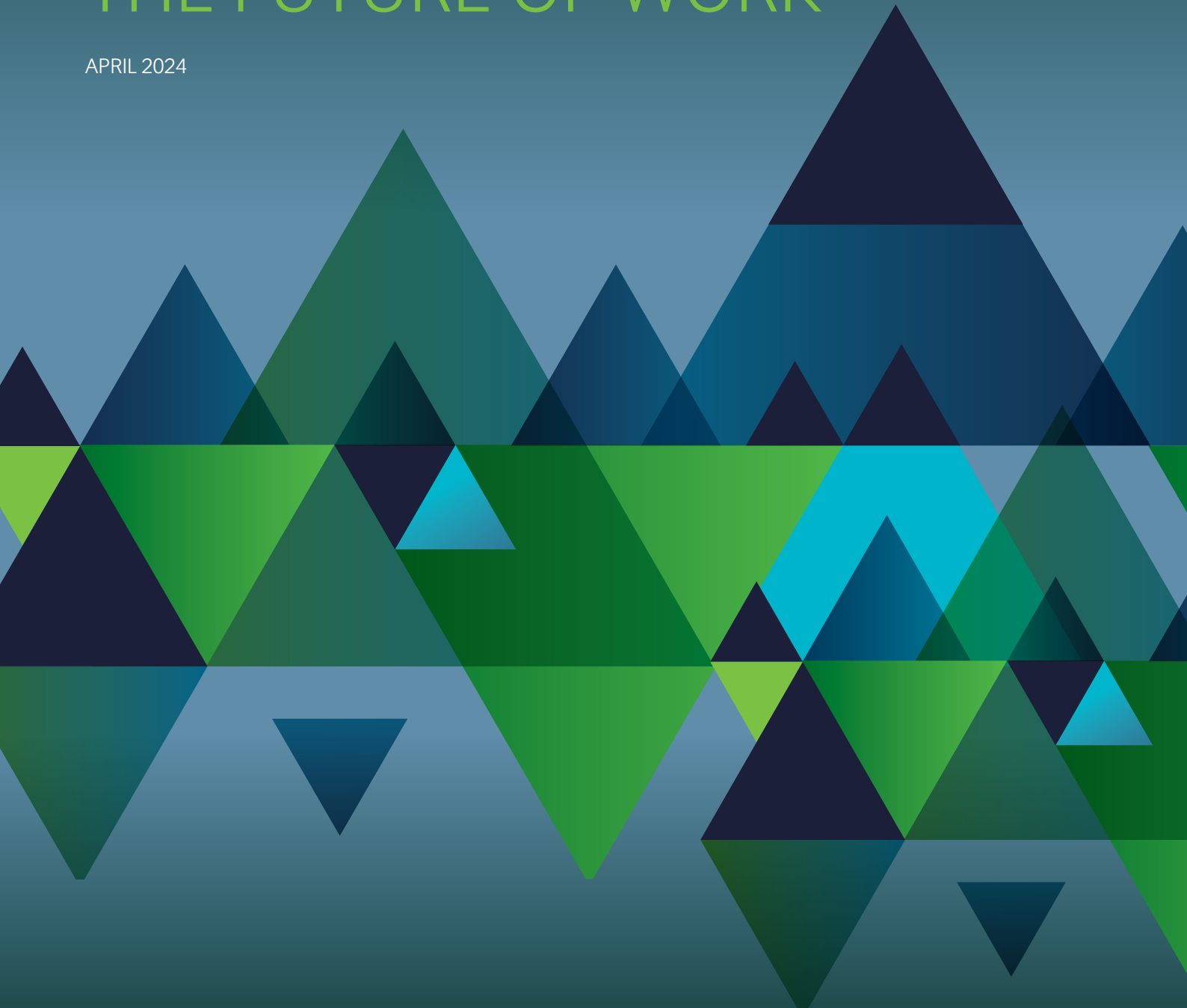


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THE AI AWAKENING — PRODUCTIVITY AND THE FUTURE OF WORK

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EXECUTIVE SUMMARY

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Erik Brynjolfsson is the Jerry Yang and Akiko Yamazaki Professor and Senior Fellow at the Stanford Institute for Human-Centered AI (HAI), and Director of the Stanford Digital Economy Lab. He also is the Ralph Landau Senior Fellow at the Stanford Institute for Economic Policy Research (SIEPR), Professor by Courtesy at the Stanford Graduate School of Business and Stanford Department of Economics, and a Research Associate at the National Bureau of Economic Research

(NBER). One of the most-cited authors on the economics of information, Brynjolfsson speaks globally and is the author of nine books, over 100 academic articles and five patents. He holds Bachelors and Masters degrees from Harvard University in applied mathematics and decision sciences and a PhD from MIT in managerial economics.

