

THE RISE OF AI

TECHNOLOGY AND INNOVATION REPORT, MARCH 2024



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INTRODUCTION

As the Liontrust Global Innovation team, it is perhaps not surprising we believe that innovation is the biggest driver of stock returns. Why? To put it simply, innovative companies have better fundamentals – they grow faster, build better barriers to competition and are more resilient and adaptable in tough times. Over the long term, the most innovative companies tend to rise to the top and so do their stocks.

There is no more innovative area than the technology sector and right now we are at the very beginning of a brand-new cycle of technology and innovation, which is being driven by the rise of artificial intelligence (AI). This has the potential to create enormous value and those companies that can harness the benefits of AI, while also capturing value for their shareholders through barriers to competition, will achieve strong investment returns.

At the same time, the technology sector has been working through a significant recession that began in 2022. This is the end of the old cycle and the beginning of a new one. Firms are cutting wasteful costs and extraneous projects and focusing on their core business. There were excesses in the last cycle, particularly during Covid. But the best technology companies have not shied away from making tough decisions in the past couple of years. Such companies will be first in and first out of the macroeconomic challenges arising from an environment of higher interest rates.

In turn, the impact of technology, through AI in particular, on the economy and society over the coming years will be significant. AI is already beginning to demonstrate the ability to drive productivity gains far and wide in the economy. This will be a major positive for economic growth, but we do not yet know what the impacts may be on potential job losses and broader societal risks, and what approach governments will take towards any trade-offs.

In the interview on the next page with renowned academic Professor Joshua Gans, we asked him for his views on some of these questions, as well as where he is most excited about the potential for AI and how he sees companies evolving to make the most of the new technologies available to them.

Further on in the report we hear from Michael Secora of Recursion, the exciting young biotechnology company using AI to decode our biology and develop groundbreaking new drugs. We also speak to Andrew Giessel of Moderna, the pharmaceutical and biotechnology giant behind mRNA vaccines and more besides.

We hope you find this report interesting and enjoy reading it as much as we did writing it.

CONVERSATIONS WITH AN



EXPERT



PROFESSOR JOSHUA GANS

The Liontrust Global Innovation team spoke with Professor Joshua Gans – the Jeffrey Skoll Chair in Technical Innovation and Entrepreneurship at the Rotman School of Management, University of Toronto – on the economics of AI, how it impacts the way we work, the best strategies for companies and regulatory risks.

Professor Gans is one of the world's leading economists on AI and his most recent book, co-authored with his colleagues at the University of Toronto, is the acclaimed *Power and Prediction: The Disruptive Economics of Artificial Intelligence* published by Harvard Business Review Press.



What are the main ways AI will affect the economy in terms of the way we work, how companies are run and how companies will compete?



AI is really at its core an advance in statistics, in particular the statistics of prediction. What these new techniques have done by virtue of clever algorithmic design and also a massive amount of computing power is to start to dramatically drop the cost of prediction. And every other time we've had that sort of transformation, when you've taken something that's quite costly and made it really cheap, there's been a whole lot of flow on applications and progress.

The biggest gains of all, however, come not from mere applications but when you get true transformation, when an entire industry is essentially reorganised by an input becoming cheap. Historically, think of how the taxi industry was effectively completely upended by the mobile phone. No one saw Steve Jobs introduce the iPhone and said "well, that's it for the taxi industry".

But these transformational impacts will take time because human reorganisation always takes time. AI will improve prediction, but it won't necessarily improve all the stodgy human stuff that slows down transformation. The real exciting developments for AI, which we're starting to get a glimpse of, is still to come in ways that we can't quite anticipate at the moment.

For things we're already predicting, like the weather or traffic, then we can improve our predictions and do it better. But the more interesting applications are where we didn't previously realise that the problem we were facing was a prediction problem, such as self-driving vehicles.



Do you expect companies that are prepared to reorganise to fully embrace AI to outcompete the companies that aren't prepared to do it?



There will be environments in which it's a good way to go to completely reorganise and design a technically superior system. But, more typically, it will be about tacking on automation and that will be quite difficult. It will be case by case based on the benefits of AI prediction versus all the costs that come from integrating this prediction. You will have to decide whether the juice is worth the squeeze.

way so it can reconfigure and churn out the right bricks accordingly. But think about all the other moving parts, getting it onto the shelves etc. Lego has a very fine-tuned process already and you need to make sure your new overall system operates better.

For example, I recently visited the factory of Lego in Billund in Denmark. There is lots of automation in producing these billions of different types of bricks, 24/7. We could use AI to do better demand prediction for different models of Lego and send that back to the factory floor in an automated

Furthermore, even where it is appropriate to reorganise the whole company for AI, you'll still need some way during the transition to take care of all the exceptions through human intervention when AI makes mistakes. AI can perform well, but only within the bounds of the laws of statistics. So if you've got model instability or bad data, it's going to do bad things as well.



What evidence has got you most excited so far about the potential of AI?



Well it's been hard to sit there during the last year or so and not just see that there's all manner of exciting things going on. Firstly, AI, and generative AI especially, has the biggest benefit through allowing someone who doesn't have skills or experience to mimic the productivity of somebody who does.

Sometimes it's given the term "upskilling", but it's not really upskilling because no one's learning any new skills. It's just that the skills you previously had to acquire through years of training have now been handed to you. Much like when you've got a navigation app on your phone, you can now perform at the level of a London taxi driver who has acquired the knowledge. That's an interesting set of effects occurring all over the place now and it's quite incredible.

For businesses, they'll have an easier time hiring and expanding and not be limited by the amount of training or experience people have. We're already seeing that in areas like coding.

Secondly, it's the extra stuff that AI is going to allow us to do. People worry all the time about AI taking jobs. But as far as I can tell, especially in the service industry, there's almost no one who hasn't got other things to do if they could just be relieved of some monotonous task or can get it done a lot quicker. So I suspect that's where we're going to end up. People are going to be able to do more, they're going to move to where the AI isn't and we will evolve our work much the same way as we did when we first got a computer.



What are the most important things the government can do on AI policy and what do you think the worst things are that they might do?



It's very tricky. I must admit, I'm a long-standing regulatory economist and I've never seen such a negative reaction and call to regulate a technology than I have for AI. And for the most part, it's purely on the basis of speculation. We haven't had AI do significant damage to something yet. The danger is that you might regulate something and squash an opportunity to apply AI that would have been quite innocuous, and you slow down progress.

A reasonable approach to regulation for now is trying to improve some of the practices by which we develop AI models and understand what they are. I think companies are doing that anyway. If you put out an AI-based product, you are still subject to product liability laws so you can't just throw it out there without thinking about what damage it could do, particularly when it comes to medical applications and anything involving human safety and human interactions that might be harmful.



