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Artificial Intelligence and Related Technologies in Investment Perspective

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We are in the very early innings of a multiyear growth phase driven by AI as this disruptive technology will transform every aspect of business and society. The race is on to create artificial general intelligence which will require ever-increasing model sizes with trillions of parameters. On the other end of the spectrum, there is considerable progress being made on improving AI models, so that they can run on edge devices, like PCs and smartphones, and create new and compelling capabilities.

— Sanjay Mehrotra, CEO, Micron. Q2 FY 2024 Earnings Call, March 2024

…every technological revolution…going back from the internet to telephones, railroads, or canals—has been accompanied by early massive hype and a stock market bubble as investors focus on the ultimate possibilities of the technology, pricing most of the very long-term potential immediately into current market prices. And many such revolutions are in the end often as transformative as those early investors could see and sometimes even more so—but only after a substantial period of disappointment during which the initial bubble bursts…So it is likely to be with the current AI bubble.

— Jeremy Grantham, GMO. "The Great Paradox of the U.S. Market!" March 2024

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Summary and Conclusions

Artificial intelligence (AI) is defined as a machine's ability to perform cognitive functions usually associated with human minds such as perceiving, reasoning, learning, interacting with an environment, problem solving, and even exercising creativity.[1] The technology underlying Siri and Alexa rests on AI. By using AI, businesses have the potential to expand their markets and revenues as well as to make their operations more efficient and more profitable.

It is amazing that two years ago most investors hardly knew of the existence of AI although early stages of the technology have been around for years. In 2023, largely because of the emergence of ChatGPT and related products, press and investment reports on AI, and management comments in earnings calls (the statement by Micron's CEO), the shares of technology companies most affected by AI took off. Some portfolio managers and strategists feel that the market is way ahead of itself and that early investors should be prepared for disappointment (Jeremy Grantham). It is possible that both Micron's CEO and Grantham are correct.

This paper offers the following conclusions:

- The AI revolution is for real and is comparable to the great inventions that drove U.S. economic growth from 1870 to 1970. It is already affecting in a measurable way U.S. business investment in equipment and infrastructure required to implement AI on a broad basis.

- The capabilities of AI are extraordinary and will be widely applied throughout U.S. society. AI is still in the early stages of a massive rollout.

- From the standpoint of corporate users of AI, its implementation is expected to increase revenues, reduce costs, and generally improve productivity. Already the impact is being seen in the demand for equipment to support AI (such as computer processors and semiconductors). While it is impossible to know at this stage the magnitude of the contribution of AI to S&P 500 Index company profitability, I believe over time it will be material and central.

- Entering 2024, the long-term outlook in the eyes of many economists and investment strategists appeared lackluster as a result of declining economic growth rates, persistently high inflation, elevated interest rates, outsized chronic government deficits, growing burdensome federal debt, and a potentially stagnant labor force. The Congressional Budget Office in its most recent 30-year forecasts projected real GDP growth of 2% per annum and inflation rates at 2% per annum, which in the eyes of some economists seem optimistic.[2] AI, in my view, radically changes this outlook. Over time, real GDP rates should increase to 3% as a result of AI, and there are estimates from leading financial institutions suggesting even higher rates are possible. Increased economic growth should result in expanded personal income and an improvement in the standard of living. In addition, as shown in this paper, another consequence of higher growth will be to stabilize government finances and potentially to reduce the burden of federal debt.

- This favorable forecast, if realized, will significantly improve the investment outlook. The United States appears to be in the leading position in the development and implementation of AI. This means that the growth in revenues and earnings of American publicly held companies that are developing and implementing AI technology and applications may be

[1] McKinsey, https://www.mckinsey.com/~/media/mckinsey/featured insights/mckinsey explainers/what is ai/what-is-ai.pdf April 2023
[2] Congressional Budget Office, https://www.cbo.gov/publication/59711, March 2024.

the most attractive in the global universe. Because adopting AI requires significant resources, our largest multinational companies generally will be the first to benefit significantly. Many of the companies that are currently profiting from AI are very well financed and exhibit strong earnings growth momentum. Accordingly, we continue to recommend for long-term investors, a U.S.-centric large-cap investment strategy.

"Great Inventions" brought about periods of accelerated growth in the U.S. economy, real incomes, and the standard of living.

Robert Gordon's seminal study of American growth between 1870 and 1970 provides an ideal starting point for considering the impact of artificial intelligence on the U.S. economy.[3] Gordon asserts that the remarkable growth achieved in this 100-year period, particularly between 1920 and 1970, was made possible "by a unique clustering in the late nineteenth century…of 'great inventions'." These include the inventions of electrical power generation and distribution and the internal combustion engine, which together gave rise to electric lighting, power for appliances and motorized manufacturing, and the automobile. American life was additionally transformed by running water, the telephone, improvements in handling and processing food, the betterment of working conditions, the emergence of the entertainment industry through movies, radio and later television, discoveries in medicine, jet aviation, air-conditioning...the list goes on and on. The question arises whether AI, machine learning, robotics, and related technologies constitute transforming "great inventions" that will have a similar impact on growth in the 2020s, 2030s and beyond.

