787/2e2f4eea-en (accessed 1 May 2018).

National Commission on Technology, Automation and Economic Progress, (1966) “Technology and the American Economy” USGPO .Washington, DC. February, available at: https://files.eric.ed.gov/fulltext/ED023803.pdf (accessed 1 May 2018)

O’Boyle, E.H., Pankaj, C.P., Gonzalez-Mulé, E. (2016), “Employee ownership and firm performance: a meta-analysis”, *Human Resource Management Journal*, Vol. 26, Iss. 4, November, pp. 425–448, available at: https://onlinelibrary.wiley.com/toc/17488583/26/4 (accessed 1 May 2018).

Oxera (2007), “Tax-advantaged employee share schemes: analysis of productivity effects”, HM Revenue & Customs Research Report No. 33, August, HM Revenue & Customs, Oxford, UK, available at: http://webarchive.nationalarchives.gov.uk/20080804003221/http://www.hmrc.gov.uk//research/index.htm (accessed 1 May 2018).

Brown, J., Gosling, T., Sethi, B., Sheppard, B., Stubbings, C., Sviokla, J., Williams, J., Zarubina, D., Fisher, L., (2017), "Workforce of the future: The competing forces shaping 2030", PwC, available at: https://www.pwc.com/gx/en/services/people-organisation/workforce-of-the-future/workforce-of-the-future-the-competing-forces-shaping-2030-pwc.pdf (accessed 1 May 2018).

Rhokeun, P., Kruse, D., Sesil, J., (2004), "Does Employee Ownership Enhance Firm Survival?, in Perotin, V. and Robinson, A., (Eds.), *Employee Participation, Firm Performance and Survival*, Volume 8 in the Series, Advances in the Economic Analysis of Participatory & Labor-Managed Firms, Emerald Publishing Limited, Bingly, UK, pp.3-33, available at https://www.emeraldinsight.com/doi/pdfplus/10.1016/S0885-3339%2804%2908001-9 (accessed 1 May 2018).

Rosenthal, S.M. and Austin, L.S. (2016), "The dwindling taxable share of U.S. Corporate Stock", Special Report, tax notes, Tax Policy Center, Urban Institute & Brookings Institution, 16 May, available at: http://www.taxpolicycenter.org/publications/dwindling-taxable-share-us-corporate-stock/full (accessed 1 May 2018).

Saez, E. (2011), "Lecture 196: Income inequality and redistributive policies", Econometrics Lecture, Econometrics Laboratory, University of California, Berkeley, September, available at: https://eml.berkeley.edu/~webfac/eichengreen/e196_fa11/saez_196_9-21-11.pdf (accessed 1 May 2018).

Simon, H.A., (1965), *The Shape of Automation for Men and Management*, Harper & Row, New York, NY.

Tsacoumis, S., and Willison, S., (2010), "O*NET Analyst Occupational Skill Ratings: Procedures," FR-08-70, Human Resource Research Organization (HumRRO), National Center for O*NET Center, Alexandria, VA March, available at: https://www.onetcenter.org/reports/AOSkills_Proc.html (accessed 1 May 2018).

U.S. Bureau of Labor Statistics, 2018. "Employment Projections", available at: https://www.bls.gov/emp/ (accessed 1 May 2018).

Exhibit 1: The Advance of AI Robots in Cognitive Space

1997 IBM's Deep Blue beats Chess champion Kasparov
2011 IBM's Watson defeated human Jeopardy champions
2016 Google's Alpha Go algorithm defeated Korean Go master Lee Sedol

2016 Carnegie Mellon's Libratus beat top poker pros
2016 University of Alberta's Deep Stack won No Limit Texas Hold'em Poker Tournament

2017 Google's Alpha Go algorithm defeated World Go champion Ke Jie
2017 Google's AlphaZero learns Chess and Go and beats chess and Go programs in weekend

2018 LawGeex AI program beats 20 human lawyers in finding problems with legal contracts.

Exhibit 2: Responses of 352 AI Experts to Questions about Years until a Machine Can do a job Better and More Cheaply Than a Human"

