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AI is the New Macro Part II: An AI Powered Productivity Boom

We believe AI will be the key driver of equity markets over the next decade, significantly impacting the labor market, productivity and sector concentration, as well as margins and free cash flow (FCF) generation. We briefly summarize these four implications below. Part I of our four part series focused on implications for the labor market. Part II examines productivity, which has been the primary determinant of our prosperity and welfare. In turn, since at least Gutenberg, technologies like AI have been the critical driver of productivity.

Four key implications of AI: Overview

First, AI will be highly disruptive to the U.S. labor market, with a majority of occupations changed materially over the next two decades. It is estimated that 80% of the U.S. workforce could have at least 10% of their tasks affected by the introduction of large language models (LLMs).[1] Further, about 20% of workers may see at least 50% of their tasks impacted.[2] The sectors most exposed to AI are healthcare, education, retail, finance, legal services and customer support, as well as manufacturing and defense. However, as occurred during previous technological waves (steam engine, electricity, internet), we project overall employment and real wages to rise significantly over the next ten to twenty years.

Second, the diffusion of AI across the economy is expected to increase U.S. productivity by 10% to 15% over next two decades. The easy lifts include customer service, coding and writing, but we also predict increased efficiency from teachers, doctors, lawyers, taxi drivers, and others. It is estimated around 60% of jobs will have their productivity increased by 30% over the next two decades.[3] Additionally, general purpose technologies (GPTs) like AI invariably result in entirely new products and even sectors, and this is what always drives the bulk of productivity gains.

AI's impact is likely to echo that of previous GPTs, especially the internet and electricity. However, for investors, there can be a tortuously long lag from the time a new technology emerges until it becomes ubiquitous and truly moves the needle on margins and FCF. For example, it took 30 years for both

[1] See "GPTs are GPTs: An Early Look at the Labor Market Impact Potential of Large Language Models," OpenAI, 2023.

[2] This is not unusual. It is what occurred from 1890 as electricity diffused across the economy and in the decades following 1790 when the steam engine and complementary technologies displaced 90% of jobs, primarily in agriculture.

[3] "Machines of the Mind: The Case for an AI-Powered Productivity Boom," M. Baily (Brookings), E. Brynjolfsson (Stanford) et al, 2023.

electricity and computers to reach 50% adoption. As often occurs during these phase transitions, one major impact of AI will be to sharpen the difference between companies that excel at technology (superstar firms) and those that do not.

Third, AI will turbocharge the "winner-takes-most" dynamic witnessed over recent decades. Digital business models involve huge fixed-cost investments (in data, algorithms and compute), creating enormous economies of scale. Further, network effects ensure scale begets more scale, a dynamic that has created quasi-monopolists in search, e-commerce and social networking. This means the lion's share of value created will be captured by a small number of superstar firms, resulting in increased concentration in most sectors.

However, it is invariably the case that "titans rise and titans fall," so it is probable that several of last decade's winners will misstep and tumble from grace. Few of the companies that started on top in 1890, in the case of electricity, or in 1970 for computers, were still there 30 years later. Identifying the next generation of titans though is always challenging, for both VCs and equity investors alike, with a legion of plausible aspirants already launching AI products.

