Automation, AI & Work

Laura D. Tyson & John Zysman

We characterize artificial intelligence as "routine-biased technological change on steroids," adding intelligence to automation tools that substitute for humans in **physical** *tasks and substituting for humans in routine and increasingly nonroutine* **cognitive** *tasks. We predict how AI will displace humans from existing tasks while increasing demand for humans in new tasks in both manufacturing and services. We also examine the effects of AI-enabled digital platforms on labor. Our conjecture is that AI will continue, even intensify, automation's adverse effects on labor, including the polarization of employment, stagnant wage growth for middle- and low-skill workers, growing inequality, and a lack of good jobs. Though there likely will be enough jobs to keep pace with the slow growth of the labor supply in the advanced economies, we are skeptical that AI and ongoing automation will support the creation of* **enough good jobs***. We doubt that the anticipated productivity and growth benefits of AI will be widely shared, predicting instead that they will fuel more inequality. Yet we are optimistic that interventions can mitigate or offset AI's adverse effects on labor. Ultimately, how the benefits of intelligent automation tools are realized and shared depends not simply on their technological design but on the design of intelligent policies.*

Amazing new automation and digital technologies are transforming work and the economy.[1] Artificial intelligence is the latest tool in a toolkit of "automation" technologies that perform tasks previously performed by humans, often more cheaply, faster, and better.

Most humans depend on income from work for their livelihoods, and we focus on how AI, like other forms of automation, affects work. A key question is how AI and AI-enabled intelligent tools will impact the supply of and access to good jobs that provide middle-class earnings, safe working conditions, legal protections, social insurance and benefits, and career-building opportunities. In the advanced market economies and democracies that are the focus of this essay, political and social stability depends on the availability and accessibility of good jobs.

With supportive fiscal and monetary policies adequate to maintain high levels of employment, it is likely that there will be *enough jobs* to keep pace with the slow growth of the labor supply in these economies. But we are skeptical that AI along with ongoing automation will support the creation of *enough good jobs*. And we are doubtful that the anticipated productivity and growth benefits of AI will be

© 2022 by Laura D. Tyson & John Zysman
Published under a Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) license
https://doi.org/10.1162/DAED_a_01914

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

widely shared, predicting instead that they will fuel income and wealth inequality. Yet we are optimistic that wise interventions can change the trajectory of AI's adverse effects on labor. Comparative experiences highlighted in this essay reveal that both policies, like social insurance, training and education, and taxation, and institutions, like collective bargaining, can accelerate, offset, moderate, or intensify these effects.

Contemporary AI uses advanced computation to automate specific tasks at or above human cognitive capacity. Its development rests on advances in computing power and hardware, the proliferation of vast data sets, and evolving algorithms for analyzing and drawing statistical inferences and predictions.[2] Powered by machine learning (ML), recent AI breakthroughs are achieving human-comparable results across an expanding range of human tasks.[3] Despite remarkable advances, however, current AI applications remain narrow and task specific, with little ability to transfer "learning" from one problem to another. Narrow AI can displace humans in *low-level cognitive demand* tasks that are repetitive, data intensive, optimization-based, and asocial, but it cannot yet substitute for humans in most *high-level cognitive demand* tasks involving reasoning, real-world knowledge, judgment, and social interactions.

Narrow AI is also impacting human tasks both by adding intelligence to robots and production systems and by powering digital platforms that facilitate transactions between buyers and sellers. In a self-reinforcing cycle of data collection, analysis, and prediction, AI is driving the growth of digital platforms like Amazon for selling goods, Netflix for selling video services, and Uber and Upwork for selling labor services. Indeed, large tech platform companies in the United States and China, with massive amounts of data, extensive digital platforms, and relatively small employment compared with their revenues, currently account for about two-thirds of all business investment in AI.

"Artificial general intelligence" (AGI) has no clear definition, no clear time frame, is not yet a matter of business and policy concerns, and is therefore not our focus.[4] Instead, we concentrate on how narrow but rapidly evolving AI applications are likely to affect labor and livelihoods over the coming decade. Since even narrow AI applications are not yet widespread, our analysis by necessity draws on evidence about the impacts of other forms of automation on labor in the advanced industrial countries during the last three decades.

Predictions about the future effects of AI are replete with uncertainties both about the pace and scope of future scientific breakthroughs and about the pace and breadth of AI deployment. *Scientific advances determine whether a human task is technically automatable, but they do not determine whether it will be automated. That depends on deployment decisions.* In market economies, businesses make most of these decisions shaped by their strategies and the market, institutional,

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

and policy environments in which they operate. High taxes on labor relative to taxes on machinery and software, for example, have been a significant driver of business investments in automation technologies. Nonetheless, their deployment has been gradual because of substantial lags in the development of organizational capacities required for their effective utilization.[5]

Both historical evidence and economic logic indicate that on its current trajectory, AI will continue, intensify, and accelerate automation's adverse effects on key labor market trends in the advanced economies. These effects include the polarization of employment and wages, slow wage growth for middle- and low-skill workers, a significant premium in the wages of highly educated workers, a decoupling of wage growth from productivity growth, a decline in labor's share of value added, and growing income inequality.