- General purpose technologies (GPTs) have changed the world as we know it, and artificial intelligence is the most general of GPTs yet seen.
- Machine learning is rapidly advancing; with each progression the need for human input will diminish and machines will increasingly become autonomous.
- Rather than lead to vast job losses, AI should augment workers not replace them. AI can enhance human skills and knowledge, but is not infallible, meaning humans need to remain in the loop.
- Previous transformative change suggests it may take a while before we see the full benefits. Cultural resistance, especially in Europe, could create regulatory barriers, slowing the implementation.
- AI could double productivity if we embrace its creative destruction. This could dramatically increase aggregate living standards and potentially solve the huge fiscal problems facing many governments.
- There is the potential for massive gains in wealth, but this could be concentrated, with some sections of society losing out.
- The next ten years could be the best in human history so far, but it could also be the worst should cyber security protocols and regulation fail to evolve appropriately to recognise the threats associated with bad actors.

GENERAL PURPOSE TECHNOLOGIES AND HUMANITY

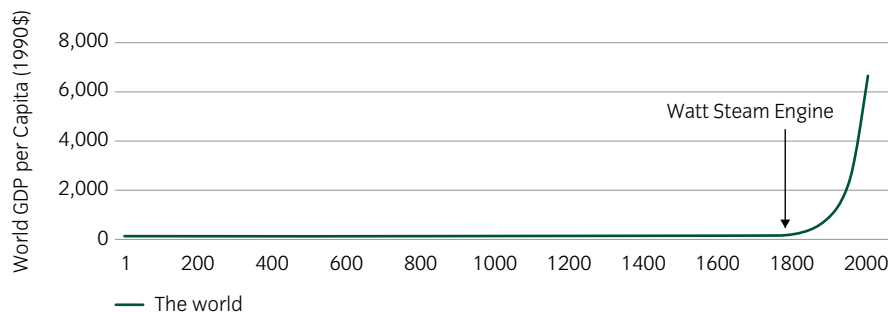
GPTS CHANGED THE WORLD AS WE KNOW IT

For most of human history, the living standards of the average man or woman did not rise much above subsistence level. That changed dramatically around 250 years ago with the advent of the Industrial Revolution which was ignited by the invention of the steam engine by James Watt. The compounding effects of the technological achievements that occurred since that point means we are, on average, 30 to 50 times richer than our ancestors of even a few hundred years ago (see Figure 1).

Humanity's ability to harness technology to alter our environment, to build and to produce has risen dramatically and continues to improve at an exponential rate, compounding year after year. In particular, the rise of a particular class of technologies which cut across all different sector of the economy are, in the eyes of many economists, the primary driver of changes in our world: general purpose technologies (GPT).

The steam engine was arguably the first GPT and signified the beginning of the Industrial Revolution. Other GPTs followed: railroads, electricity, the internal combustion engine and the computer, all of which drastically impacted pre-existing economic structures and elevated living standards. I would argue that artificial intelligence (AI) is our generation's GPT.

Figure 1: The Industrial Revolution bent the curve of history¹



AI COULD BE THE MOST IMPORTANT GPT YET SEEN

A GPT has three important characteristics:

1. It is pervasive and affects the broad sectors of the economy.
2. It can be improved over time.
3. It is able to spawn complementary innovations.

Artificial intelligence not only fulfils the criteria of a GPT, but it is also arguably the most general of general-purpose technologies that we have ever seen. Demis Hassabis, the creator of Google DeepMind once said “our goal is to solve intelligence, and then use that to solve the other problems in the world”. That is what makes AI different; once you have solved intelligence then you can then direct that intelligence to solving everything else, which may engender significant positive benefits.