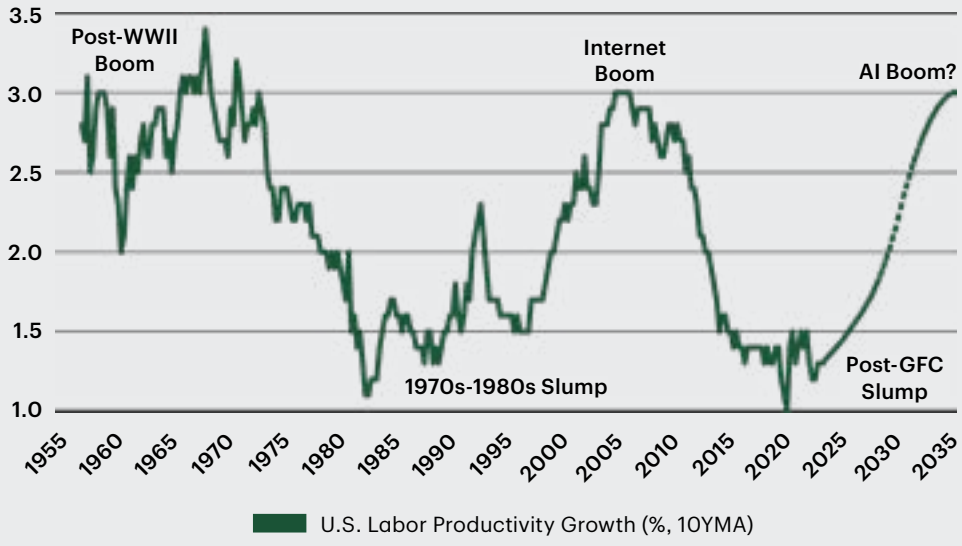
Finally, business strategies for the digital era are capital-light, emphasizing intangible rather than physical capital, and employ relatively few people. These features, plus the economies of scale discussed above, result in business models that are remarkably powerful for margins, FCF, return on invested capital (ROIC), and shareholder yield.[4] This means companies and sectors with comparatively high AI exposure are likely to significantly outperform over the medium-term. Regarding country-level allocation, three factors favor the U.S. relative to China, Japan, and Europe: a majority of the world's private investment in AI occurs here, the U.S. favors a relatively light regulatory touch, and America delivers a supportive ecosystem of universities and venture capital.

We expect AI to drive a repeat of the internet productivity boom

The remainder of this paper examines the implications of AI for productivity growth. To begin, note that U.S. productivity averaged an impressive 2.1% growth rate since WWII. However, this masks two boom periods, 1947 to 1970 and 1995 to 2005, when growth averaged 2.5% to 3.0%, and two slumps, when the mean was closer to 1.5% to 2.0% **(Figure 1)**. We believe the economy is exiting the post-GFC slump and entering a period similar to that starting in the 1990s,

Figure 1 – We Expect the Diffusion of AI Across the Economy to Increase U.S. Productivity by 10 - 15% Over the Next Two Decades

However, there is a long lag before emerging technologies gain scale and measurement issues are becoming ever more challenging.



Source: Bloomberg Finance L.P., Bureau of Labor Statistics (BLS)

[4] See our paper, "When "Bits" Meet "Atoms": Implications of the Second Machine Age for Corporate Profitability and Traditional Business Models," 2018.

when a wave of investment in computers and internet technologies drove a surge in productivity growth.

A number of studies have taken a bottom-up approach to estimating potential efficiency gains. One examined a database with 1,016 occupations which are analyzed in terms of 2,087 detailed work activities or 19,265 specific tasks.[5] One of their key conclusions is that: With access to an LLM, about 15% of all worker tasks in the U.S. could be completed significantly faster. When incorporating software and tooling built on top of LLMs, this share increases to between 47% and 56% of all tasks. Overall, this study suggests the potential for highly significant productivity gains from the diffusion of AI.

Additionally, many consultants and investment banks have produced estimates for the impact of AI on productivity. Goldman Sachs forecasts U.S. productivity growth could rise by just under 1.5% per year over a 10-year period following widespread adoption (which they believe will take roughly a decade), with a smaller but meaningful impact between now and then. McKinsey expects AI to increase U.S. productivity by 0.5 to 0.9 ppts annually, which is about half the Goldman forecast. Note that both estimates are incremental to the Congressional Budget Office (CBO) projection of 1.5% productivity growth, so suggesting quite impressive gains over coming years.