Automation is not the only force behind these trends. Globalization, outsourcing, the decline in unionization and collective bargaining coverage, and the growing monopsony or "wage-setting" power of businesses are also significant factors.[6] These factors in turn have been enabled or reinforced by automation. Globalization and outsourcing, for example, have been turbocharged by robots and digitization in logistics, transportation, and communication.[7] By enabling the outsourcing of routine jobs to low-wage locations, networked technologies and automation, underpinned by the digital revolution, have propelled globalization, decreasing employment and constraining wage growth in manufacturing and tradable services in the advanced economies.

Yet while these factors have been at play in all of the advanced countries, there have been important differences among them in the consequences for labor. The varied outcomes have resulted in part from differences in policies, institutions, and societal norms of fairness. Strong competitive economies like Germany, Sweden, Canada, and Denmark have experienced the same technological and globalization forces as the United States, but their workers have fared much better.[8]

Examining *tasks* within occupations is a widely used optic to understand the impact of automation on labor, and we organize our analysis with this approach. Occupations encompass numerous tasks, only some of which are automatable or AI-susceptible.

Like other automation tools, AI impacts human tasks through three broad effects: the *displacement* effect, or the decrease in demand for labor in tasks that are automated; the *productivity* effect, or the increase in the demand for labor in nonautomated tasks; and the *reinstatement* effect, or the creation of new tasks for labor. Over time, but at a highly uncertain pace, automation's displacement effects are offset to some extent by both its productivity and reinstatement effects.[9]

The displacement effects can be immediate, significant, and palpable, and are themselves negative for employment and labor's share in value added. In contrast, the productivity and reinstatement benefits can take years, even decades, to mate-

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

rialize with significant frictional and structural unemployment, wage losses, and growing inequality along the way. In the long run – that ill-defined concept frequently used by economists – automation, productivity growth, and rising employment and wages move together.

But automation always involves disruption and, with it, winners and losers. Trade-offs can and do persist for "shorter" time horizons relevant to businesses, workers, citizens, and political leaders, and they have economic, social, and political consequences. History is replete with evidence that the social and political costs of labor market disruptions triggered by technological change can be significant.[10] And while displacement effects may hit particular locations or regions, productivity and reinstatement benefits can occur elsewhere: the costs often fall in one place and the benefits in another, complicating politics and policy.[11]

During the last thirty years, there is evidence that while automation's displacement effects have accelerated and intensified, its productivity and reinstatement effects have been slower to materialize and smaller than expected.[12] *The social and economic dislocations have grown, while the offsetting benefits have not been as robust or rapid as anticipated and have not been broadly shared.* In the United States, for example, despite growing automation and computerization of work, productivity growth slowed by nearly half to an annual rate of 1.5 percent during the last half century, and industries that led in the use of new information and communication technologies did not perform better in terms of total factor productivity, output, or employment growth. Nor is the United States alone: other advanced industrial economies have also experienced slowing productivity growth, the causes of which remain uncertain and robustly debated.[13]

Much of the automation during the last three decades is often called "routine-biased technological change," or RBTC, because it has substituted for humans in routine physical and increasingly routine cognitive tasks while increasing the demand for humans in nonroutine tasks. Both routine manual and routine cognitive occupations as a share of employment have fallen over the last thirty years. RBTC has been particularly important in automating tasks in structured, predictable environments like automobile production in factories and bookkeeping in offices.

We characterize AI as "RBTC on steroids" for two reasons. First, AI is adding intelligence to robots and other forms of automation that substitute for humans in routine and increasingly nonroutine physical tasks – think assembly-line production and warehousing. Second, AI is substituting for humans in a widening array of both routine and increasingly nonroutine cognitive tasks.[14] Cognitive tasks that are currently technically feasible for AI tend to be routine, data-intensive, and asocial (such as customer support, basic office support, and insurance underwriting). Physical tasks that are technically feasible for AI also tend to be routine, data-intensive, optimization-based, and asocial, and require limited dexterity and a structured environment (like assembly-line inspection or fruit harvesting). Most

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

high-level cognitive demand tasks in which inputs and outputs are not easily quantifiable with data, and which require both social interaction and cross-domain thinking, complex strategy, or creativity (such as the work of business and health professionals, teachers, and artists) are not directly in the crosshairs of current AI.[15]

If, as we conjecture, AI is RBTC on steroids, then its future effects on labor will be similar to the effects on labor from other forms of RBTC automation during the past thirty years. The first of these effects is the "polarization" of employment and, to a lesser extent, of wages. Many of the occupations hollowed out by RBTC over the previous three decades have been in manufacturing, which provided good jobs for millions of middle-skill, middle-wage workers. Polarization is reflected in a decline in the share of middle-skill occupations in total employment and increases in the employment shares of both low-skill and high-skill occupations, with the largest gains in the latter.[16] Although RBTC has been polarizing, it has been "upgrading" or "upskilling" in the sense that the decline in middle-skill occupations has been largely offset by an increase in high-skill occupations as shares of total employment.[17]

Polarization, in turn, has contributed to widening wage gaps among workers, with slow, stagnant, or even negative wage growth for workers whose occupations have been displaced by automation, and wage growth for those whose occupations have been enhanced by productivity gains or by the creation of new tasks. Earnings inequality has grown across the advanced industrial economies, largely driven by the rising pay gap or education premium between workers with a college-level education or rigorous training (like apprenticeships in Germany) whose skills have been complemented by RBTC and those with lower levels of education or training whose skills have been displaced.[18]

As a result of its sizable displacement and polarization effects, RBTC automation has also been a factor behind the decoupling of wage growth from productivity growth.[19] In theory, in competitive labor markets, wage growth should be commensurate with productivity growth in the long run, but productivity growth has outpaced both average and median wage growth over the past three decades. As noted earlier, the long run can be very long indeed, and there are large and lengthy aberrations along the path to getting there. Moreover, labor markets are usually not competitive, as narrowly defined by economists, and the sharing of productivity gains with workers depends not only on market forces but on the relative power of workers and employers. Relative power in turn is often reflected in tax and social policies and in institutions like corporate governance rules that favor owners over workers.