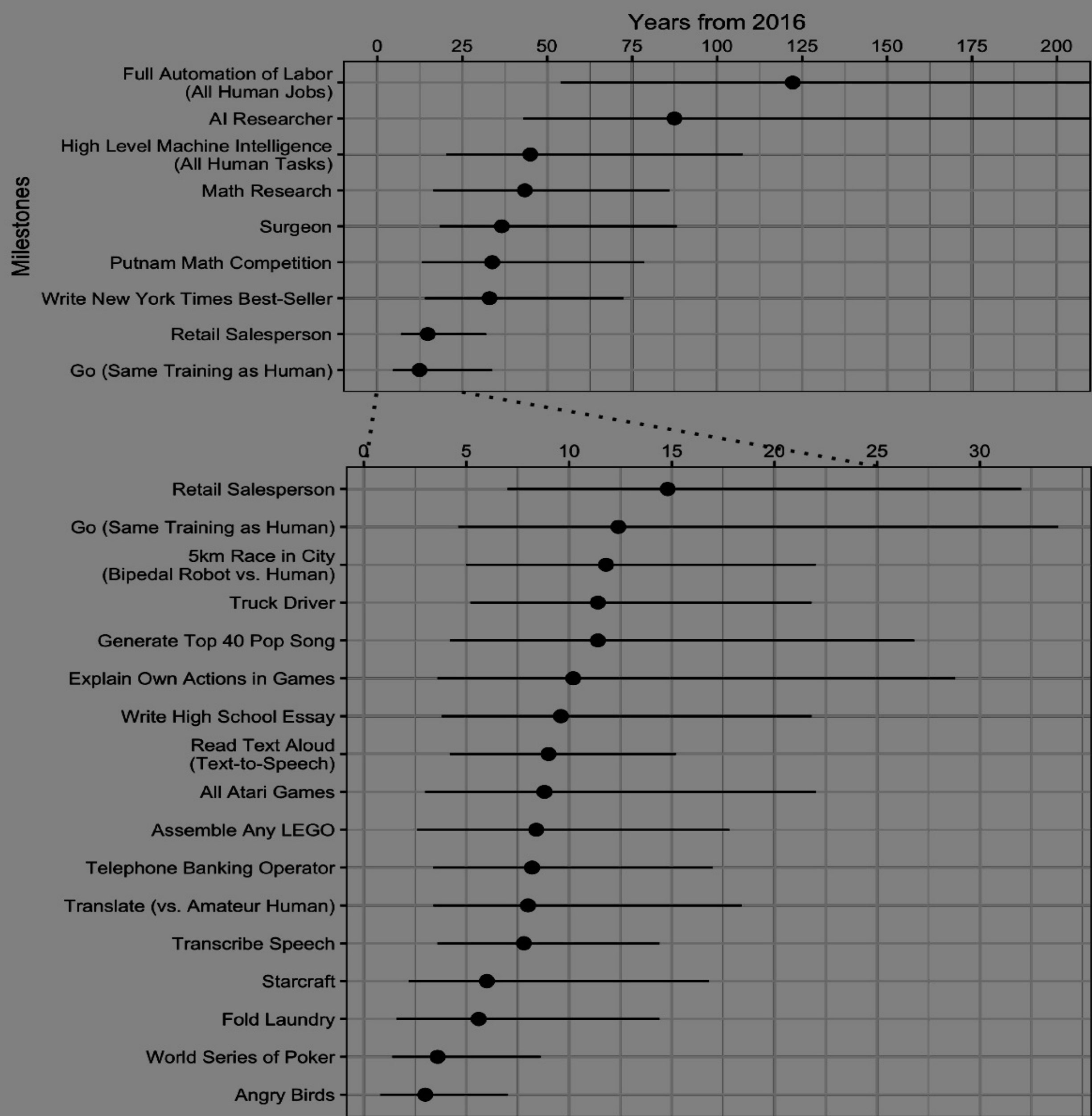