Table 1
Productivity and GDP Real Annual Growth

Gordon's Data

	Productivity Annual Growth
1870-1920	1.79%
1920-1970	2.82%
1970-2014	1.62%

U.S. Burea Labor Statistics Data

	GDP Annual Growth	Productivity Annual Growth	Implied Labor Force Annual Growth
1970-1993	2.99%	1.80%	1.19%
1994-2004	3.42%	2.70%	0.72%
2005-2016	1.82%	1.50%	0.32%

[3] *The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War*, Robert J. Gordon, Princeton University Press, 2016.

Gordon noted that "economic growth [measured by real GDP growth rates] since 1970 has been simultaneously dazzling and disappointing." There was one period of 10 years from 1994 to 2004 when productivity and growth surged, attributable to inventions in information and communications technology. In the other years since 1970, U.S. productivity and growth were less robust. Reference is made to Table 1. The point is that the economic impact of the advances in computers, telecommunications, and the Internet until now has been limited.

It is axiomatic that economic growth is the sum of changes in productivity plus changes in the labor force. The data in Table 1 also imply that future growth will depend increasingly on productivity rather than growth in the labor force, which is steadily decelerating owing to declining birth rates.

Gordon offers a dim assessment of the prospects for increased productivity and growth over the next 25 years. He does not discuss the possibility of a "great invention" because he doesn't see one on the horizon. It is fair to say no one else did in this period either. Furthermore, there are factors that will limit growth such as rising income inequality, disparity in educational levels, a shrinking labor force, and the burden of huge government debt. Reference is made to Table 2.

Others have picked up on this theme. Peter Oppenheimer in his book on structural changes and super cycles in markets wrote that future economic growth could be impeded by the rising cost of capital (higher interest rates), lower population growth, the drag from climate change, the shift from globalization to regionalization, the rise in commodity costs, increased government spending and the burden of higher federal debt, and the burden of higher capital and infrastructure spending.[4]

Table 2
Robert Gordon's Forecast on U.S. Productivity and Income Growth

Item	Growth Rate Per Annum		
	1920-1970	1970-2014	2015-2040
	Actual	Actual	Estimates
Labor Productivity	2.82%	1.62%	1.20%
Real GDP Per Person	2.41%	1.77%	0.80%
Real Median Disposable Income Per Person	2.25%	1.46%	0.30%

Source: Robert Gordon, The Rise and Fall of American Growth
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The Congressional Budget Office (CBO), a well-respected non-partisan government entity, projected the real growth of GDP and productivity from 2021 through 2034. Real GDP is projected to rise at a fairly steady rate of around 2.0% per annum and productivity at 1.4% per annum, implying that the growth in the labor force will average around 0.6% per annum.[5] These forecasts

[4] *Any Happy Returns: Structural Changes and Super Cycles in Markets*, Peter C. Oppenheimer, John Wiley & Sons, Ltd., 2024, Chapter 10 "The Post-Modern Cycle."
[5] Congressional Budget Office, Economic Projections, February 2024 https://www.cbo.gov/data/budget-economic-data. The Bureau of Labor Statistics recently forecasted that the growth in the U.S. labor force between 2022 and 2032 would only amount to 0.3% per annum. BLS, Employment Projections, 2022-2032, September 6, 2023. McKinsey, in its 2023 study *Generative AI and the Future of Work in America*, estimated that the labor force would grow between 2022 and 2030 by 0.5% per annum. Job losses of 5.5 million jobs will be lost in

are considerably more optimistic than Gordon's estimates contained in Table 2. The value of Gordon lies in his analysis of the past, not the future. The estimates of the CBO are more in line with the Fed's forecasts and the consensus of economists reported by Bloomberg and are consistent with the growth rates for GDP and productivity between 2005 and 2016 shown in Table 1. It is fair to conclude that most forecasts do not yet take into account the potential impact of AI on economic growth and productivity.

It seems likely that AI will be deemed a "great invention."

Anticipating the potential of AI, an extraordinary investment boom in equipment and infrastructure is already underway.