What is your level of optimism for improvements in healthcare through AI?



The opportunities for AI in healthcare are enormous and there is huge potential to collect data, train models and do randomised control trials. But the challenge is it's potentially held up by all manner of laws that limit our ability to do these things. We've got existing regulations in health that are very damaging to every single stage in the innovation process. With AI, there's also the potential problem that even when

you finally get FDA approval, you are back in the regulatory process every time you do a software update.

I can see a huge opportunity if there were one country that cracked open the book and said: "We can grab this entire industry if we just get rid of these barriers." Because many of the barriers are for the most part harmful.



You have worked a lot on blockchain and cryptocurrencies. Are there complementarities between blockchain and AI?



In terms of using AI within blockchains, blockchains use lots of data and some of the security problems there come from pushing forward predictions that have been hijacked in some way. So if you marry the two technologies together, you could have more reliable predictions in blockchain and you could trust a lot more. That said, this hasn't turned out to be such a big problem yet, so we haven't quite seen the benefit of AI in blockchain yet.

When it comes to whether blockchain can help AI – well you know, I've been fascinated by blockchain as a technology for a long time and I think there remain lots of interesting aspects to it. But after a period of time, you have to sit back and ask 'are the transformative applications really there?' 'Is it really able to do something that you can't do elsewhere?' And for blockchain, for the most part, the answer is no.



Do companies need to be building AI capabilities internally or, with the likes of Open AI, can they rent AI expertise off the shelf? Will the leaders who create the most value from AI, particularly through realising system reorganisation gains, be doing it all in-house?



There are lots of constraints on businesses doing AI in-house; most notably at the moment there is a lack of talent you can secure for that purpose. The talent has gone where the scale is and the scale is in these companies providing the more general purpose solutions. The good news is those seem to be progressing quite rapidly and we're all learning a lot as we go.

They've had to control the architecture. If the architecture is running off an AI tool, this has to be superior, which means the chances are you will have to do this yourself. That said, Uber rearchitected its industry, and it didn't have to control the phones or even the navigation software to do so. But I feel such cases are rare beasts.

On the second part of your question, every other time anyone has had that sort of vision, they've really had to

Ultimately, time will tell. Certainly, for most businesses, off the shelf is really the only option. But there is so much opportunity to use off-the-shelf AI, that it is not too bad.



Finally, you have studied lots of historical technologies and their related innovation and disruption. What is your sense of where AI will rank in terms of its impact? Is it potentially one of the most transformational technologies that have come along?



I think that it's got the makings of a truly transformational technology. What I like is just how widespread and diverse the potential applications are. It is very wide and the opportunities are all over the place.

Is there some limit technically that we might hit before we can do all these marvellous things? Of course, that's something we don't know. There have been plenty of other technologies like blockchain, drones and 3D printing that just didn't technically perform well enough to be transformational. But we are in a great upswing with AI and I'm pretty optimistic about it.

WHAT INVESTORS ARE ASKING...



What is the investment case for technology companies?

We believe investing in technology is compelling for three key reasons: i) technology stocks have the best fundamentals of any sector – not just growth, but the highest return on invested capital (ROIC), free cash flow margins and lowest leverage; ii) technology stocks have a strong long-term historical returns profile, underpinned by strong growth in earnings; iii) we are at the beginning of a new technology cycle driven by AI that we expect to generate strong earnings growth over the coming years.



What are the risks of investing in technology?

As with any investment, technology stocks have risks. They can be volatile and subject to swings in sentiment and macroeconomic and financial conditions.

Moreover, not every great technology or innovation is a good investment. To minimise this risk, we seek to invest in technology companies that i) create high value for customers through innovation; ii) capture value for shareholders through barriers to competition; iii) have good management; and iv) generate strong returns on capital.

AI is in its early stages and therefore while there is huge potential, there is also the heightened risk to investors of backing the wrong horse. This requires a flexible mindset and investment process and the willingness to change one's views as the facts on the ground change.



What key metrics do you look for in technology and innovative companies?

The Global Innovation team primarily considers four factors: value creation through innovation, value capture through barriers to competition, good management, and strong returns on invested capital.

If a company meets our requirements on these four characteristics, then we consider including it in our Global Innovation 200 universe. Inclusion in the funds is then determined by valuation upside. We seek to buy companies in a cyclical downturn where possible.

We seek a persistently high strong return on invested capital (ROIC) and for more established companies and an upward trajectory in ROIC for companies earlier on their journey. Across all companies, we demand a sound balance sheet, particularly a healthy net debt to EBITDA (earnings before interest, taxes, depreciation, and amortization) ratio.



What impact will AI have on the economy and stocks?

We view AI as a general purpose technology, meaning the potential productivity gains are everywhere. Quantitatively, it is of course difficult to project the coming impact but estimates from McKinsey suggest that generative AI could ultimately add \$2.6 trillion to \$4.4 trillion to the global economy annually¹, while Goldman Sachs believes that AI could eventually increase annual global GDP by 7%². Although the projections of generative AI's productivity boost vary (with some forecasting as much as a 14% global GDP boost by 2030)³, the direction and significance of the uplift is widely accepted.

Crucially, we believe AI has the potential to enable certain companies to both create and capture value, our key requirements for the potential of innovation to drive stock returns.



Is the UK/Europe benefiting from AI or is it mainly a US story?

The US is currently leading the AI race but will by no means be the sole beneficiary. Europe has led the effort to regulate AI across developed nations, Canada has been the first country to announce a national AI strategy and the UK is investing heavily in AI infrastructure, including a \$100 million strategic investment in semiconductor procurement. In Harvard Business Review's 'top ranked AI nations' index, the UK sits in third position (behind the US and China), with Germany and France coming in fifth and sixth positions respectively.⁴

The UK is **investing heavily** in AI infrastructure, including a

\$100 million

strategic investment in semiconductor procurement



Mega-cap technology companies may reside in the US, but companies that enable and benefit from AI can be found across the world. ASML, a Dutch leading supplier to the semiconductor industry, has a virtual monopoly in the production of extreme ultraviolet lithography machines (which pattern the tiny details on advanced microchips, including AI chips). Beyond European technology companies, L'Oréal is pioneering 'beauty-tech' through harnessing AI.



Are the companies behind AI technology making any money yet?

AI sits on the shoulders of the past three major information technologies – the internet, mobile and cloud – which means that some of the leading companies in these technologies (including the Magnificent 7) are currently leading in AI and already generating incremental profits. For example, Nvidia (with around 85% AI-related revenues) generated over \$6 billion in net profit last year, while Broadcom (with around 25% AI-related revenues) generated over \$14 billion in net profit. Moving up the tech stack, although value creation will take time to disperse up to the software application layer, pioneers in AI like Adobe and Salesforce are already successfully monetising AI.