GPTs are the key driver of productivity

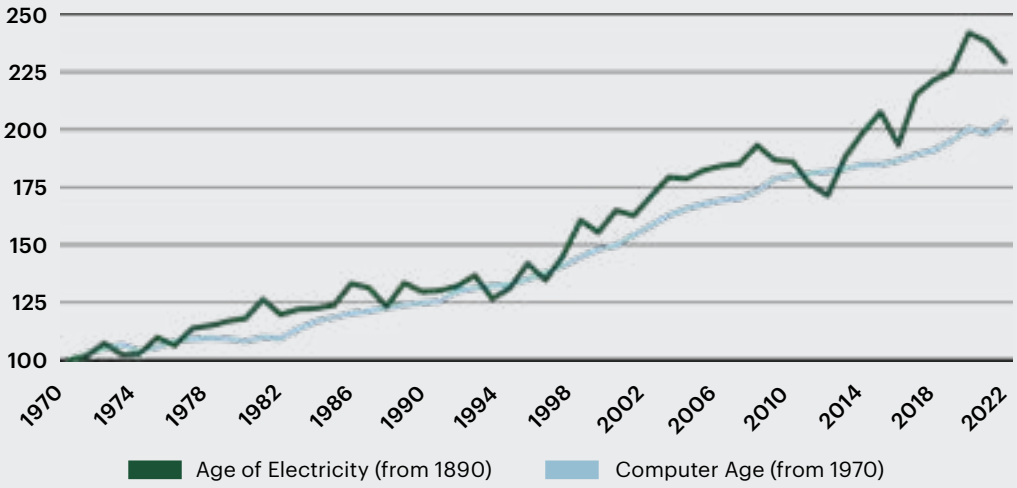
Another way to assess the likely impact of AI on productivity is to look backwards to previous GPTs.[6] For example, two comparatively recent technologies exhibited almost identical rates of diffusion **(Figure 2)**. This remarkably similar pattern appears even though the emergence of electricity from 1890 and the computer age from 1970 were almost a century apart.

One takeaway from Figure 2 is that it takes a considerable time—often more than is commonly appreciated—to hit 50% adoption for new technologies. In the case of both electricity and the internet, it took 30 years. We expect something similar for AI, although the adoption curve is likely to be steeper this time.

As a third example, consider the steam engine, which drove the first industrial revolution and unprecedented gains in productivity, but first required almost a century of complementary innovations (the engine was initially designed to pump water out of mines and, decades later, the first train tracks were made of wood). As Nick Crafts of the University of Sussex emphasizes, James Watt's steam engine was patented in 1769. Yet the first serious commercial railway, the Liverpool to Manchester line only opened in 1830, and the core of the railway network wasn't built until 1850. That was 80 years after the seminal patent.

Figure 2 – Labor Productivity from the Beginning of the Computer Age (1970) and Electricity (1890)

Productivity trends for the two GPTs are 98% correlated, at least until the WWII productivity boom.



Source: Bloomberg Finance L.P., Bureau of Labor Statistics (BLS), OECD and "Productivity Trends in the U.S.," J. Kendrick (GWU), 1961

Note: Indexed to 100 in 1890 for electricity and 1970 for computers.

[5] "GPTs are GPTs: An Early Look at the Labor Market Impact Potential of Large Language Models," OpenAI, 2023.

[6] To qualify as a GPT a technology must: be pervasive or ubiquitous, improve over time, and spawn complementary innovations. Over the last 10,000 years there have only been 25 GPTs, including money, the wheel, writing, printing, the steam engine, electricity, computers, the internet and now AI. "Economic Transformations: GPTs and Long-Term Economic Growth," R. Lipsey et al, 2005.

The next GPT, electricity, played out similarly. Thomas Edison demonstrated the electric light bulb in 1879, but twenty years later candles still reigned supreme and only 3% of U.S. households had electricity (the 50% threshold wasn't reached until 1925). Further, although the electric motor was developed in 1886, it was initially greeted with deep skepticism and its key selling point was being cheaper than steam power. Additionally, a major obstacle was that 19th century factories had a single power source that drove every machine, utilizing a central shaft and an elaborate system of gears, pulleys, and belts.