Goldman Sachs estimates that AI investment could reach $100 billion 2025 in the U.S. and globally $200 billion, indicating the United States is accounting for around half of projected total investment. An enormous amount of equipment such as AI servers must be shipped to prepare for AI adoption. The consulting firm 650 Group estimated that AI server shipments will increase from 1 million units in 2023 to 6 million in 2028. Corresponding revenues will rise from $40 billion in 2023 to an estimated $285 billion in 2028.[6] The initial major beneficiaries of AI will be the manufacturers of AI support equipment: servers, semiconductors, and other components. Over the longer-term, Goldman Sachs estimates that AI-related investment could peak as high as 2.5% ($750 billion) to 4% of GDP ($1.2 trillion) in the U.S., which will be an important stimulus to growth.[7]

Fueling this investment is the widespread belief that AI will forever change the way we work, innovate, and create.

Like earlier general-purpose technologies, such as electricity, the steam engine and the internet (a reference to Gordon), generative AI could fundamentally change how most goods and services are produced, transform industries, and create entirely new jobs. Here's why.

- AI Will Be Pervasive. Its general capabilities mean generative AI can be integrated in many different contexts to supplement or replace many activities currently done by humans.

- AI Will Spawn Complementary Technologies and Infrastructure. Companies across industries are rushing to adopt AI in their fields. The development of ancillary business applications is necessary to fully leverage AI's benefits.

- AI Is Experiencing Exponential Growth and Economies of Scale. AI's computing workload has been doubling every three to four months since 2012 and is likely to accelerate even further.[8] Open AI's GPT-3 and GPT-4 were released just two years apart, and the latter is significantly more complex, can interpret images received as inputs, is 40% more accurate in its responses, and scores significantly higher percentiles on many standardized tests.

- AI Is Reshaping Industries. Broad-scale automation will reshape the nature of jobs and business models, with transformative implications across industries including: healthcare (image analysis); finance (algorithms for fraud detection); transportation (autonomous vehicles); retailing (personalized shopping, inventory management, supply chain

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customer support and sales and office support owing to AI, but more jobs will be required in other occupations like health care.

[6] JPMorgan, "Takeaways from AI Conference Call with 650 Group", March 12, 2024.

[7] Goldman Sachs, https://www.goldmansachs.com/intelligence/pages/ai-may-start-to-boost-us-gdp-in-2027.html, November 7, 2023.

[8] It is astonishing that, although AI was being used over the past 10 years, we did not recognize the technology.

optimization); education (adaptive tutoring systems); marketing (predictive analytics, personalized messaging); and so much more.

- AI Is Accelerating Innovation. AI has the potential to accelerate research and development and unlock new insights that inform and inspire innovation efforts. Many leaders in the field think this may be AI's paramount application. One example is in new drug research. This point is worth exploring further. AI's potential in innovation rests on its ability to quickly sift through vast datasets and to analyze vast amounts of unstructured data. AI can identify new patterns, reveal insights, and discover better ways of doing things; AI can improve the accuracy of predictions and models.

AI is expected to stimulate significant increases in productivity and economic growth.

Estimates of the boost to labor productivity owing to AI span a wide range of between 1.5% and 3.0% per annum. This may not sound like much, but the difference in productivity between the high growth years of 1920–1970 and the lower growth years of 1970–2014 was only 1.2 percentage points.

Goldman Sachs has forecasted that artificial intelligence could raise productivity by just under 1.5% per annum over a 10-year period following widespread adoption. GDP similarly should rise by the same amount, 150 basis points per annum.[9]

According to Goldman, Sachs, AI should start having a measurable impact on US GDP in 2027 and begin to affect the growth of other economies in the years that follow.[10] The big point is that the U.S. is ahead of the rest of the world in AI and will benefit first. The foundation of the GS forecast is that ultimately 25% of labor tasks in advanced economies (less in developing economies) can be automated.[11]

JPMorgan has estimated the potential impact on real GDP growth of between 1.4% and 2.7% per year across developed markets. This estimate, if realized, would be comparable to past periods of technologically driven surges in productivity. JPMorgan based its estimate on its finding that traditional and generative AI applications could potentially automate 14% to 27% of current work activities in the United States over the next 10 years.[12]

If the long-term real growth of the United States is assumed at around 2% per annum and GDP advances in line with productivity, U.S. GDP growth could be boosted to a level above 3% per annum, a 50% increase. The point is that AI could have a profound impact on the growth of real GDP and real incomes.

AI is expected to have an important impact on capital markets, particularly equities.

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[9] The CBO offers an interactive spreadsheet tool which allows one to see the relationship between increases in productivity and GDP. An increase in productivity by 0.5 in each year from 2027 through 2034 would increase GDP real growth from 2.0% per annum (the baseline forecast) to 2.6% per annum, which seems to confirm that same increase percentage points to productivity will be additive to GDP growth. The tool does not permit scenarios at higher rates of productivity. CBO, Interactive Workbook, https://www.cbo.gov//system/files/2024-04/60074-Workbook.xlsx.

[10] Oppenheimer, *op cit*, page 273.