¹ Source: “Statistics on World Population, GDP and GDP per Capita, 1-2008 AD”. Angus Maddison, IMF.

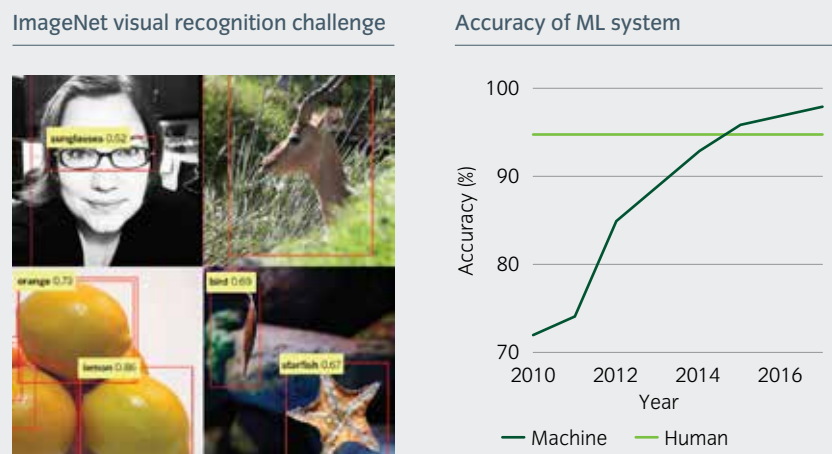
Artificial intelligence continues to improve, and in just the past decade, has reached a point where it now matches or surpasses human performance, completing tests and tasks with greater accuracy than humans can.

Already, we are beginning to see real world examples of just how rapidly this is happening. For example, recent tests of AI's ability to identify nuances between similar animals, objects or plants revealed an ability to identify distinct objects with greater accuracy than human beings.

AI IN ACTION – IMAGE RECOGNITION

The ImageNet challenge was set up by Stanford professor Fei-Fei Li. It has compiled a data set of 14 million images, each carefully labelled, and tracks the ability of both humans and AI to recognise these images over time. When professor Li set up ImageNet in 2010 machines weren't very good – they could recognise just over 70% of the images versus around 95% for the average human in the test. As we can see from Figure 2, the human score hasn't changed, but the machine score has rapidly climbed and now exceeds human capability. A major driver of this improvement was the introduction of deep learning, a technique created by Geoff Hinton, which radically enhanced machine learning abilities.

Figure 2: In image recognition, machines have already surpassed humans²



MACHINE LEARNING IS RAPIDLY ADVANCING

A NEW WAVE IN THE MACHINE AGE

These advancements in machines can be broadly categorised into waves. The first wave of the machine age was the creation of machines that helped humanity with physical work, such as the steam engine. The second wave created machines that aided human cognition. The invention of coding, creating software that instructed machines to complete tasks, was a pivotal moment at the start of that era. Once scaled, this innovation produced productivity gains that unlocked trillions of dollars of value.

²Source: [The AI Index](#), 2023.

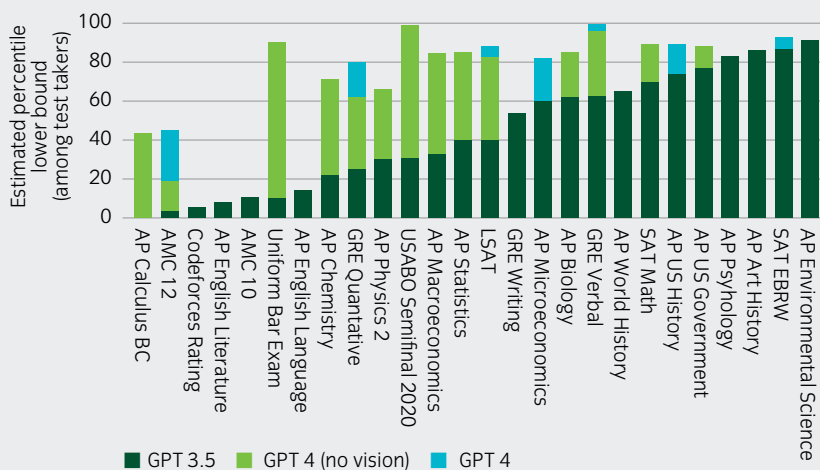
We're now at what I believe is a new wave, where instead of humans writing code, the machines write it themselves. Historically we have taught machines to learn by providing lots of examples of successes and failures, which over time allows the machine to find patterns. But if you provide enough data, machines can learn how to solve problems on their own. This is machine learning. As this new wave progresses, the need for human input will diminish and machines will increasingly become autonomous. This is progressing at a far more rapid rate than we saw with the steam engine and it's going to create a lot of turbulence. Inevitably, there are going to be winners and losers as this technology develops, and the winners are likely to be those companies that best prepare themselves for the changes ahead.