The decoupling of wage and productivity growth has contributed to a decline in labor's share of national income.[20] Indeed, automation has been a major driver of the decline in labor share most acute in manufacturing, and within manufacturing, most acute in industries undergoing rapid automation. In addition,

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

a declining labor share of national income has been mirrored in a rising capital share, further increasing income inequality, since capital returns are concentrated at the upper end of the income distribution.

The slow growth of pretax market incomes for the bottom 95 percent of wage earners has been the main driver of increasing income inequality in the advanced market economies over the past half century, and automation has played a major role.[21] The United States has been an outlier: no other advanced industrial economy has experienced an equally large rise in income inequality or equally severe wage stagnation for rank-and-file workers. Both eroding union coverage and a declining real minimum wage have been important factors behind the comparatively large gap between productivity growth and median wage growth, the comparatively large earnings inequalities by education, and the significant real wage decline for low-educated male workers in the United States. In contrast, in Germany, another large competitive market economy experiencing the same RBTC automation and globalization forces, broad collective bargaining rights, works councils, a generous social insurance system, a robust training system, and a national minimum wage have mitigated the adverse effects of automation on the supply of good jobs and have fostered more inclusive growth.[22]

Overall, RBTC automation has contributed to rising income inequality through a number of channels. It has resulted in stagnant or falling real wages for middle- and low-skill workers, favoring wages of high-skill workers complemented by automation; it has driven a large and persistent gap between wage growth and productivity growth; it has reduced labor's share and increased capital's share in value added; and it has produced "winner-take-all" income gains for superstar innovators and superstar firms with significant product market and monopsony power, contributing to rising income inequality both among them and between them and their workers.[23]

All of these factors are "market" explanations of wage stagnation and income inequality that reflect changes in the demand for different types of labor and capital resulting from RBTC automation. We are concerned that these market factors are likely to persist and indeed may strengthen as RBTC on steroids reduces the demand for labor with low and middle skills (and wages) performing both physical and cognitive routine tasks while increasing the demand for labor with skills required for nonroutine tasks of both types.

At the same time, we recognize that AI is likely to make human work more productive in some existing tasks and to create new tasks requiring human skills that cannot be replaced by AI capabilities. Uniquely human skills not susceptible to AI currently include social/interpersonal skills (teachers, care and health care workers, physical therapists, and hairdressers); physical skills in unpredictable environments (construction workers and plumbers); and general intelligence skills required for nonroutine tasks and problem-solving (management and artists).

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

For many occupations, the future of work is likely to involve growing interdependence between human skills and AI skills: for example, between the interpersonal skills of doctors and teachers with the complementary AI skills of data analysis, diagnostics, and prediction. Such complementary or partnership occupations in turn are likely to require high-level education and/or technical training for the human partners. Overall, such occupational changes are likely to fuel wage and income inequality between those workers whose skills are displaced by AI and those whose skills are complemented. A key but unanswered question is how the rewards from work will be shared between humans and their partner intelligent tools, between labor and the owners and creators of these tools.

So far, we have focused on how AI is affecting labor demand through the automation of tasks and occupations. Now we broaden our focus to consider how AI is affecting labor through enabling digital platforms that are creating new tasks and new forms of organizing work.[24] We believe that digital platforms, the use of which surged during the COVID-19 pandemic, will expand rapidly. To predict AI's future effects on labor, therefore, it is necessary to look through the lens of digital platforms. AI is enabling three types of digital platforms.

- *Platforms for selling goods* (such as Amazon and Netflix) recast what tasks are performed by humans and where. Accelerated by COVID-propelled changes in business practices to reduce workplace density and provide contactless service to customers, transactions continue to move from in-person, brick-and-mortar retail to e-commerce and digital platforms, with tasks shifting from shop floors to warehouse operations and long- and short-haul delivery and transportation.
- *Platforms for labor services* (such as Upwork, Lyft, and TaskRabbit), which utilize algorithms and real-time data to match workers with tasks, are having a growing impact on labor across industries. These platforms cover a wide range of tasks spanning nonroutine cognitive work like accounting and software work, nonroutine physical and technical work like electrical and plumbing services, and routine personal services like transportation and care.[25] Workers typically are matched with tasks for multiple clients, usually on a temporary project basis. Such work is often referred to as "gig work." Gig workers, including the digital assembly-line "ghost workers" who provide much of the human intelligence behind AI software, are part of the "on-demand gig economy."[26] And in response to COVID, new work-related platforms from Google to Zoom are expanding to facilitate remote or hybrid work for cognitive tasks.
- *Platforms for renting out assets* (such as Airbnb and BlaBlaCar) also offer new labor and income opportunities, even while they alter the character of work and the skills required for tasks.