Relative to this system, electric motors offered decisive advantages—they were smaller and mobile, and the concept of unit drive meant each individual machine could have its own power source. Still, it took a full generation for factory layouts to be reorganized to fully harness the benefits of electric motors. Transformations that turbo-charge productivity take decades and are extremely disruptive to the status quo. In particular, most successful incumbent companies in 1890 did not survive the transition.

Occupation and sector examples: AI offers "expertise on tap"

The previous section analyzed the impact of previous GPTs, from the steam engine to the internet, demonstrating why that makes us optimistic regarding the future of productivity. We now switch gears and take a more bottom-up approach, examining the productivity outlook for several of today's occupations and sectors. The overall message is decidedly positive, but profound measurement issues mean official statistics will dramatically understate the true extent of AI-induced productivity gains.

Spending on AI is accelerating across the board, but most notably in healthcare, finance, and education. In terms of tasks, the easy lifts include writing, coding, and customer service. To illustrate the impact of the latter on employment, McKinsey expects customer service and office support roles to decline by roughly 15% over the next decade (i.e., from 35 mn to about 30 mn jobs), directly affecting retail salespeople, cashiers, secretaries and administrative assistants, office clerks and customer service reps.

Further, our previous paper discussed five examples of occupations where AI is already leading to drastic improvements in productivity: programmers/coders (Copilot makes engineers 55% faster at completing coding tasks), writers (the average time taken decreased by 40% for mid-level professional writing tasks), call center workers (an immediate 14% bump in productivity), taxi drivers (also 14%, especially for those with less experience) and radiologists (over 50% of practices have adopted AI but the productivity improvement is difficult to quantify).

Our earlier note also highlighted a study out of Stanford's AI center, "Will Generative AI Make You More Productive at Work? Yes, But Only If You're Not Already Great at Your Job." While the title is somewhat tongue-in-cheek, the sentiment is supported by a large number of academic studies, as well as media reports of AI's passable college-level essays and famously flawed legal briefs.

Overall, it appears that, for a wide variety of occupations, AI can already augment basic abilities and increase the productivity of less-skilled workers, allowing them to perform at levels previously achieved only by their more experienced colleagues. We'll now move on from occupations to examine three sectors where AI is beginning to have a dramatic impact, although the positive effect on output and productivity is often difficult to measure and quantify.

AI and personalized education: This isn't science fiction, it's six months away

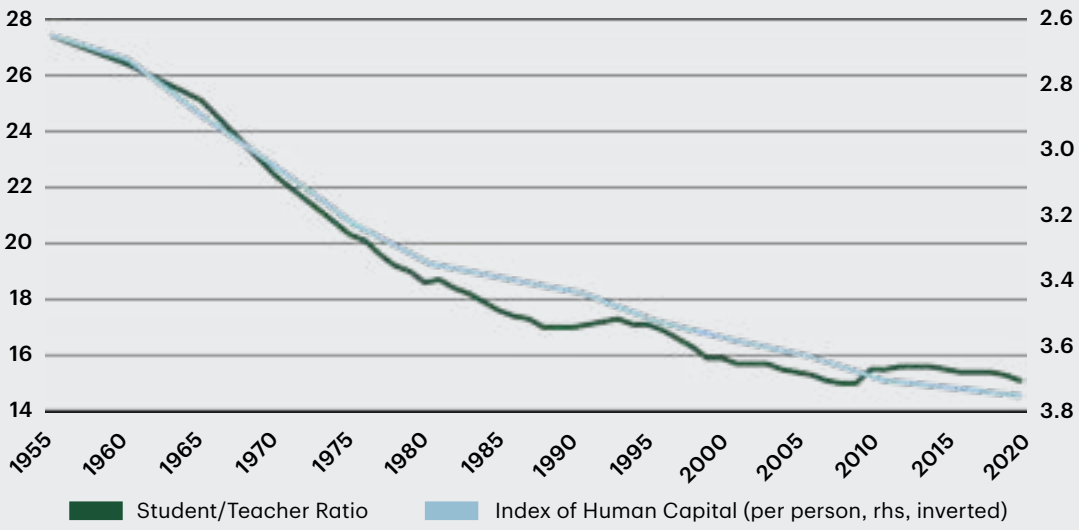
Today we have the tools, teaching assistants powered by AI, to make personalization a reality in the classroom. Leading the charge is Khan Academy, which has more than 150 million registered users and is available in over 50 languages. Its AI tutor, Khanmigo, takes the lecture out of the classroom and allows students to learn at their own pace. It also provides instant feedback on essays or math reasoning, with the aim of driving a deeper level of engagement and, ultimately, a two-sigma improvement in students' performance.