MACHINE LEARNING, GENERATIVE AI AND ARTIFICIAL GENERAL INTELLIGENCE EXPLAINED

Machine learning allows an AI application to solve problems by providing examples of successes and failures. By using vast amounts of data, machine learning can independently recognise patterns, establishing the parameters of success and failure, and predict outcomes, giving computers the ability to make decisions without the need for any specific programming. In essence, it seeks to imitate how humans learn from experience and complete tasks based in its data.

The next stage in the AI evolution is generative AI. While machine learning is focused on analysis of existing data and pattern recognition, generative AI uses machine learning techniques to create entirely new data and produce content, such as images, text, audio and video. In fact, generative AI applications have exhibited the ability to pass common examinations and the rapidity of its improvement is stark, as depicted by Figure 3, which exhibits the performance of two generations of a well-known generative AI application in several US exams.

Figure 3: Change in exam performance with iterative versions of Chat GPT³



These results are only going to get more impressive with the release of new applications like Chat GTP 5 and beyond. The speed at which machine learning and generative AI applications are advancing could unlock trillions of value in productivity gains and new products. Some researchers believe we may quickly enter the realm of artificial general intelligence (AGI), which will allow for complex problem solving with ever greater accuracy. The only limits would potentially be generating the vast amounts of electricity these huge data centres require.

³Source: OpenAI, 2023.

THE ECONOMIC IMPACT OF AI

AI SHOULD AUGMENT WORKERS RATHER THAN REPLACE THEM IN AGGREGATE

The rise of artificial intelligence has produced much commentary about its potentially profound effects on labour markets, and commentators have devoted many column inches to the looming prospect of vast numbers of jobs becoming obsolete.

Daniel Rock at the Wharton School of Business at the University of Pennsylvania undertook a study to assess this, working with a team at OpenAI, and the conclusion was that most of the workforce will be affected by Generative AI. Specifically, the study predicted that:

1. 19% of US workers could have over 50% of their work tasks affected.
2. 80% of US workers could have over 10% of their tasks affected.
3. Higher income jobs face greater exposure – knowledge workers at risk.

However, none of the roles could be 100% replaced by AI. Therefore, the AI story is not one of mass unemployment or the wholesale replacement of workers. Instead it is one of transformation, with generative AI augmenting workers' abilities to do some tasks better but unable to help with others. Despite the scope of its capability, AI will still struggle when confronted with novel problems and unfamiliar scenarios. For all its predictive capacity, machine learning still relies upon training data sets and will face a long tail of unusual problems across industries, which will require human input.

One significant finding from the study, which sets AI as being very different to earlier GPTs, is that it found that middle and high-income workers are most likely to be affected by AI, with manual or blue-collar workers the least affected. This represents a reversal of the experience in the 20th century and early 21st century, where blue collar workers faced the largest impacts from technological advancement.

Some workers may lose their jobs, but broadly speaking the impact from AI will be to give us new tools and, if used correctly, offer better ways of working and enable all workers to do things they couldn't do before. Often, the way in which predictive AI works will require human involvement in a given task because, although the AI may use the data it has to predict an event, prediction may be different to reality. If asked a question about what a dog is going to do, a predictive AI may predict that it barked, as that is the most common answer, but this time the dog may run or sit, and a human is needed to pick out the actual reality from the predicted reality.



The AI story is not one of mass unemployment
or the wholesale replacement of workers
– instead it is one of transformation.