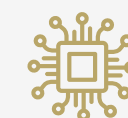
Are technology company valuations currently high due to expectations for AI?

While there are always over and undervalued companies in the market, we believe that overall current technology valuations are justified by fundamentals. Although AI is sometimes compared with the 2000 dotcom bubble, valuations are nowhere near the levels reached in that episode. In 1999, the S&P 500 IT sector traded at a forward price-to-earnings ratio of 75 times, representing a 3 times premium to the overall market; today, the S&P 500 IT sector trades at about 28 times and a 1.4 times premium to the overall S&P 500 index and the Nasdaq 100 index trades at a 1.3 times premium. We believe the current valuations are justified given strong fundamentals (the technology sector has the highest ROIC and lowest leverage of all sectors) and superior growth, which will be further aided by AI tailwinds.



Is AI just the technology sector?

General purpose technologies such as AI impact most sectors, not just technology companies. Business use cases among those that stand to benefit the most from AI fall across four areas: customer operations, marketing and sales, software engineering, and R&D – functions that span the vast majority of companies across industries.



General purpose technologies **such as AI**

impact most sectors,
not just technology companies

Life sciences is a sector that could see the biggest impact as a percentage of revenues. For example, drugs could be discovered and validated much faster using AI. Meanwhile, AI prompts are also helping to drive digital sales for consumer-facing brands such as McDonald's, and the role of virtual assistants present meaningful opportunities for customer-engagement heavy platforms like Airbnb.



Will the Magnificent 7 be the main winners in AI or are there opportunities for smaller companies too?

The Magnificent 7 companies are at the forefront of AI. Having suffered significant stock price declines in 2022, they had a strong 2023 as the new technology cycle began. While it is rare for the leaders of a previous cycle to transition successfully into the next one, these companies are well-positioned to benefit from AI due to their leveraging of the internet, mobile and cloud, and their access to data, capital and innovative capabilities.

Yet, the opportunities in AI extend beyond the tech giants. AI will have broad and transformative effects. We expect companies far below the Magnificent 7 to compete in many different ways. Their agility and ability to start from scratch, alongside the open-source nature of AI tools, allow them to focus on niche AI areas, develop unique applications, or solve specific problems.



How does generative AI differ from standard AI?

Generative AI is a significant step forward in AI capabilities. While standard AI uses data to make predictions, such as recommendations for consumers based on data on their previous and other activity, generative AI uses data to create original content, in the fields of language, imagery, sounds and video.

The increased capabilities of generative AI over and above those of standard AI lie crucially in its ability to contextualise text and other data. This in turn has been enabled by rapid progress in computing power and methodological developments in handling natural language in all its complexity, particularly the introduction of the Transformer model in 2017.

The emergence of generative AI means that AI has become applicable to a much larger range of tasks than before and is likely to have much larger effects on economic activity.



What are the main risks of AI?

Businesses that delay AI adoption risk falling behind competitors that do not delay. Conversely, embracing AI brings its own set of challenges, including the need for significant investment in technology and talent, the high energy intensity associated with accelerated computing, potential biases in algorithms, and navigating data privacy and ethical use.

From a social perspective, risks include the misuse of AI by bad actors, such as in cybersecurity breaches, deepfake creation, and digital scams, underscoring the need for robust ethical and safety regulations. AI is likely to displace jobs but also drive economic growth and create new opportunities.

¹The economic potential of generative AI, The next productivity frontier. McKinsey & Company, June 2023

²The Potentially Large Effects of Artificial Intelligence on Economic Growth, Briggs/Kodnani. Goldman Sachs, March 2023

³Sizing the prize, PwC's Global Artificial Intelligence Study: Exploiting the AI Revolution, 2023

⁴Charting the Emerging Geography of AI, by Bhaskar Chakravorti, Ajay Bhalla, and Ravi Shankar Chaturvedi. Harvard Business Review, December 2023

WHY INVEST IN TECHNOLOGY?

The old-fashioned view of the technology sector is that it is blessed with lots of growth but little else. We believe this view is outdated and that arguably the technology sector is the highest quality sector in the stock market.

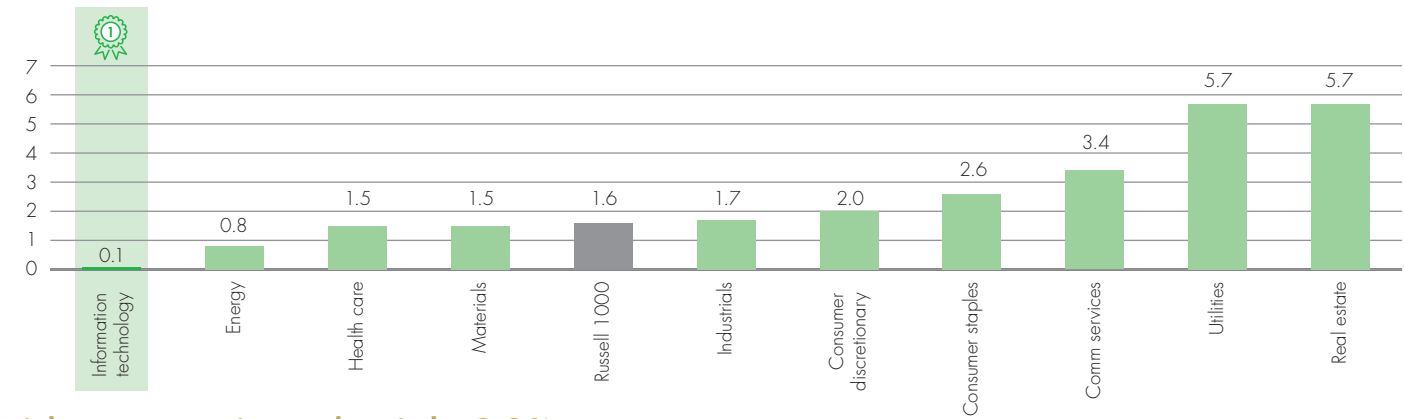
While the technology sector has historically achieved high growth, as the charts below show, today it is also the sector with the lowest leverage, highest returns on equity and highest free cash flow margins – key attributes of high-quality companies.