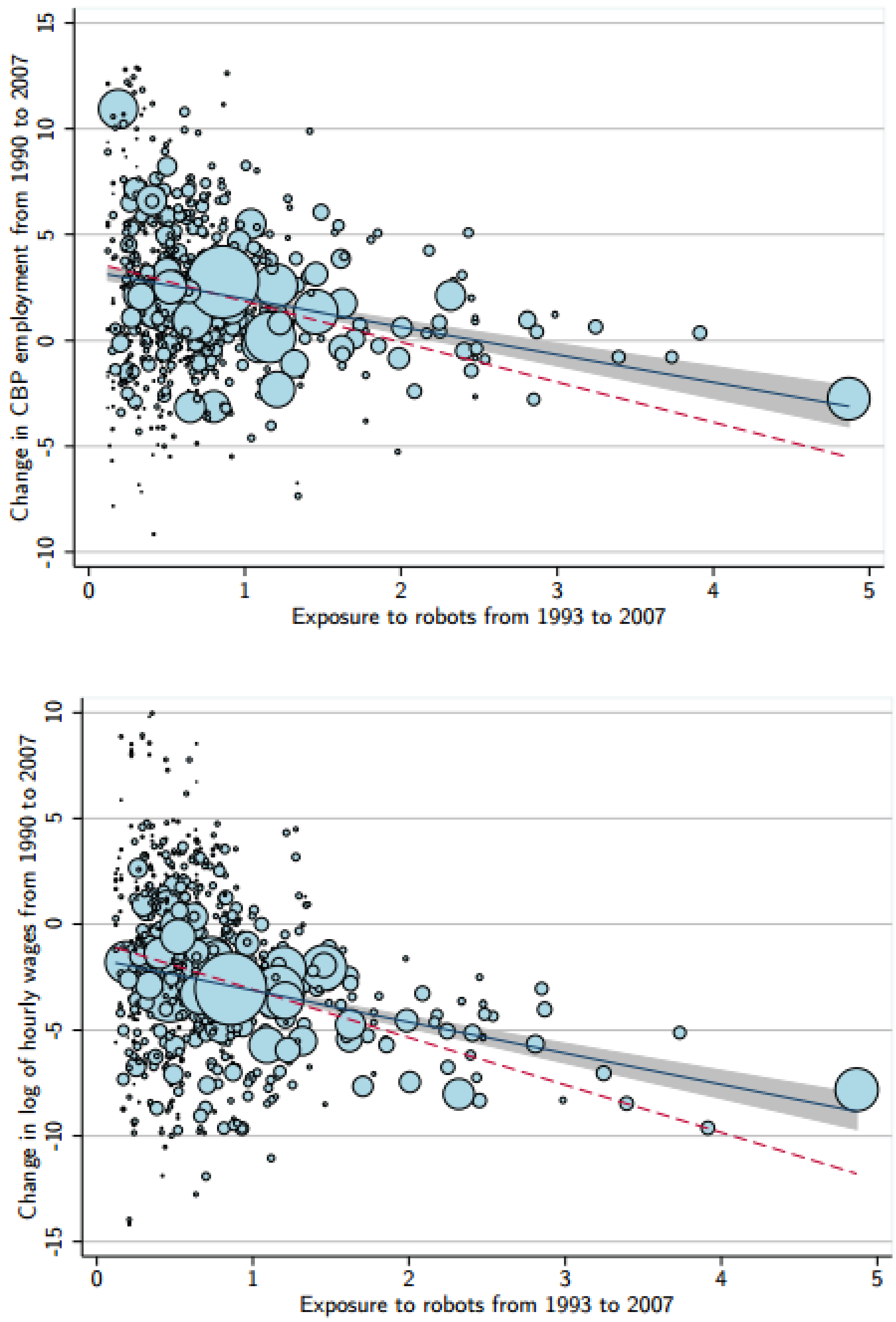