AI IN ACTION – ENHANCING CUSTOMER SERVICE

Several companies have begun to introduce AI tools to help their workers, and an area which is already seeing clear benefits from AI is customer service. In this example of AI in action, we can look at a financial services company that introduced an AI tool from a company called Cresta AI. This technology doesn't seek to replace the call centre operators, it seeks to supplement them. When a call or message is processed, the AI can provide the operator with information which will help them to resolve the customer's issue. The AI can also provide suggestions for how the operator should respond. You can see an example of this in Figure 4.

As this was introduced in a phased rollout, where some staff received access before others, it was possible to analyse the impact of the technology over a relatively large data set of 5,000 people. As we can see in Figure 5, the impact is immediately obvious, with around a 14% improvement in performance on average. These productivity benefits grew over time as workers became used to working with the system.

Figure 4: An example of AI in customer service⁴

A. Sample customer issue

Visitor ✕

My name is Alex. I'm super frustrated. I've had customers calling me all day saying they can't access their information on the website or that the website isn't loading. I need this fixed asap.

11:31:15 AM

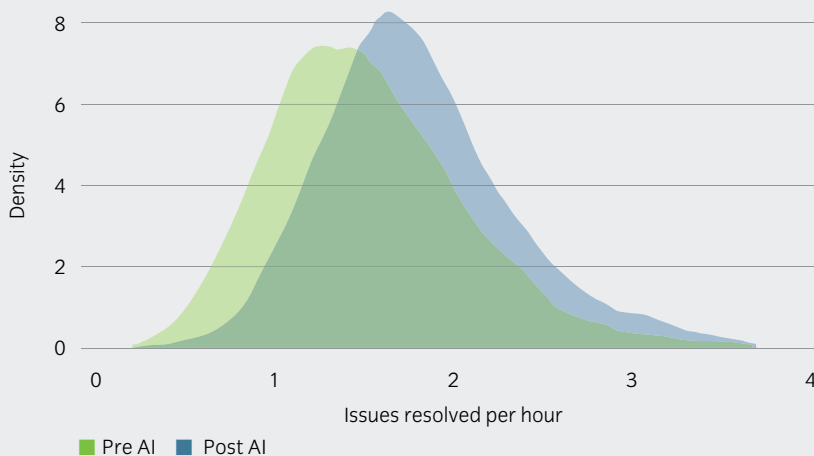
B. Sample AI-generated suggested response

Open → Understand → Recommend → Close

I completely understand, Alex! I can definitely assist you with this! Can you please provide the email associated with your account? fb

It is nice to meet you, Alex. Happy to help you get this fixed asap! To set expectations, what I'll do first is find your account with us the system and then we can walk through this step by step. Sound good? fb

Figure 5: The benefits of AI augmentation are clear⁵



^{4,5}Source: CRESTA, 2023. For illustrative purposes only.

POSITIVE ECONOMIC OUTCOMES BUT ALSO CHALLENGES

We believe the evidence suggests AI will probably grow the economic pie, producing enormous benefits and increasing output. However, the benefits could be very concentrated in a small group. Some other people may get no benefit and it may be negative for certain people. That dynamic is not new; globalisation and free trade made the economic pie bigger, in aggregate producing more wealth. However, certain populations experienced concentrated losses which created political instability and populist revolts.

Like workers, companies will also experience a dichotomy between winners and losers. Certain companies will benefit immensely from productivity gains derived from generative AI, but it will also destroy perhaps hundreds of billions of dollars of profit as the technologies eliminate inefficiencies that have allowed certain companies to insulate themselves from competition.

THE STORY OF ELECTRIFICATION MAY PROVIDE CLUES TO HOW QUICKLY CHANGE MAY ARRIVE

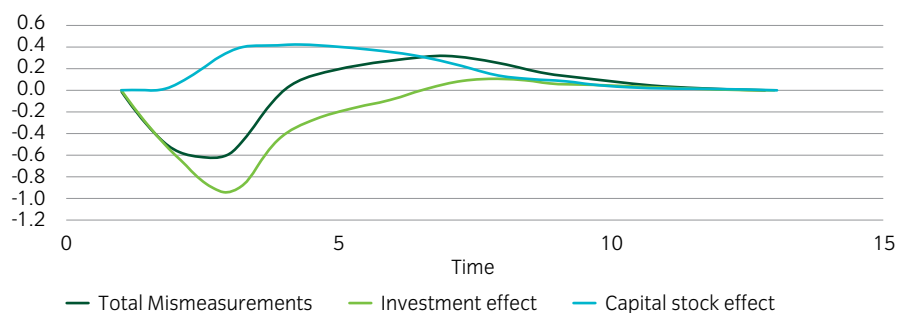
However, this process of creation and destruction will not happen overnight. Even though the capabilities of AI are enormous and improving exponentially, adopting them to change how we work could take years or decades to fully implement. Earlier generations of general-purpose technology can offer instruction in this regard.