For educators, Khanmigo aims to be a comprehensive teaching assistant, creating real-time progress reports that are much more helpful than today's standard end-of-unit tests. This technology allows teachers to spend more time and energy on one-on-one interactions with their students. However, as Tyler Cowen of GMU cautions, transformations take time: "Big changes are in the offing, but they will arrive slowly. Classroom practices, for better or worse, are among the stickiest of human institutions. A lot of instruction hasn't changed much for thousands of years."

What does all this mean for productivity in the sector? Unfortunately, we'll probably never know. While education is a $1.3 tn industry, representing 6.4% of U.S. GDP, the government does not report productivity statistics for it, citing the difficulty of

Figure 3 – Measuring Output and Productivity in Education is Fiendishly Difficult

The student/teacher ratio has declined by 45% since 1955, but this partially reflects improved output quality.



Source: National Center for Education Statistics, Federal Reserve Economic Data, Penn World Tables

measuring outputs.[7] If output is simply the number of elementary and secondary students enrolled, then the productivity trend has been dismal **(Figure 3)**. Since 1955 the student/teacher ratio has declined by 45% (42% for public schools and 61% for private). However, this might be partially due to higher human capital per student, reflecting the increased demands of today's knowledge economy.

The coming AI revolution in healthcare

We now turn to a second sector, healthcare, where AI also holds enormous potential to boost productivity. Unfortunately, though, output is again extremely difficult to measure, primarily reflecting the complex nature of services provided.

Almost every industry has been majorly upleveled by technology over recent decades. Healthcare is the biggest remaining prize and many commentators posit that AI will have a bigger impact there than in any other industry. One reason to be optimistic is that 9% of overall AI spend from 2017 to 2022 was in healthcare, representing the largest share of any sector. However, even though healthcare is arguably the most information-intensive industry in the economy, one-third of the world's data resides in the sector, it uses information technology among the least of any industry. This is one reason Mckinsey forecasts U.S. healthcare employment to increase by an eye-popping 30% (from 18 mn to 23 mn jobs) over the next decade.

In our previous paper we discussed AI's impact on several aspects of healthcare. To illustrate, doctors often spend two hours a day on dictation and transcription. Existing AI tools can shorten that to 15 minutes and with fewer errors. Additionally, ChatGPT has achieved an overall accuracy of 72% on 36 common diagnoses.[8] Soon this will be above 80%, arguably sufficient for use in a clinical setting, complementing the judgement of doctors. Also, AI is increasingly used for image analysis, which includes reading MRIs, evaluating pathology reports, and interpreting ECGs. Further, the technology has enormous potential to improve the hit-and-miss process of drug discovery. Finally, there are numerous non-clinical use cases, including customer service, scheduling, and billing.

When will we see this promised revolution appear in the productivity statistics? As the above quote suggests, probably no time soon. According to the BLS, labor productivity for U.S. hospitals grew at a dismal annual rate of 0.0% for the period 1987 to 2021. One reason is measurement problems, as the

[7] "To measure productivity in education, we must first define the inputs and the outputs. Not surprisingly, this is a much more difficult task in education than it is in manufacturing." Source: "Defining Productivity in Education: Issues and Illustrations," by E. Hanushek (Stanford) et al, 2017. One potential measure of output quality is standardized test scores for math and reading, which have improved modestly since 1970. Source: https://www.nationsreportcard.gov.