Figure 2: Timeline of Median Estimates (with 50% intervals) for AI Achieving Human Performance. Timelines showing 50% probability intervals for achieving selected AI milestones. Specifically, intervals represent the date range from the 25% to 75% probability of the event occurring, calculated from the mean of individual CDFs as in Fig. 1. Circles denote the 50%-probability year. Each milestone is for AI to achieve or surpass human expert/professional performance (full descriptions in Table S5). Note that these intervals represent the uncertainty of survey respondents, not estimation uncertainty.

Source: Grace et.al. (2017), Figure 2, arXiv:1705.08807v2

Exhibit 3: Robot Density in an Area (based on industrial mix) negatively related to employment and wages in Commuting Zones in US, 1933-2007



Source: The panels shows the residual plot, based on details from Acemoglu, D.and P. Restrepo (2017), Figure 7, Panel B and Figure 8, Panel A, http://www.nber.org/papers/w23285.

Exhibit 4: The Share of Private Sector Workers with Some Form of Ownership: 2014

Ownership of Capital or Stream of capital-related income	Own company stock	Profit-Sharing	Gain-sharing	Stock Options	ALL Types of ownership
Percentage of workers with given form of ownership	19.5%	35.8%	25.3%	7.2%	44.7%
Size of Financial stake					
Mean value	$45, 342	$8,347	$7,689		
Median value	$10,000	$2,000	$2,000		
Financial Stake as Percent of Salary					
Mean	95%	11%	10%		
Median	23%	5%	4%		

Source: Calculated from NORC General Social Survey 2014, reported in https://www.nceo.org/articles/statistical-profile-employee-ownership

Exhibit 5: Attitudes toward Employee Ownership and Legislation

1. Support or opposition for "concept of companies being owned by their employees, so that all the workers at a company share in its success?" % support -% oppose"

	By ideology	By party identification	
Very liberal	89%	Democrat	72%
Somewhat liberal	64%		
Moderate	64%	Independent	35%
Somewhat Conservative	37%		
Very Conservative	16%	Republican	39%

2. Would you support or oppose a bill/legislation that makes it easier for employees to own a part of the business where they work

	By ideology	By party identification	
Very liberal	87%	Democrat	66%
Somewhat liberal	51%		
Moderate	46%	Independent	31%
Somewhat Conservative	15%		
Very Conservative	-9%	Republican	31%

3. Would you pay more for a product with this EO Mark on its package?

Would not pay more	52%
Would pay up to 10% more	21%
Would pay 11% to 20% more	10%
Would pay 21% to 30% more	7%

4. Employee Ownership Compared to Other Certifications

	Employee-Owned Certified	Fair Trade Certified	Great Place to Work	Certified B Corporation
Much more likely to buy	13%	11%	4%	4%
Somewhat more likely to buy	28%	24%	16%	10%
No change	50%	52%	64%	67%
Somewhat less likely to buy	3%	5%	5%	9%
Much less likely to buy	6%	8%	10%	10%

Source: https://www.nceo.org/articles/surveys-show-strong-preference-employee-owned-products-services

[1] *Guardian*, Jan 11, 2017; *Wired*, Nov 28, 2017 *Morningstar*, Dec 4, 2017; *New York Times*, Dec 11, 2017; *Popular Mechanics*, Feb 27, 2018, *Newsweek*, Jan 15, 2018

[2] https://www.extremetech.com/extreme/233746-ai-beats-doctors-at-visual-diagnosis-observes-many-times-more-lung-cancer-signals ; https://hbr.org/2017/07/ai-may-soon-replace-even-the-most-elite-consultants ; https://www.engadget.com/2017/08/29/robot-caregivers-are-saving-the-elderly-from-lives-of-loneliness/

[3] Frey and Obborne (2013); Manyika et.al. (2017); Brown and Sandholm (2018), etc. Nedelkoska and Qintini (2018) downplay the range of jobs in which AI robots can compete wit humans and stress that the main effect is likely to fall on low skill jobs, polarizing the labor market.

[4] See Mishel and Bivens (2017) for the traditionalist view.

[5] Simon (1965)

[6] http://theconversation.com/twenty-years-on-from-deep-blue-vs-kasparov-how-a-chess-match-started-the-big-data-revolution-76882. Although Kasparov's emotional response to some machine moves contributed to his defeat, there is little doubt the machine would have improved to defeat him in a future contest.

[7] https://www.techrepublic.com/article/ibm-watson-the-inside-story-of-how-the-jeopardy-winning-supercomputer-was-born-and-what-it-wants-to-do-next/

[8] https://www.wired.com/2014/05/the-world-of-computer-go/ By 2014, the estimated time for in 2014 to ten years time;

http://www.businessinsider.com/ai-experts-were-way-off-on-when-a-computer-could-win-go-2016-3?IR=T

[9] https://www.tastehit.com/blog/google-deepmind-alphago-how-it-works/

[10] https://en.wikipedia.org/wiki/AlphaGo.

[11] https://www.theguardian.com/technology/2017/jan/30/libratus-poker-artificial-intelligence-professional-human-players-competition. Also see Brown and Sandholm (2018); Moravčík, et.al. (2017).