The introduction of electricity in the 1880 and 1890s took decades to generate productivity gains, as the old steam driven technology was so integrated into pre-existing methods of production and design. Electricity did not prove transformative until factory designs and production processes adapted to take advantage of the new technology. Central steam engines were slowly replaced with electric motors, but it was only in the 1920s, when someone realised that it would be more efficient to have an individual electric motor for each piece of equipment, that productivity started to boom. This allowed the creation of what we now know as assembly lines, where equipment can be laid out to match the process of production rather than being clustered around a giant central motor.

Applying the lessons from the past, it is clear we must combine new general-purpose technology with new methods of organising production and new ways of thinking to reap the rewards. This reorganisation to facilitate the introduction of new technology may lead to an initial drop in productivity, due to implementation costs, before a company begins to harvest the benefits.

Accordingly, the trajectory of the productivity gains from AI will most likely resemble a J-curve, as shown by the dark green line in Figure 6. Initially, a business implementing AI may see an initial drop in productivity as it contends with implementation costs and reordering processes. However, following a period of transition, the effects will prove transformative and substantial gains will accrue.

Figure 6: The productivity J-curve⁶



⁶ Brynjolfsson, Rock and Syverson, "The Productivity J-Curve" American Economic Journal: Macroeconomics, January 2021

IMPLEMENTING AI COULD DOUBLE US PRODUCTIVITY GROWTH

Companies seeking to use AI in their operations need a plan and the ability to track any progress. It is not enough to buy the technology and assume miracles. We believe a task-based approach that decomposes all the individual tasks undertaken by a company and evaluates those that can be enhanced by AI appears most appropriate. Once assessed, companies should focus on those tasks which offer the chance for the greatest potential productivity payoff and apply AI there.

Secondly, tracking key performance indicators such as employee productivity, cost reduction process efficiency and revenue growth, among others, is crucial and provides a reference point to other organisations in a company's industry.

While implementation may come with some upfront costs, the expected productivity gains from AI⁷ over a longer-term horizon are meaningful. In fact, one estimate⁸ suggests AI could double US productivity growth rates over the next decade, rising from around 1.4% per year to roughly 3% per year, dramatically boosting aggregate living standards and offering solutions to seemingly intractable problems such as the US budget deficit and healthcare costs.

These benefits will not derive from AI technology alone, but by having clear plans and a task-based analysis that identifies the most salient opportunities for gains.

Although this technology is amazing, there is huge resistance in the United States and Europe to change. There is a strategy to try to be conservative and to preserve the old jobs rather than embracing new jobs. Paradoxically, I think that is a much riskier strategy. Although it may seem dangerous to embrace the creative destruction that AI could bring, ultimately every successful society has succeeded because of a willingness to adapt. In the US, new business formation and the number of companies that are less than five years old have trended downwards for twenty years. The number of people who move from one company to another has dropped, as has the number of people moving to different geographic locations. Every metric of dynamism is trending downwards, and I think that's a big reason why productivity growth has disappointed for so long.

Therefore, productivity has been poor, not because the technology isn't there to enhance it, but because of a conservatism that has prevented the business transformation needed to fully embrace it. We need to change our culture, change our regulations and be willing to embrace this transformation.

If we do that, then the next ten years could be the best ten years yet seen in human history. We could see higher productivity and growth, with positive implications for issues such as fiscal deficits and, on a human level, improvements in health care and longevity could benefit us all. But at the same time, we could be about to face the worst ten years if bad actors end up embracing this technology and using it for nefarious ends – we could see the creation of new viruses, the scope for huge economic disruption and potentially spiralling increases in the volume of misinformation.

^{7,8} Brynjolfsson and Petropoulos, "The Coming Productivity Boom", MIT Technology Review, June 2021.

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