[8] "Assessing the Utility of ChatGPT Throughout the Entire Clinical Workflow," by A. Rao et al, Massachusetts General Hospital, 2023.

ultimate question of how to define output in the hospital industry is subjective and open to debate. Additionally, most of the productivity growth in the sector has come in the form of improved quality, which is much easier to measure with standardized manufactured goods than services like healthcare. Further, innovations that have reduced costs and increased productivity—such as moving from inpatient to outpatient care—are not captured in the standard measures.[9]

Further, in many other service sectors where the output is not standardized (e.g., law, accounting, consulting), statisticians use prices and billing information to help estimate output and productivity. However, medical insurance partially insulates consumers from market prices, a problem exacerbated by the heft of government programs, such as Medicare and Medicaid, which represented 42%, or $1.8 tn, of national healthcare spending in 2022.

The challenges statistical agencies face in accurately measuring output and productivity in service sectors like healthcare and education is an extremely big deal and getting bigger. Healthcare accounts for 24% of consumption, up fourfold since 1960. The sector now employs 30% more workers than manufacturing, a big change from 1990 when it employed less than half. More broadly, services today account for around 70% of consumption and an even higher share of employment. And as the quote below illustrates, this is a problem the BLS has long been cognizant of.

In general, it is more difficult to calculate productivity in services than in manufacturing. However, there are exceptions, such as retail, where output is well defined, and productivity has averaged an impressive 3.2% from 1987-2022. This growth has been led by nonstore retailers (e-commerce) with its whopping 9.1% annual improvement **(Figure 4)**.[10]

Further, productivity is challenging to calculate even in some manufacturing intensive industries, particularly when the government is the main client, market prices are lacking, and technology is changing quickly. To illustrate, the defense sector represents over 3% of U.S. GDP and is closer to Silicon Valley than ever. Military AI is used for processing data from satellites to help soldiers on the battlefield, while image recognition software helps identify targets. Further, autonomous drones are used for surveillance, delivering supplies and hitting targets. There is also an increasing role for robots which Mustafa Suleyman views as AI's body or physical manifestation.

On August 28, the U.S. Defense Department unveiled its "Replicator" drone program which aims to create thousands of AI-enabled autonomous unmanned systems over the next two years. The objective is to shift away from expensive, vulnerable platforms (aircraft carriers, large planes) toward cheaper, smarter systems. Good luck to the statisticians in D.C. trying to calculate the productivity implications of the DoD's increased emphasis on bits versus atoms.

Figure 4 – Retail Sector Productivity has been Strong, Largely Driven by E-commerce, which is Increasingly AI-enabled

We use sales per employee here as a rough proxy for productivity.

Source: Bloomberg Finance L.P., Bureau of Labor Statistics (BLS)

[9] "Measuring Productivity in Healthcare," L. Sheiner et al, Brookings, 2016.

[10] On the other hand, grocery stores have not only exhibited weak productivity growth, a measly 0.7% rate since 1987, but this partially reflects self-checkout kiosks, which MIT's Acemoglu refers to as a so-so technology that doesn't actually deliver value.

As a final example from the manufacturing sector, let's briefly consider the productivity potential of autonomous vehicles (AVs). There are currently 3.5 mn workers in the U.S. driving trucks, taxis or buses. At some point AVs will reduce this number dramatically, resulting in a significant increase in aggregate productivity (around 2% over 10 years is a reasonable but overly narrow estimate). Up to now though, AVs have had a negative impact on measured productivity, as the total global investment already exceeds $250 bn, with little driver displacement or consumer adoption so far. Further, many incumbent auto companies appear to believe they can adopt AV technology without fundamentally restructuring their business model and processes. The historical precedents are not terribly encouraging and suggest a classic case of the innovator's dilemma.

Has economic progress become harder or has progress become harder to measure?

The above sections explained why we believe AI will provide a major boost to productivity. However, official statistics will only partially capture this new trend because they suffer from several measurement errors. For a start, the output of knowledge workers is difficult to measure, as we've illustrated for the education and healthcare sectors, but is more broadly applicable. Further, new products are arriving faster, and intangible investment including AI is now multiples larger than its tangible counterpart.[11] The bottom line is that economic progress is increasingly taking forms that are not readily measured in U.S. national accounts.