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

Platform-mediated work is growing rapidly as a share of nonstandard employment arrangements (including independent contractors, temporary and on-call workers, and part-time workers) that already account for 25–31 percent of the working age populations in the advanced economies.[27] More than half of those participating in such arrangements use income from them to supplement their income from other sources. The platform-mediated gig portion of nonstandard employment arrangements is still small, accounting for an estimated 1–3 percent of total employment, but it is expanding quickly.[28]

Gig workers lack the legal and social protections provided in standard employment contracts, resulting in precarious jobs with low and unstable incomes, limited access to social insurance, minimal training and career development opportunities, exposure to health and safety risks, and low to zero collective bargaining rights.

As AI-enabled platforms transform relationships between employers and workers, new ways to finance and deliver social and legal protections are required to make gig and other platform jobs "good jobs." When COVID sharply reduced the demand for gig workers, most of the advanced economies added temporary measures, like pandemic unemployment benefits in the United States, to compensate workers for lost income.

Pre-COVID, many governments in Europe and a few U.S. states were already working on permanent measures to protect or empower gig workers. The United Kingdom, for example, added a new "worker" category, distinct from both the traditional employee category and the self-employed category, to its labor law. Some European countries are exploring extending social protections usually associated with standard employment contracts – such as unemployment and disability insurance, health coverage, and parental leave – to gig workers on labor services platforms.[29] Such benefits could be provided and financed through new "portable benefits programs," allowing workers to accumulate benefits on a prorated basis for time worked for different employers.[30]

Looking to the future, two forces will shape the demand for human labor in different tasks and occupations: the demand for goods and services that people want and the capabilities of intelligent tools and systems, empowered by AI, to produce and deliver them. Based on these two forces, over the next decade, we anticipate shifts in the composition of employment in the advanced industrial economies from occupations like office support, production, and warehousing that consist of many routine tasks to occupations in health care, education, technology, and the arts that encompass many nonroutine tasks.[31] The upskilling of employment is likely to continue with job growth concentrated in high-wage occupations and job declines in low- and middle-wage ones, further polarizing the labor market and fueling wage inequality. And the displacement and transition costs for workers who lose their jobs to AI and automation and who require different skills for new jobs are likely to be substantial, raising the question of who should bear these costs.[32]

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

These predicted shifts in occupations and their labor market effects are likely in both manufacturing and services that together account for more than 90 percent of employment. Manufacturing has been the locus of the hollowing out of "good" middle-skill, middle-wage jobs during the past thirty years, driven by robots, RBTC, and globalization. While manufacturing employment has fallen as a share of total employment, manufacturing output has not fallen nearly as sharply as a share of GDP. There have been significant productivity gains from automation, but they have not been broadly shared. A disproportionate share has gone to capital, not to workers, as evidenced by both the rising gap between productivity growth and wage growth and the fall in labor's share of value added. Moreover, the declines in manufacturing employment and wages have fallen hardest on workers in the lower half of the earnings distribution, on workers with less than a college degree, and on locations or regions in which manufacturing was a significant share of economic activity.

Similar disparities in the distribution of both displacement costs and productivity benefits are likely as AI drives further automation of manufacturing. Overall, the hollowing out of manufacturing jobs is likely to continue but also to be smaller than what occurred during the last thirty years. A new wave of AI-powered automation with increasingly programmable, semi-dexterous, and interconnected machines will optimize production systems. The resulting changes are likely to affect manufacturing employment by optimizing tasks that have already been automated and by creating new complementary tasks with required new skills for workers to operate new smarter systems. The pace at which manufacturing tasks are automated will depend not only on evolving AI capabilities but also on the improved dexterity of robots and production systems. Overall, AI is not likely to add significant risk of additional job displacement to "shop-floor" manufacturing workers, but it is likely to displace workers doing routine cognitive tasks in back offices.[33]

Based on both rising incomes and changing demographics, the demand for services will remain robust in the advanced industrial societies. Indeed, services already account for most (more than 80 percent) employment and almost all employment growth during the last several decades. Service occupations run the gamut from highly paid health and business professionals to middle-wage educators to low-wage retail clerks and hospitality workers. Given the diverse character of the service sector, we highlight briefly some of AI's implications in two large service industries: retail and health.

Artificial intelligence is transforming the *retail industry* across its value chain. On the demand side, businesses are shifting from traditional in-store channels to e-commerce channels, especially digital platforms, to anticipate demand and personalize the customer experience. On the supply side, AI is being applied to improve inventory forecasts, optimize merchandising and

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

product assortment, and automate warehousing and store operations. Overall employment in retail is likely to continue to decline, but the demand for humans in routine and nonroutine cognitive tasks in such areas as customer service, management, and technology deployment and maintenance is likely to increase. In contrast, routine manual jobs such as cashiers, drivers, packers, and shelf stockers are projected to decline, reducing low- to middle-wage job opportunities for workers with only a secondary education. In both manufacturing and services, the pace of change in AI-enabled drones and autonomous vehicles will impact the pace at which human tasks and wages in short-haul and long-haul transportation, two major middle-wage occupations, are affected.