We believe these strengths are somewhat underrated by many investors. While technology companies may have justifiably

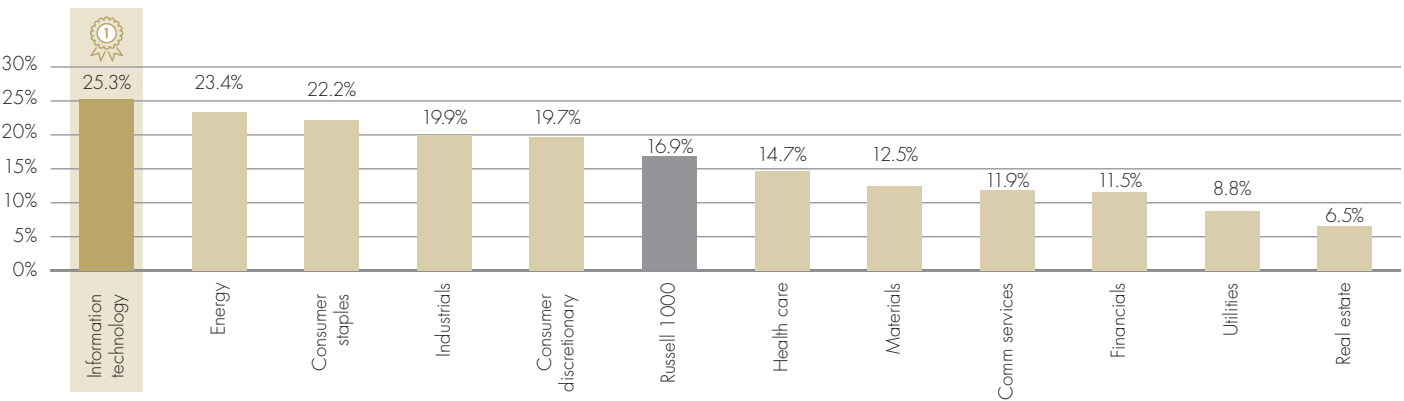
earned a reputation for specialising in spending rather than making money in the past, good technology companies now make money, and plenty of it. In many a tech naysayer’s eyes, this was never supposed to happen. Yet technology companies are among the best positioned companies to manage higher interest rates and tighter financial conditions given their high returns on capital and low reliance on cheap capital.

Best fundamentals

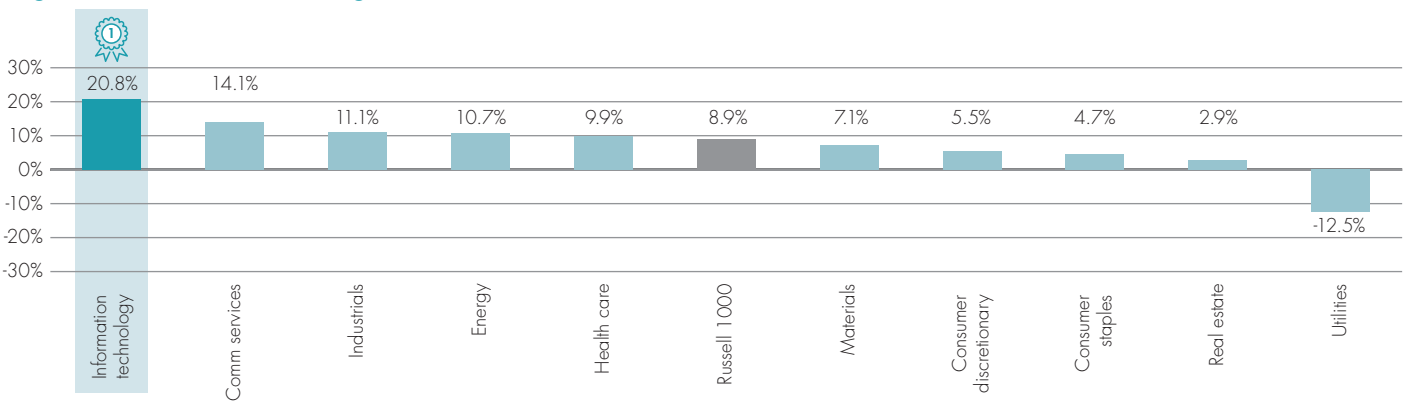
Lowest Leverage: Net debt to EBITDA



Highest return on invested capital: ROIC %



Highest free cash flow margin



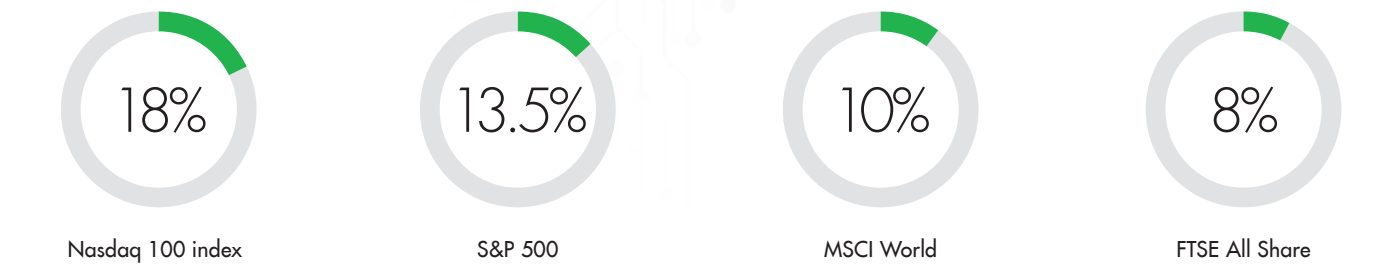
Source: Bloomberg, Russell 1000 Index, data as at 14.02.24. Past performance does not predict future returns.

We often encounter the argument that technology companies owe much of their success over the past decade or so to low interest rates and that higher interest rates over the coming years will hamper them.

It is extremely difficult to predict the path of interest rates over the coming years – and we do not take a strong view on it – but we firmly believe that even if higher rates are sustained, they will not affect the progress of good technology companies or our ability to achieve excellent returns investing in them.

Technology companies won on the fundamentals in the 2010s

Technology stocks performed strongly in the 2010s because they delivered on the fundamentals. Over the course of the decade, technology stocks as represented by the Nasdaq 100 index returned about 18% per year – ahead of the still strong S&P 500 annualised return of 13.5%, the MSCI World return of 10% and the FTSE All Share return of 8%.

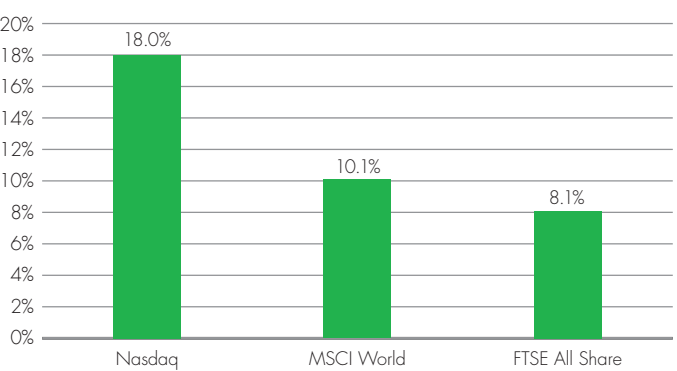


How much of that 18% per year was driven by technology companies’ fundamentals and how much by multiple expansion? The answer may come as a surprise. A huge 15.5% of the 18% (an 86% share) was due to fundamentals: 14.2% of earnings per share growth per year and an average annual dividend yield of

1.3%. Only 2.5% per year was due to expansion of the price-earnings multiple. Huge fundamental successes over the decade such as Apple (25% average annual EPS growth) and Google (17% average annual EPS growth) trip off the tongue but there were many more in the ranks.