Productivity is a WWII industrial concept and poses few problems when dealing with standardized, manufactured goods that you can drop on your toe. It is a quite different matter in an intangible, knowledge economy, with a stunning pace of digital innovation and the services' share surpassing 75%. A Fed researcher recently concluded the mismeasurement could be 2% annually, with the acceleration of mismeasurement in the 21st century being close to 1% per year.[12]

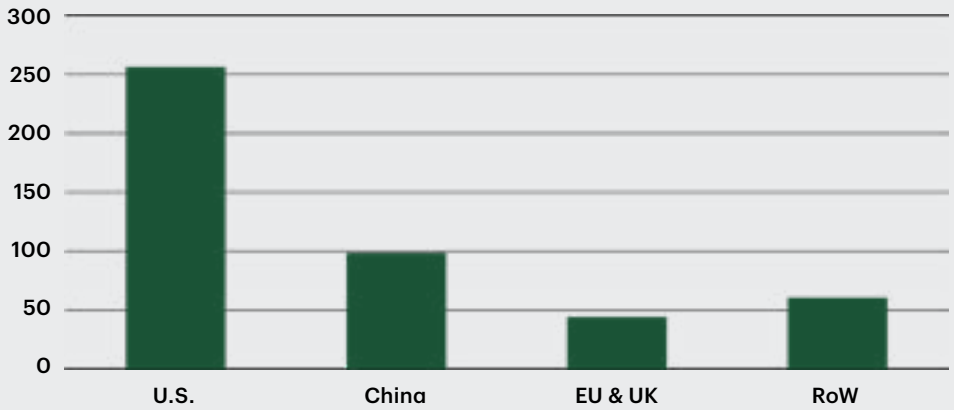
All this suggests economic statistics are, at best, a rear-view mirror, so the impact of AI will show up in many other places before macro indicators offer confirmation. Our soft data watchlist includes: overall AI investments (the Stanford AI Index provides a wealth of details), VC activity (data from PitchBook and CrunchBase), sales of "picks and shovels" (such as GPUs), and the quality of apps being launched. Unfortunately, the hype-cycle introduces an enormous amount of noise into this effort.

AI and American exceptionalism

Having examined the impact of AI on various occupations and sectors, we now briefly discuss which regions are likely to experience the largest boost to productivity. There are several factors that favor the U.S. relative to China, Japan, and Europe. First, a majority of the world's private investment in AI occurs in the U.S. **(Figure 5)**. Also, America

Figure 5 – Total Private Investment in AI (USD bn, 2013-2022)

Over the last decade, U.S. private sector investment in AI is 2.6x that in China and 5.8x that in the EU and UK combined.



Source: Stanford AI Index Report, 2023

[11] Ocean Tomo, a merchant bank specializing in intellectual capital, estimates the share of S&P 500 market value attributable to intangible assets has risen from 17% in 1975 to 90% in 2020.

[12] "Evidence of Accelerating Mismeasurement of Growth and Inflation in the U.S. in the 21st Century," L. Nakamura, Philadelphia Fed, 2020.

leads in terms of the total number of newly funded AI companies, hosting 1.9 times more than the EU and the UK combined, and 3.4 times that of China. Second, in sharp contrast to the EU, the U.S. favors a relatively light regulatory touch.

Third, America offers a supportive ecosystem of universities and an unrivalled VC network. To illustrate, from 2018 to 2022 VC investments in the U.S. topped one trillion dollars, roughly three-times the total for China and almost tenfold that for the UK. Finally, America's spending on R&D, much of which is now focused on AI, is accelerating **(Figure 6)**.

However, it is possible that America's dominance will be challenged by China, which has an explicit national strategy to be the world leader in AI by 2030. One advantage of China's top-down model is that it can marshal the state's full resources behind this goal. Moreover, China already leads in some applications, such as robot installations, and is focused on several complementary technologies, including semiconductors, quantum computing, drones and autonomous vehicles.