In the *health care sector*, job growth is likely to remain strong. Indeed, both pre and post COVID, the health sector has topped the list of projected job growth in the advanced economies. Health care jobs cover a broad range of skills and incomes, from low-skill, low-wage jobs like orderlies and home care assistants through middle-skill, middle-wage jobs like lab technicians and paramedics to high-skill jobs like nurses, dentists, radiology technologists, and physicians. All of these job categories are projected to grow to keep pace with rising demand for health care services.

Within health care, AI is likely to complement the demand for high-wage workers performing nonroutine tasks requiring specialized skills and education while substituting for workers performing routine tasks. In particular, AI applications are likely to substitute for humans in data-dependent cognitive tasks in administrative and office support activities and patient relationship management while increasing the demand for humans in work performed by health professionals like nurses, doctors, physical therapists, and dentists whose responsibilities require high-level cognitive and/or highly skilled physical and social interaction tasks. The automation of administrative and data collection tasks, further enabled by telemedicine platforms, could be transformative for nurses who spend on average a quarter of their time on such duties, empowering them to use AI-informed results to offer more real-time health advice, diagnosis, and treatment.[34]

Many health care occupations are likely to require collaboration between humans with the requisite social skills and intelligent tools with the requisite data capabilities to deliver state-of-the art personalized services at scale. The scope for collaboration between humans and AI in health care is already apparent in the utilization of AI-enabled robots to address the interrelated demographic challenges of aging and shrinking populations. Japan, for example, is leading the way in robot use in tasks in nursing homes and hospitals, both to fill gaps in the supply of human labor available for these tasks and to complement the humans required to do them.

Throughout this essay, we have focused on the effects of AI and automation on the composition of *demand* for human labor in tasks, occupations, and jobs. Yet, as the example of Japan's adoption of robots in health care illus-

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

trates, employment, wages, and good jobs depend not only on the demand for human labor but also on its supply.[35] All of the industrial economies face a slowdown in the growth of their working age populations, albeit to differing degrees, and this is likely to result in shortages and upward pressure on wages both in occupations and jobs that are not currently susceptible to substitution by AI and in those that are complemented or enabled by it. As labor markets recover from COVID, there is already concern in the United States and in several European countries about future shortages of workers with the skills and education required to meet demand in growing sectors like health care and software engineering. Such shortages in turn are likely to accelerate innovation, investment, and deployment of AI-enabled automation technologies to substitute for human labor.

AI and the intelligent tools and systems it enables will automate many routine tasks, change existing tasks, and create new tasks for humans, often involving new forms of human and machine collaboration and new forms of work organization. There will be – indeed there already are – both winners and losers in this process of ongoing structural change. It is not sufficient to assert that as AI technologies transform work, there will ultimately be broad economic gains that are widely shared. That is not a technologically determined outcome but rather a societal choice. To foster both economic growth and the social and economic equity on which their prosperity and political stability depend, the advanced market economies must develop policies to share the disruption costs and productivity benefits of AI broadly, consistent with societal norms of fairness.

The availability and accessibility of good jobs should be core policy goals, yet achieving them is not trivial. To maximize the odds for success and to transform all jobs into good jobs, three broad types of policy interventions are warranted. First are lifelong education and training policies to equip workers with the skills they need for *access* to good jobs, along with active labor market policies to help them *transition* to these jobs. Second is the extension of social benefits and legal protections to cover workers in all businesses, including platform businesses. And third is a combination of income-support policies, including minimum wages, tax credits for work, and basic income supplements, to raise the after-tax earnings of workers who remain in low-wage jobs – including many routine service jobs in leisure and hospitality, health care, and childcare, many of them held by women and low-educated workers – to livelihood levels.[36]

Finally, it is important to emphasize that the effects of AI on work are not technologically determined but depend on the incentives of both those leading AI research and innovation and those investing in AI deployment. The prevailing narrative behind AI innovation and deployment in the business and research communities, a narrative particularly pronounced in the United States, where decisions reflect shareholder interests and workers have limited voice in business decisions, focuses on AI's ability to outperform humans, not on the creation of good jobs.

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

This narrative has been fostered by tax policies that raise the cost of labor and reduce the cost of capital, encouraging businesses to focus on automation technologies that reduce employment and cut labor costs without offsetting labor productivity growth. R&D tax incentives and other forms of government support for research in labor-saving technologies have reinforced the narrative, but well-designed policies could change it.[37]

Ultimately, how the economic benefits of intelligent machines and tools are realized and shared depend not on their technological design but on the design of intelligent policies needed for an inclusive AI era.[38]

AUTHORS' NOTE

The authors are grateful to the Ewing Marion Kauffman Foundation, the German Federal Ministry of Labour and Social Affairs (BMAS), and the American Academy in Berlin for their generous support for this work. Our research was a product of collaboration with the Hertie School, Humboldt Institute for Internet and Society, Weizenbaum Institute, and WZB Berlin Social Science Center. We thank Dafna Bearson and Camille Carlton for their outstanding research assistance.

ABOUT THE AUTHORS

Laura D. Tyson, a Fellow of the American Academy since 2002, is Distinguished Professor of the Graduate School at the Haas School of Business and Founder and Co-Faculty Director of the Sustainable and Impact Finance Initiative at the University of California, Berkeley. She also chairs the Board of Trustees at UC Berkeley's Blum Center for Developing Economies. She served in the Clinton administration as the Chair of the Council of Economic Advisers and as Director of the National Economic Council. She is the author of many publications, including *Who's Bashing Whom: Trade Conflicts in High-Technology Industries* (1992).