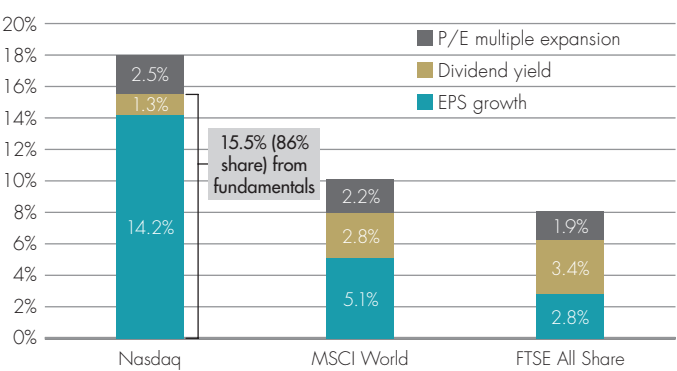
Best returns

2010’s decade annualised stock returns



Source: Bloomberg, data as at 19.10.23.

Breakdown – 2010’s decade annualised stock returns



Source: Bloomberg, data as at 19.10.23.

Tech’s outperformance driven by fundamentals

Further, the contribution from multiple expansion was arguably justified, with technology companies coming off the back of a decade in which they were deeply disliked by investors following the tech bubble and subsequent bust around the turn of the century. The 2.5% expansion of the price earnings multiple was also not much more than the 2.2% average annual multiple expansion of

the MSCI World index and 1.9% of the FTSE All Share. Today, the Nasdaq 100 sits, as it did at the end of the last decade on the eve of Covid, at a 30% premium to the S&P 500, having fallen as low as 0% in 2012. We believe this is reasonable given technology companies’ significantly higher structural growth and lower leverage than the rest of the market.

Past performance does not predict future returns.

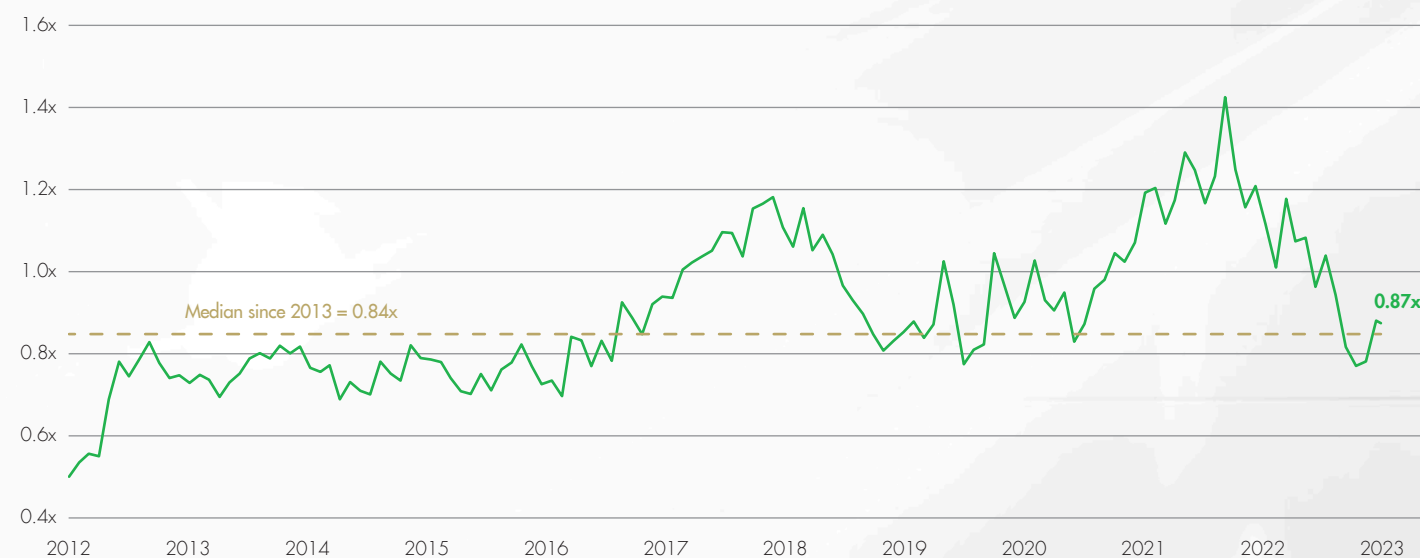
MAGNIFICENT

Much was made in 2023 of the strength of the so-called Magnificent 7 stocks (Apple, Microsoft, Alphabet, Amazon, Meta, Nvidia and Tesla) and the “narrowness” of their leadership of the overall stock market.

The Magnificent 7 were indeed strong in 2023 and this was for two key reasons – they were oversold in 2022 and they are leaders in AI. However, a close look reveals that the gains in technology in 2023 were a lot broader than just the Magnificent 7. In fact, 100 of the 132 technology companies in the Russell 1000 beat the overall Russell 1000 median stock return of 13.7% in 2023 in US dollars. That is broad, not narrow.

Furthermore, the valuations of the Magnificent 7 are not as problematic as some have argued. When assessing valuation multiples for companies with good growth prospects, it is essential to take this growth into account and this can be done by using a PEG ratio (forward price/earnings multiple divided by long term expected EPS growth). The Magnificent 7's average PEG ratio relative to the overall S&P500 at the end of 2023 was 0.7 times, which is a discount to its average over the past decade of 0.84 times.

PEG ratio: Magnificent 7 versus median S&P 500 stock



Source: Goldman Sachs (RHS), Bloomberg as at 14.11.23. YTD = Year to Date; PEG = PE to Growth.

Past performance does not predict future returns.



Microsoft

Alphabet

amazon

Meta

nVIDIA

TESLA

THE AI REVOLUTION

The rise of AI – a new cycle

We believe a new technology and innovation cycle has begun based on AI that will drive strong earnings growth for the companies that can take advantage of it, just as previous technology and innovation cycles have done.

AI's 'iPhone' moment – 2022

Despite AI's long-standing history of scientific development – and no small degree of commercialisation already – it took the seminal launch of Open AI's ChatGPT consumer-interfacing generative AI large language model in November 2022 to see AI breakthrough into the mainstream of public consciousness. This launch effectively served as AI's "iPhone moment", with significantly accelerating adoption across companies and consumers.