[12] For the 20th century lyrics from Annie Get Your Gun, see https://genius.com/Irving-berlin-anything-you-can-do-lyrics.

[13] https://www.predictiveanalyticstoday.com/top-intelligent-personal-assistants-automated-personal-assistants/

[14] Science Alert, https://www.sciencealert.com/it-took-4-hours-google-s-ai-world-s-best-chess-player-deepmind-alphazero. The article quotes one human expert declaring, "This algorithm could run cities, continents, universes."

[15] https://www.theguardian.com/science/2017/oct/18/its-able-to-create-knowledge-itself-google-unveils-ai-learns-all-on-its-own

[16] https://www.npr.org/sections/alltechconsidered/2016/12/11/504953475/behold-a-robot-hand-with-a-soft-touch

[17] The IFR is an industry association of robot manufacturers. Its count of robots uses the ISO 8373:2012 definition: An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes ...for use in industrial automation applications. See: https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-2:v1:en

[18] But robots have not attained the flexibility to beat humans over the wide breadth of welding work outside automobiles so the number of welders overall has fallen only modestly.

[19] The measure of routine is taken from the Department of Labor's O*NET data base of occupational characteristics, following work by Autor et al. and Deming (2017) that stresses the importance of that dimension of work on the effects of technological change on employment or earnings.

[20] For instance, impacts within areas could be differentiated between the high robot intensity industries, which are likely to be impacted first, and other sectors, and area differences in robots could be examined among establishments with Census's forthcoming Survey of Manufacturers module on robots. Occupational attributes beyond routine work could be linked to robots. The difference between Graetz and Michael's (2015) estimated positive effects of robotization on wages in country-industry calculations and the negative estimated effects on wages in the US area and occupation analyses and Germany industry also could be explored.

[21] Freeman (2014) ("Who Owns the Robots Rules the World" https://wol.iza.org/articles/who-owns-the-robots-rules-the-world/long. Asimov created the three laws of robotics.

[22] https://en.wikipedia.org/wiki/Three_Laws_of_Robotics quotes from "Handbook of Robotics, 56th Edition, 2058 A.D. The laws forbid robots from injuring humans; require that robots obey human orders beings except where that injures a human; and protect its own existence as long as this does not harm or disobey a human.

[23] Machine learning algorithms "learn" from data and make predictions by fitting the data to predict future outcomes and determine best decisions. With big data, the algorithms often learn from part of the data (training data set) and test the prediction equations on another part of the data (test data set). For some of the major algorithms see https://en.wikipedia.org/wiki/Outline_of_machine_learning#Machine_learning_methods

[24] https://en.wikipedia.org/wiki/Bio-inspired_robotics

[25] Elon Mosk's Neuralink seeks to build a pathway between an enhanced or wired brain and an external computer device. https://www.theverge.com/2017/3/27/15077864/elon-musk-neuralink-brain-computer-interface-ai-cyborgs https://www.outerplaces.com/science/item/17444-neuralink-brain-implant-elon-musk-black-mirror. See also Kiki Sanford "Will This "Neural Lace" Brain Implant Help Us Compete with AI?" *Nautilus Blog,* 4 April 2018. Hong et.al. (2018) report on advances in brain-mapping that blurb the distinction between neural and electronic networks.

[26] The elasticity of labor demand in a two factor model is decomposable into a weighted average of the elasticity of substitution (σ) and the elasticity of product demand (η), with the weight being labor's share of cost (a). $a\eta + (1\text{-}a)\,\sigma$

[27] ARKInvest estimates that in 2015 dollars industrial robots that cost $131,000 in 1995 fell to $68,000 in 2005 and to $31,312 in 2014 – real price drops of 6.5% a year in 1995-2005 and 8.6% per year in 2005-2014 https://ark-invest.com/research/industrial-robot-costs The Boston Consulting Group estimated that the nominal price of welding robots used by the automobile industry fell from $55,000 in 2005 to $33,000 in 2014 – a drop of 5.7% per year, or -7.9% per year in constant dollars. See https://www.slideshare.net/TheBostonConsultingGroup/robotics-in-manufacturing