John Zysman is Professor Emeritus in the Department of Political Science at the University of California, Berkeley. His publications include *The Highest Stakes: The Economic Foundations of the Next Security System* (1992), *Manufacturing Matters: The Myth of the Post-Industrial Economy* (1987), and *Governments, Markets, and Growth: Finance and the Politics of Industrial Change* (1983).

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

ENDNOTES

[1] For a comprehensive analysis of automation's effects, see David Autor, David Mindell, and Elisabeth Reynolds, *The Work of the Future: Building Better Jobs in an Age of Intelligent Machines* (Cambridge, Mass.: MIT Press, 2020); and James Manyika, Susan Lund, Michael Chui, et al., *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation* (New York: McKinsey Global Institute, 2017).

[2] Thomas W. Malone, Daniela Rus, and Robert Laubacher, "Artificial Intelligence and the Future of Work" (Cambridge, Mass.: MIT Future of Work, 2020); Michael I. Jordan, "Artificial Intelligence–The Revolution Hasn't Happened Yet," *Harvard Data Science Review* 1 (1) (2019); Gary Marcus, "The Next Decade in AI: Four Steps Towards Robust Artificial Intelligence," arXiv (2020), https://arxiv.org/abs/2002.06177; John Zysman and Mark Nitzberg, *Governing AI: Understanding the Limits, Possibilities, and Risks of AI in an Era of Intelligent Tools and Systems* (Washington, D.C.: Wilson Center, 2020); Mark Nitzberg and John Zysman, "Algorithms, Data, and Platforms: The Diverse Challenges of Governing AI," BRIE Working Paper 2021-1 (Berkeley: Berkeley Roundtable on the International Economy, University of California, Berkeley, 2021); and Kevin Roose, *Futureproof: 9 Rules for Humans in the Age of Automation* (New York: Random House, 2021).

[3] Machine learning is the primary computer science breakthrough enabling contemporary AI. ML is a form of context-dependent statistical inference, in which algorithms are trained on vast amounts of data and improve ("learn") automatically through training. Deep Learning is a machine learning method that adjusts "weights" in multiple layers of artificial neural networks (ANNs) based on training data, and has powered the recent breakthrough, human-comparable AI results.

[4] While not dismissive of the possibility of AGI, many scholars agree that the focus of policy and regulation should be on the impacts of narrow AI. See, for example, Gary Marcus and Ernest Davis, *Rebooting AI: Building Artificial Intelligence We Can Trust* (New York: Pantheon Books, 2019); and Erik Brynjolfsson, Tom Mitchell, and Daniel Rock, "What Can Machines Learn, and What Does It Mean for Occupations and the Economy?" *AEA Papers and Proceedings* 108 (2018): 43–47.

[5] Erik Brynjolfsson, Daniel Rock, and Chad Syverson, "Understanding and Addressing the Modern Productivity Paradox" (Cambridge, Mass.: MIT Future of Work, 2020).

[6] Maarten Goos, Alan Manning, and Anna Salomons, "Explaining Job Polarization: Routine-Biased Technological Change and Offshoring," *American Economic Review* 104 (2) (2014): 2509–2526.

[7] Laura D. Tyson and Michael Spence, "Exploring the Effects of Technology on Income and Wealth Inequality," in *After Piketty: The Agenda for Economics and Inequality*, ed. Heather Boushey, J. Bradford DeLong, and Marshall Steinbaum (Cambridge, Mass.: Harvard University Press, 2017), 170–208.

[8] Anke Hassel and Bruno Palier, eds., *Growth and Welfare in Advanced Capitalist Economies: How Have Growth Regimes Evolved?* (Oxford: Oxford University Press, 2021); Autor et al., *The Work of the Future*; and Christian Dustmann, "Trade, Labor Markets, and the China Shock: What Can be Learned from the German Experience?" in *Combating Inequality: Rethinking Government's Role*, ed. Olivier Blanchard and Dani Rodrik (Cambridge, Mass.: MIT Press, 2021), 117–124.

[9] Daron Acemoglu and Pascual Restrepo, "Automation and New Tasks: How Technology Displaces and Reinstates Labor," *Journal of Economic Perspectives* 33 (2) (2019): 3–30. The

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

following lectures summarize the conclusions, with supporting data, on ongoing research by Acemoglu and Restrepo on automation, AI, and the effects on labor. Daron Acemoglu, "Tasks, Automation and Labor Market," presentation and lecture at Gorman Conference & Lectures 2020, virtual event, October 12, 2020; and Daron Acemoglu, "New Tasks, Good Automation and Bad Automation: Implications for the Future of Work," presentation and lecture at Gorman Conference & Lectures 2020, virtual event, October 13, 2020.

10 This is well documented in Carl Benedikt Frey, *The Technology Trap: Capital, Labor, and Power in the Age of Automation* (Princeton, N.J.: Princeton University Press, 2019); and Barry Eichengreen, *The Populist Temptation: Economic Grievance and Political Reaction in the Modern Era* (New York: Oxford University Press, 2020).