Whether to embrace AI or not is arguably far less of a choice than it once was, because it is now necessary to compete in a rapidly growing range of industries and tasks. This is why we believe a new technology and innovation cycle has just begun and why we are only five minutes into the "football game". Nevertheless, the history of AI is a rich and illuminating one:

RESURGENCE – 1990s TO EARLY 2000s

The 1990s and early 2000s witnessed a resurgence in AI, driven by strong progress in computing power and scientific developments in the statistical field of machine learning. This era saw the development of algorithms capable of learning from data, shifting the methodological focus of research from mathematical rule-based approaches to more empirical data-driven approaches. The victory of IBM's Deep Blue over chess grand master Garry Kasparov in 1997 was a memorable milestone, symbolising the potential of AI.

GENERATIVE AI – LATE 2010s TO PRESENT

The most recent revolution in AI has been the rise of generative AI, enabled by the development of the Transformer model in 2017. This model, introduced in a paper titled "Attention Is All You Need" by researchers at Google, was a breakthrough in handling natural language. It led to the creation of large language models, such as Open AI's GPT (Generative Pretrained Transformer), with an unprecedented ability to generate informative, coherent and contextually dependent text.

These generative models have already been applied in a variety of fields, from creating realistic images and text to aiding drug discovery. Their ability to learn from huge datasets and generate new content has opened up vast new frontiers, which leads us to the present juncture.



ORIGINS – 1950s

The origins of AI lie in the pioneering work of Alan Turing, the famous British mathematician, who in a 1950 paper proposed the idea of a machine that could simulate human intelligence. In this, he devised the famous 'Turing Test' as a measure of a successful simulation, in which humans cannot tell whether they are conversing with another human or a machine. The 'Dartmouth Conference' at Dartmouth College in the US in 1956 is often considered the official birthplace of AI as an academic field. Here, the term 'artificial intelligence' was first used, setting the stage for a research programme that continues today.

In these early years, there was much optimism. Academic researchers predicted that machines capable of human-level intelligence would be a reality within a generation. However, the limitations of early computing power and complexity of natural language understanding frustrated early expectations.



THE AI WINTER – LATE 1980s TO 2000s

The 'AI winter' began in the late 1980s, a period marked by much scepticism about AI's ultimate potential. Early AI systems struggled to scale and adapt to real-world complexities, leading to disillusionment and reduced funding.



THE RISE OF DEEP LEARNING – 2010s

A turning point in AI history came with the development of deep learning techniques, particularly the deployment of neural networks, which allowed for much richer non-linear predictions than simple linear regression-based approaches. This was epitomised by the success of AlexNet in 2012, a seminal model that dramatically improved the performance of image recognition.

These advancements led to the emerging use of AI in the economy, from internet search to GPS route planning, both led by Google, to recommender systems pioneered in social network feeds such as Facebook and Instagram. The key to these successes was the ability of deep learning systems to learn and predict using huge amounts of data.



The new technology cycle

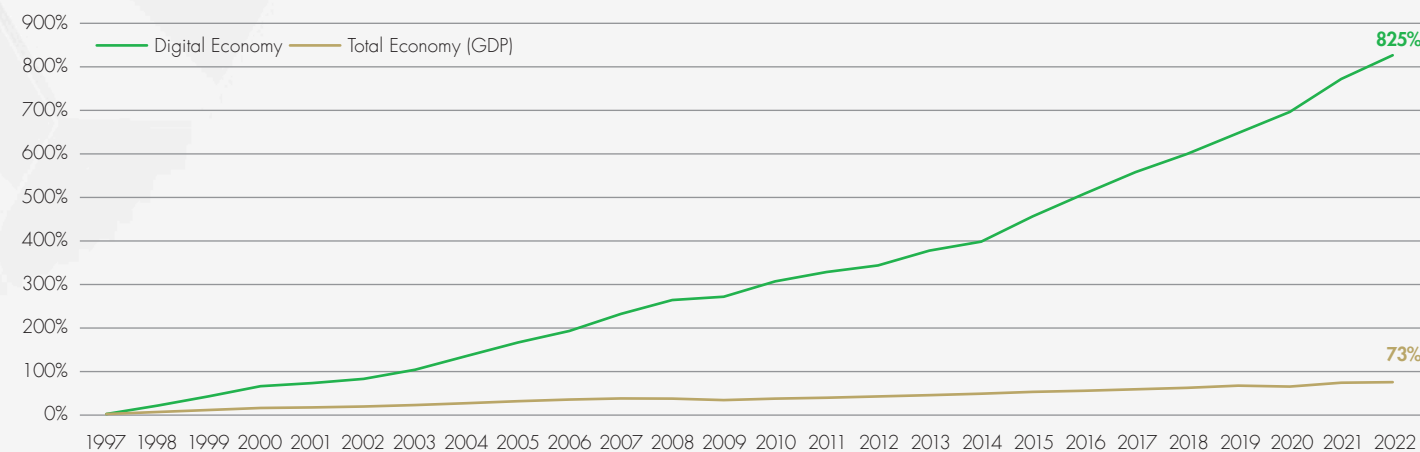
We expect the AI-driven technology and innovation cycle that has just begun to be a particularly strong one for stock returns for the companies that can harness AI. This is because, as we detail below, we believe AI is a particularly powerful technology in terms of its value creation and capture credentials.

Furthermore, AI is standing on the shoulders of giants in terms of previous recent major technologies, namely the internet (breakthrough 1995), smartphones (breakthrough 2007) and cloud (breakthrough 2012), which have driven very strong growth