Implications for investors: We are very early in the AI adoption cycle and ensuing productivity boom

The diffusion of AI across the economy is expected to increase U.S. productivity by 10% to 15% over next two decades. The sectors most likely to experience a productivity boost include healthcare, education, finance, legal services and customer support, as well as manufacturing and defense.

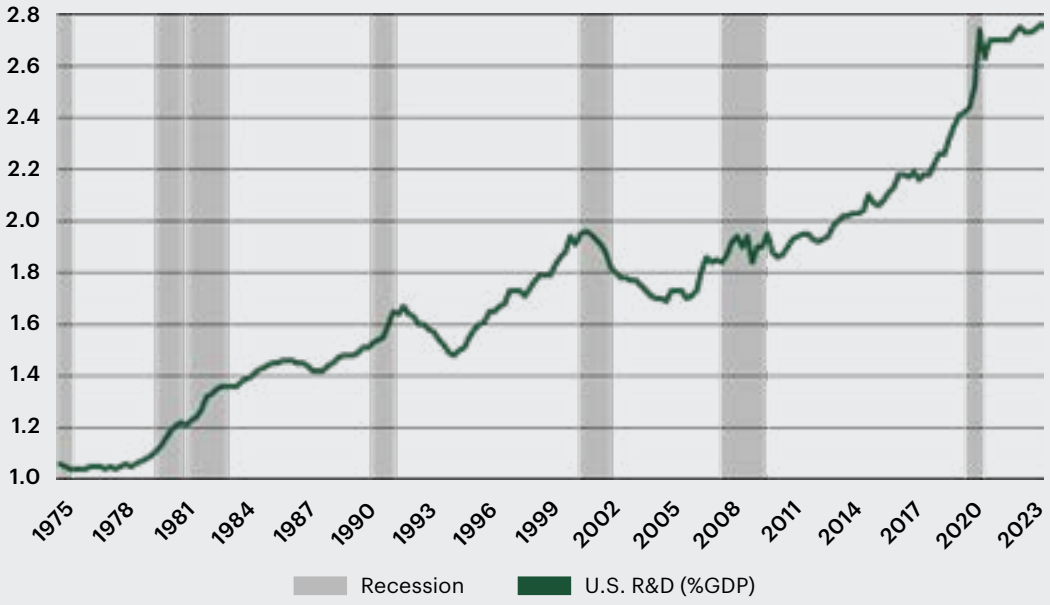
However, official statistics will only partially capture these improvements because the output of knowledge workers is difficult to measure, new products are arriving faster, and intangible investment including AI is now multiples larger than its tangible counterpart. Economic progress is increasingly taking forms that are not readily measured in national accounts.

Additionally, GPTs like AI always result in entirely new products and even sectors. While impossible to forecast, this is what ultimately drives the bulk of productivity gains. For investors, though, there is invariably a tortuously long lag from the time a new technology emerges until it becomes ubiquitous and truly moves the needle on margins and FCF.

This concludes the second in our four-part series examining the impact of AI on the economy and financial markets. The first paper showed that AI will be highly disruptive to the U.S. labor market, with a majority of occupations changing materially over the next two decades. However, as with previous GPTs, we expect overall employment and real wages to rise significantly. Our next paper will explain why AI, like all digital tech, features "winner-takes-most" dynamics. We expect increased concentration in most sectors, with a small number of companies

Figure 6 – America's Spending on R&D has Accelerated Post-GFC

With a lag, this will boost both AI activity and productivity growth.



Source: Bloomberg, BEA

capturing the vast majority of gains in value creation. Moreover, identifying the next generation of titans is always challenging, with a legion of plausible aspirants already launching AI products. Our fourth paper will examine business strategies for the digital age. They are capital-light and benefit from economies of scale, which is positive for margins, FCF, ROIC and shareholder yield. This is especially true for companies that establish themselves as superstars or global champions in the AI era.

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