11 For evidence on the regional disparities of automation's effects in the United States, see Susan Lund, James Manyika, Liz Hilton Segel, et al., *The Future of Work in America: People and Places, Today and Tomorrow* (New York: McKinsey Global Institute, 2019). See also Mark Muro, *Countering the Geographical Impacts of Automation: Computers, AI, and Place Disparities* (Washington, D.C.: Brookings Institution, 2019).

12 Daron Acemoglu, "Could We and Should We Reverse (Excessive) Automation?" in *Combating Inequality: Rethinking Government's Role*, ed. Olivier Blanchard and Dani Rodrik (Cambridge, Mass.: MIT Press, 2021), 163–170.

13 Erik Brynjolfsson, Seth G. Benzell, and Daniel Rock, "How to Solve the Puzzle of Productivity Growth," Tech Stream, Brookings Institution, May 21, 2021.

14 Daron Acemoglu, David Autor, Jonathon Hazell, and Pascual Restrepo, "AI and Jobs: Evidence from U.S. Vacancies," VoxEU, March 3, 2021, https://voxeu.org/article/ai-and-jobs-evidence-us-vacancies; Michael Webb, "The Impact of Artificial Intelligence on the Labor Market," working paper (2019); Erik Brynjolfsson, Tom Mitchell, and Daniel Rock, "What Can Machines Learn, and What Does It Mean for Occupations and the Economy?" *AEA Papers and Proceedings* 108 (2018): 43–47; and Edward W. Felten, Manav Raj, and Robert Seamans, "A Method to Link Advances in Artificial Intelligence to Occupational Abilities," *AEA Papers and Proceedings* 108 (2018): 54–57.

15 Kai-Fu Lee, *AI Superpowers: China, Silicon Valley, and the New World Order* (Boston: Houghton Mifflin Harcourt, 2018); Kai-Fu Lee and Chen Qiufan, *AI 2041: Ten Visions for Our Future* (New York: Currency, 2021); Autor et al., *The Work of the Future*; and Ajay Agrawal, Joshua Gans, and Avi Goldfarb, eds., *The Economics of Artificial Intelligence: An Agenda* (Chicago: University of Chicago Press, 2019).

16 The share of middle-skill occupations in total employment declined (11 percent), high-skill occupations grew (9 percent), and low-skill occupations grew (3 percent) between the mid-1990s to the late 2010s across OECD countries. See Organisation for Economic Co-operation and Development, *OECD Employment Outlook 2020: Worker Security and the COVID-19 Crisis* (Paris: OECD Publishing, 2020), Figure 4.1, https://doi.org/10.1787/1686c758-en.

17 Georgios Petropoulos, "Occupational Change, Artificial Intelligence and the Geography of EU Labor Markets," Bruegel Working Paper 03 (Brussels: Bruegel, 2020).

18 Florian Hoffmann, David S. Lee, and Thomas Lemieux, "Growing Income Inequality in the United States and Other Advanced Economies," *Journal of Economic Perspectives* 344 (4) (2020): 52–78; and Autor et al., *The Work of the Future*.

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

[19] David Autor and Anna Salomons, "Is Automation Labor-Displacing? Productivity Growth, Employment, and the Labor Share," Working Paper 24871 (Cambridge, Mass.: National Bureau of Economic Research, 2018); Mathilde Pak and Cyrille Schwellnus, "Labour Share Developments Over the Past Two Decades: The Role of Public Policies," OECD Economics Department Working Papers No. 1541 (Paris: OECD Publishing, 2019); Cyrille Schwellnus, Andreas Kappeler, and Pierre-Alain Pionnie, "The Decoupling of Median Wages from Productivity in OECD Countries," *International Productivity Monitor* 32 (2017); and Organisation for Economic Co-operation and Development, "Decoupling of Wages from Productivity: What Implications for Public Policies?" *OECD Economic Outlook* 2 (2018).

[20] On factors that contribute to the declining labor share, see Bennet Berger and Guntram B. Wolff, "The Global Decline in the Labour Income Share: Is Capital the Answer to Germany's Current Account Surplus?" (Brussels: Bruegel, 2017); James Manyika, Jan Mischke, Jacques Bughin, et al., "A New Look at the Declining Labor Share of Income in the United States" (New York: McKinsey Global Institute, 2019); and Caterina Astarita and Gaetano D'Adamo, "Inequality and Structural Reforms: Methodological Concerns and Lessons from Policy" (Brussels: Directorate-General for Economic and Financial Affairs, European Commission, 2017), https://ideas.repec.org/p/euf/dispap/071.html.

[21] Lucas Chancel, "Ten Facts about Inequality in Advanced Economies," in *Combating Inequality: Rethinking Government's Role*, ed. Olivier Blanchard and Dani Rodrik (Cambridge, Mass.: MIT Press, 2021), 3–30.

[22] Laura Tyson, "Automation and the Future of Work in Germany: A Summary of Research and Policy Recommendations?" Governing Work in the Digital Age Project Working Paper (Berlin: Hertie School, 2020), https://digitalage.berlin/wp-content/uploads/2021/12/2021_Tyson-WP1-Paper-FINAL-1.pdf; and Laura Tyson, "The Future of Work in Germany," *The Berlin Journal* 33 (2019).