[28] https://www.slideshare.net/TheBostonConsultingGroup/robotics-in-manufacturing

[29] https://www.robots.com/faq/how-much-does-robot-automation-cost

[30] https://laundroid.sevendreamers.com/en/ https://foldimate.com/. In 2018 a Japanese firm, Seven Dreamers, demonstrated a laundry folding machine humans priced at $16,000, too expensive for the household market but perhaps not for commercial use. https://www.theverge.com/2018/1/10/16865506/laundroid-laundry-folding-machine-foldimate-ces-2018

[31] Grace, et al, (2017, p.1 and p.2)

[32] https://www.johnlewispartnership.co.uk/about.html ; https://www.johnlewispartnership.co.uk/about/our-constitution.html

[33] For the variation in the US see https://www.nceo.org/, which specializes in ESOP forms. Also see https://bthechange.com/the-many-faces-of-employee-ownership-aa048ba262af. For variation in Europe see http://www.efesonline.org/fasuk61.htm. The EU Promotion of Employee Participation http://ec.europa.eu/internal_market/company/docs/modern/141028-study-for-dg-markt_en.pdf. The Global equity organization (https://www.globalequity.org/geo/) has information on employee ownership worldwide.

[34] https://www.nceo.org/articles/statistical-profile-employee-ownership

[35] With a mean value of stock to salary of 95% and a 5% return to the stock the salary equivalence is 4.75% (0.95 x 5%). Similarly with a median value of stock if 23%, the salary equivalence is 1,15%.

[36] Oxera (2007); Blasi, Freeman and Kruse (2016); O'Boyle, Pankaj, and Gonzalez-Mulé (2016).

[37] https://www.nceo.org/articles/research-employee-ownership-corporate-performance

[38] Rhokeun, Kruse and Sesil (2004)

[39] https://www.nceo.org/assets/pdf/articles/GSS-2014-data.pdf

[40] Kruse, Freeman and Blasi (2010) chapter 8 summarizes these studies; chapter 2 analyzes worker monitoring co-workers. For best places to work, see Blasi, Freeman and Kruse (2016); Kurtulus and Kruse (2017) examines ownership and employment fluctuations.

[41] http://news.gallup.com/poll/15832/majority-americans-want-start-own-business.aspx

[42] https://www.hbs.edu/faculty/conferences/2014-launching-the-star-lab/Documents/FT_final_2_20.pdf

[43] http://news.gallup.com/poll/228194/public-split-basic-income-workers-replaced-robots.aspx

[44] https://www.theguardian.com/world/2018/apr/23/finland-to-end-basic-income-trial-after-two-years

[45] See Blasi, Kruse and Freeman (2016) for one set of policy suggestions. The 2017 Republican Tax Bill included a section that eliminated Internal Revenue Code 162(m), obviating the Blasi-Freeman-Kruse proposal to improve the tax incentives for employee ownership by allowing deductions for executive performance pay as a business expense only if the performance plan covered all employees (as in deductions for health and retirement plans), Congress would have to devise a new tax incentive to encourage more firms to adopt ownership forms.

[46] Saez (2011); http://www.slate.com/blogs/moneybox/2013/12/17/capital_inequality_it_s_bigger_and_a_bigger_deal_than_labor_inequality.html . For trends see https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/10-25-householdincome0.pdf, figures 6 and 7.

[47] Rosenthal and Austin (2016).

[48] The Swedish mandated private pension investment system has had some problems but earns about 4% more per year than had the money been in Sweden's social security system. See http://www.investmenteurope.net/research/swedens-ppm-share-of-public-pension-shows-better-returns-than-income-share/

[49] https://www.swfinstitute.org/sovereign-wealth-fund-rankings/ A slightly different set of estimates are found in https://en.wikipedia.org/wiki/List_of_countries_by_sovereign_wealth_funds

[50] see: https://tea.texas.gov/Finance_and_Grants/Texas_Permanent_School_Fund/Texas_Permanent_School_Fund_-_Annual_Report/

[51] https://www.vox.com/policy-and-politics/2018/2/13/16997188/alaska-basic-income-permanent-fund-oil-revenue-study ;
Goldsmith (2010).

[52] http://basicincome.org/news/2016/09/alaska-us-amount-2016-permanent-fund-dividend-1022/