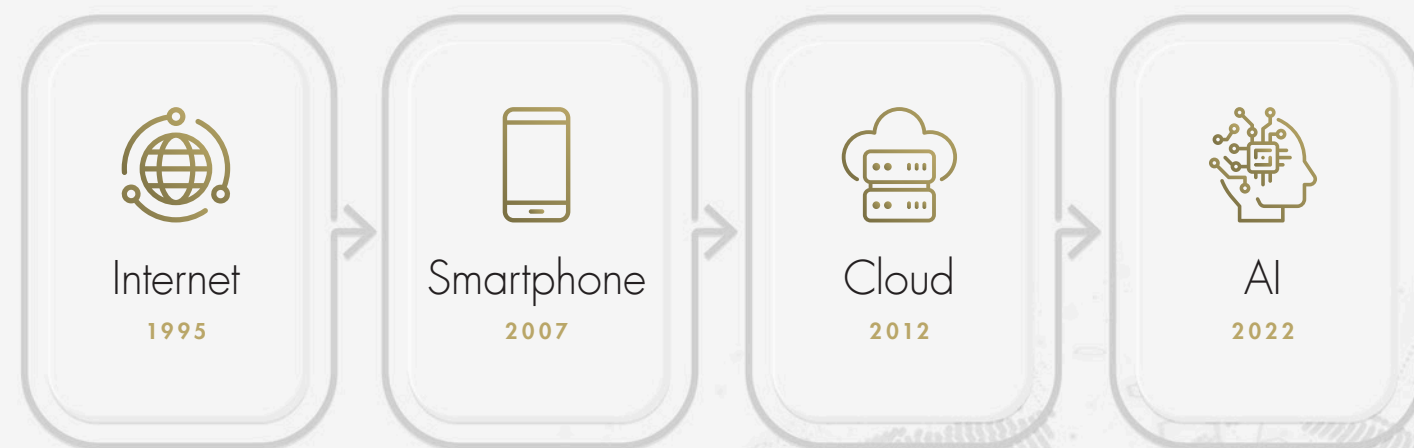
of the digital economy over the past quarter of a century: 825% cumulative growth in GDP of the digital economy between 1997 and 2022 compared with just 73% for the overall economy during the same period.

AI is a game changer

Growth of digital versus total economy 1997–2022 (US)



Game changing technology and key breakthrough year

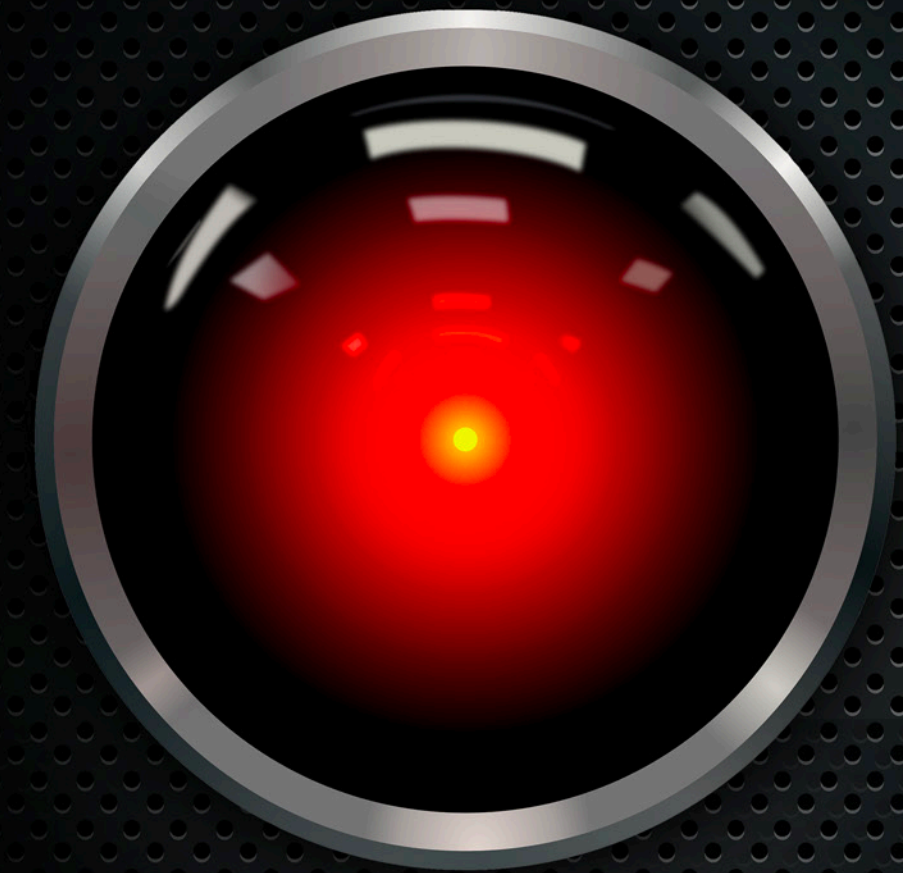


AI built on and enhances value of previous three game changers

Source: Bureau of Economic Analysis, data as at 15.02.24.

This is important because leveraging these existing powerful technologies means that the productivity gains from AI could come quicker than from previous major technologies such as steam and electricity (which took decades to generate strong broad-based

productivity gains), and could be larger given the potential to unlock as yet untapped value from these three previous giant digital breakthroughs.



Is AI a good investment opportunity? AI's value creation and capture credentials

Not every great innovation is a great investment. Last year, artificial intelligence made a giant leap into the investment mainstream. It has been the subject of immense hype, both positive and negative. On the one hand, AI is supposedly going to launch economic growth into orbit. On the other, it is about to plot to kill the human race.

In the Liontrust Global Innovation team, we judge innovation based not on how impressive the technology is or by imagining science fiction-like scenarios, but on whether it can create genuine value for customers.

For any innovation, no matter how big or small, we ask: can it dramatically drive down prices at the checkout? Can it make goods and services significantly better? The beauty of this approach is that when companies drive down prices or drive up quality, they can massively grow the market. There is hardly any more powerful source of investment returns.

Second, we ask of the value that innovative companies are creating for customers, can they capture a decent and long-lived share of it for us as shareholders? If everyone can replicate a great innovation, then many will, and no one will make any money.

Nothing but both will do. Creation without capture? Think of email. Nobody doubts that it has been a very impactful innovation, which has created immense value in driving down communication costs for billions of people around the world. But no companies have

been able to capture value and build a competitive advantage around either providing or using it.

Conversely, capture with relatively little creation? Not that we wish to court controversy but think of crypto as it stands today. A popular investment for many and at its peak it commanded a market cap of \$3 trillion – an historic feat of value capture, to be sure. But there has been little value creation by comparison. It may come in time, but the fundamental use case of a better form of currency than dollars, pounds and other official currencies for now at least remains unproven.

When we consider AI, we believe it has the potential to be both a great innovation and drive great investment returns for the right companies. Indeed, it may prove to be one of the most important innovations of all time on both counts and it is already chalking up significant customer value across the economy. Make no mistake, AI will not be contained to the technology sector but will affect every industry. Ignoring AI will mean betting against it because it will be a brutal source of disruption for many companies on the wrong side of it.

VALUE CREATION

We are all aware that we are living in a cost-of-living crisis due to high inflation and interest rates. The same is true for the cost of doing business. Innovation's ability to make things cheaper and make more and better from less will prove to be a godsend over the coming years and AI will play a central role in this.

As an example, take healthcare, a sector that accounts for around 20% of the US economy and is notoriously dogged by inefficiencies and high costs. Indeed, no other sector holds more potential to change both lives and the economy in the 21st century. Yet over 90% of research and development (R&D) for drugs fails. Companies such as Moderna, focused on mRNA-based drug discovery, and Salt Lake City-based, Nvidia-backed Recursion, focused on machine learning driven drug discovery, are using AI to raise the productivity of R&D, lower the cost and speed up the process of drug discovery.