[23] Tyson and Spence, "Exploring the Effects of Technology on Income and Wealth Inequality"; and Anton Korinek and Joseph E. Stiglitz, *Artificial Intelligence and Its Implications for Income Distribution and Unemployment* (Chicago: University of Chicago Press, 2019).

[24] Dafna Bearson, Martin Kenney, and John Zysman, "Measuring the Impacts of Labor in the Platform Economy: New Work Created, Old Work Reorganized, and Value Creation Reconfigured," *Industrial and Corporate Change* 30 (3) (2021), https://doi.org/10.1093/icc/dtaa046; and Martin Kenney, Dafna Bearson, and John Zysman, "The Platform Economy Matures: Measuring Pervasiveness and Exploring Power," *Socio-Economic Review* 19 (4) (2021), https://doi.org/10.1093/ser/mwab014.

[25] Jacques Bughin, Eric Hazan, Susan Lund, et al., *Skill Shift: Automation and the Future of the Workforce* (New York: McKinsey Global Institute, 2018).

[26] Mary Gray and Siddharth Suri, *Ghost Work: How to Stop Silicon Valley from Building a New Global Underclass* (Boston: Houghton Mifflin Harcourt, 2019); and Daisuke Wakabayashi, "Google's Shadow Workforce: Temps Who Outnumber Full Time Employees," *The New York Times*, May 28, 2019, https://www.nytimes.com/2019/05/28/technology/google-temp-workers.html?searchResultPosition=1.

[27] Jonathan I. Dingel and Brent Neiman, "How Many Jobs Can be Done at Home?" *Journal of Public Economics* 189 (2) (2020).

[28] Susan Lund, Anu Madgavkar, James Manyika, et al., *The Future of Work after COVID-19* (New York: McKinsey Global Institute, 2021).

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023

[29] Organisation for Economic Co-operation and Development, *Employment Outlook 2020*; and International Labour Organization, "The Role of Digital Labour Platforms in Transforming the World of Work," in *World Employment and Social Outlook 2021* (Geneva: International Labour Organization, 2021), https://www.ilo.org/global/research/global-reports/weso/2021/lang--en/index.htm.

[30] Libby Reder, Shelly Steward, and Natalie Foster, *Designing Portable Benefits: A Resource Guide for Policymakers* (Washington, D.C.: Aspen Institute, 2019); and Steven Hill, *Raw Deal: How the "Uber Economy" and Runaway Capitalism Are Screwing American Workers* (New York: St. Martin's Press, 2015).

[31] Three changes in business and consumer practices in response to COVID-19 are likely to reinforce these changes in the composition of labor demand: the expansion of hybrid work for both routine and nonroutine cognitive tasks; the expansion of e-commerce, reducing demand for workers in low-wage routine tasks in retail/leisure/restaurants with partially offsetting increases in demand for workers doing warehousing, delivery, and other logistics tasks; and the acceleration of AI-enabled automation and digitalization of tasks to reduce workplace density and social interaction. See Lund et al., *The Future of Work after COVID-19*.

[32] For other recent studies predicting the future effects of AI on work, see Jason Furman and Robert Seamans, "AI and the Economy," NBER Working Paper 24689 (Cambridge, Mass.: National Bureau of Economic Research, 2018); Marguerita Lane and Anne Saint-Martin, "The Impact of Artificial Intelligence on the Labour Market: What Do We Know So Far?" OECD Social, Employment and Migration Working Papers No. 256 (Paris: OECD Publishing, 2021); and Michael Chui, *Artificial Intelligence – The Next Digital Frontier?* (New York: McKinsey and Company Global Institute, 2017), 3–6.

[33] Moreover, as AI enables sensors and data, it will create new manufacturing tasks for new manufactured products that are packaged and sold as "services for everything" bundles, combining physical goods with ongoing maintenance, upgrading, and replacement services.

[34] Thomas Davenport and Ravi Kalakota, "The Potential for Artificial Intelligence in Healthcare," *Future Healthcare Journal* 6 (2) (2019): 94; and Ari Bronsoler, Joseph Doyle, and John Van Reenen, "The Impact of New Technology on the Healthcare Workforce" (Cambridge, Mass.: MIT Work of the Future, 2020).

[35] Hal Varian, "Automation Versus Procreation (aka Bots Versus Tots)," VoxEU, March 30, 2020, https://voxeu.org/article/automation-versus-procreation-aka-bots-versus-tots.

[36] For an insightful framework distinguishing preproduction, production, and postproduction policies for inclusive growth, see Dani Rodrik and Stefanie Stantcheva, "Economic Inequality and Insecurity: Policies for an Inclusive Economy" (report prepared for commission chaired by Olivier Blanchard and Jean Tirole on major future economic challenges, Republic of France, 2021), 193–328.

[37] Daron Acemoglu and Pascual Restrepo, "The Wrong Kind of AI? Artificial Intelligence and the Future of Labour Demand," *Cambridge Journal of Regions, Economy and Society* 13 (1) (2019): 25–35.

[38] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton & Company, 2016); and Laura D'Andrea Tyson, "Intelligent Machines and Displaced Workers" (Emeryville, Calif.: Berkeley Research Group, 2014).

Downloaded from http://direct.mit.edu/daed/article-pdf/151/2/256/2060567/daed_a_01914.pdf by guest on 29 September 2023