[11] Goldman Sachs, https://www.goldmansachs.com/intelligence/pages/ai-may-start-to-boost-us-gdp-in-2027.html, November 7, 2023

[12] JPMorgan Asset Management, https://am.jpmorgan.com/content/dam/jpm-am-aem/global/en/insights/The transformative power of generative AI.pdf, September 2023

Increased productivity should provide a significant lift to earnings as corporate bottom lines will benefit from direct labor cost savings, increased output from more productive workers, and the effect of reemployment of displaced workers.

Table 3			
S&P 500 Index, Corporate Earnings & GDP			
Rate of Growth, 2000 - 2023			
	2010	2023	Rate of Growth
S&P 500 Index	1257.64	4769.83	10.8%
S&P 500 Index Earnings	$83.77	$213.53	7.5%
Nominal GDP (Billions $)	$15,049	$27,356	4.7%
St. Louis Federal Reserve Bank, Standard & Poor's			

I did not find any discussion that linked future corporate earnings to nominal or real GDP growth, although it does makes sense that if GDP growth rates are increased by AI, corporate earnings should be proportionately boosted.

Over the next 30 years, the Congressional Budget Office has projected that nominal GDP will increase 3.5% to 4%, comprised of 1.7% real growth and 1.9% inflation[13], which is less than the 4.7% rate recorded between 2010 and 2023. Depending upon the impact of AI on nominal GDP by AI, it is not unreasonable to expect that S&P 500 Index earnings will advance in the 7% to 8% range over the long term, which is consistent with the 2010-2023 period shown in Table 3. Companies that are directly impacted by AI technology such as computer processing equipment and software suppliers will likely realize much higher growth.

JPMorgan noted that these impacts could take several years to materialize, markets – and equities in particular – have already anticipated AI optimism. Indeed, strong global equity performance in 2023, particularly in U.S. large caps technology stocks, has been largely influenced by excitement around generative AI technologies.

Implications of Faster U.S. GDP Growth on Federal Debt

In addition to increasing corporate earnings, the general investment backdrop will be improved by AI. In particular, the fiscal situation of the U.S. government could be markedly improved in the coming years by increased economic growth attributable to AI. It is reasonable to assume that the federal deficit will be reduced by increases in productivity and GDP. Based on an interactive tool provided by the CBO, about 75% of an incremental percentage increase in productivity will translate into a reduction of the CBO's baseline forecast of the federal deficit. I ran three scenarios: a net improvement in productivity of 0.5% (50 basis points), 1.0% (100 basis points) and 1.5% (150 basis points) over the CBO's forecast of approximately 1.6% per annum, beginning 2027 and continuing until 2054.[14]

Table 4 on the next page summarizes the projected impact on nominal GDP, the federal deficit and the federal debt as a percentage of GDP of the three scenarios compared to the CBO base case. Federal deficits gradually decline. My best guess is that incremental growth will fall in the 100 basis

[13] Congressional Budget Office, https://www.cbo.gov/publication/59711, March 2024.
[14] The CBO interactive tool only allows changes of plus/minus 0.5% in productivity. The two higher scenarios assumed the same relative impact on GDP and budget deficits as a +0.5% change.

points to 150 basis points range. It is especially noteworthy that if productivity and GDP growth are boosted 100 basis points, federal debt stabilizes at very close to the current situation in which the federal debt remains about equal to GDP. Under the more optimistic scenario in which productivity and GDP growth rise by 150 bps, the deficit is nearly eliminated by 2054 and federal debt as a percentage of GDP declines significantly. Restoring confidence in federal finances would have a power positive impact on the long-term investment outlook of the United States.

Table 4				
Impact on U.S. Economy of Incremental Growth by AI			CAGR	
Nominal GDP, Trillions $	2024	2054	Rate of Growth 2024-2054	CAGR Real Growth
CBO Forecast	$28.2	$85.2	3.8%	1.8%
Incremental Increase GDP 0.5% 2027-2054	$28.2	$94.3	4.1%	2.2%
Incremental Increase GDP 1% 2027-2054	$28.2	$104.3	4.5%	2.7%
Incremental Increase GDP 1.5% 2027-2054	$28.2	$115.3	4.8%	3.5%
Federal Deficit				
CBO Forecast	($1.6)	($7.7)		
Incremental Increase GDP 0.5% 2027-2054	($1.6)	($6.1)		
Incremental Increase GDP 1% 2027-2054	($1.6)	($4.2)		
Incremental Increase GDP 1.5% 2027-2054	($1.6)	($2.4)		
Federal Debt % GDP				
CBO Forecast	99.0%	171.7%		
Incremental Increase GDP 0.5% 2027-2054	99.0%	135.7%		
Incremental Increase GDP 1% 2027-2054	99.0%	104.4%		
Incremental Increase GDP 1.5% 2027-2054	99.0%	80.7%		
Source: Congressional Budget Office	https://www.cbo.gov/publication/59710			