Long after discovery and approval, drug prices are inefficiently expensive across the system. Moreover, health outcomes vary greatly in quality between best and average practice. As the largest health insurer and manager of health care in the US, United Health is using AI to lower drug and treatment prices and raise the quality of outcomes. Robotic surgery, through companies like Intuitive Surgical with 12 million procedures now under its belt, is improving surgical outcomes today, but there is also the potential to drive down the cost and improve the quality of surgery via AI and vast datasets of physical robotic surgical experience.

Healthcare is but one example. From retail, through companies such as Shopify, which is developing AI to help small businesses master e-commerce, through to automotive companies such as Tesla, leading the charge on autonomous driving and AI-driven robotics, to finance through companies such as Upstart, which is raising the efficiency of lending, AI has the potential to or already is driving customer value.

VALUE CAPTURE

Innovation can enable companies to build formidable barriers, driving profitability. Giants of innovation this century such as Apple and Google trip off the tongue, but many other niche innovative champions have also achieved massive profitability. Indeed, the technology sector, arguably the most innovative sector in the market, has the highest free cash flow margins and returns on invested capital of any sector.

The key question for AI and value capture is whether it will prove to level the playing field between the best companies and the rest or enable the best to accelerate further ahead. We strongly believe that while many if not most companies will become more productive through AI, the biggest gains by far will be reaped by the best companies, strengthening barriers to competition and profitability. AI will not prove a saviour to companies on the wrong side of innovation, hoping to turn the tide.

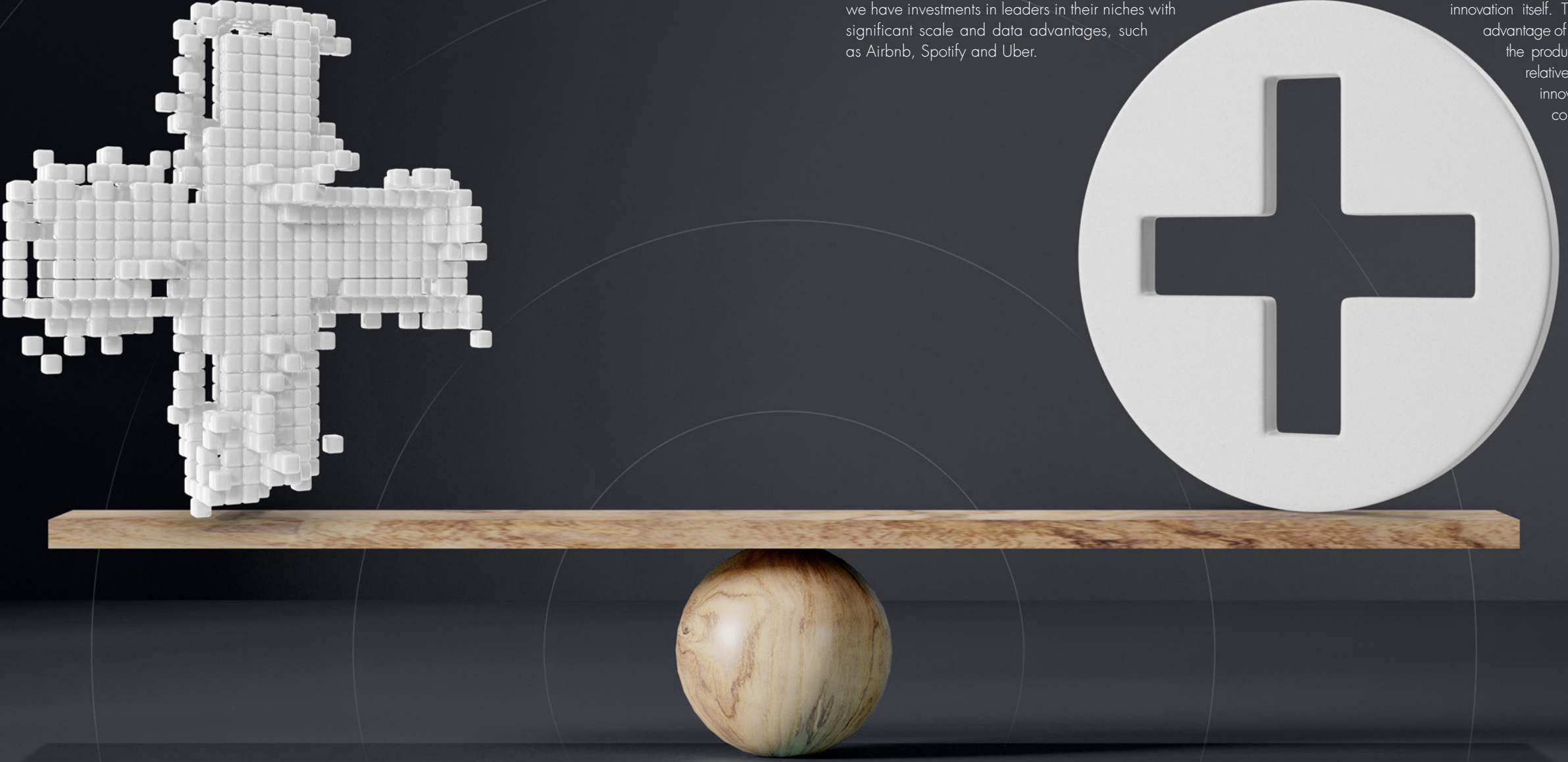
There are three reasons for this. First, AI will likely exhibit increasing returns to scale and experience because efficacy thrives above all on learning from data and experience. For this reason, we have investments in leaders in their niches with significant scale and data advantages, such as Airbnb, Spotify and Uber.

Second, even if everyone had the same data, they would not all use it. We agree with economic historians such as Nick Crafts who view AI in the historical lineage of general purpose technologies – major innovations such as steam, electricity and personal computers – that impact most sectors of the economy and give rise to powerful ripples of many further, smaller and more specific innovations.

What is special about general purpose technologies is that while they deliver incremental gains for most companies, they deliver massive gains for the most committed companies that are prepared to reorganise themselves around the technologies.

Most companies will simply not do this because the vested interests of management are too strong. Fundamentally, AI automates decision making and will have the biggest impact for companies when it makes or helps make the biggest decisions. Only companies led by exceptional management with very strong technological capabilities and a genuinely innovative culture will capitalise.

Third, AI is not just a significant innovation, but a tool for innovation itself. This will favour the competitive advantage of innovative companies, boosting the productivity of their innovative efforts relative to their peers. Continual innovation is the strongest barrier to competition of all.



How we invest in AI: the new technology stack

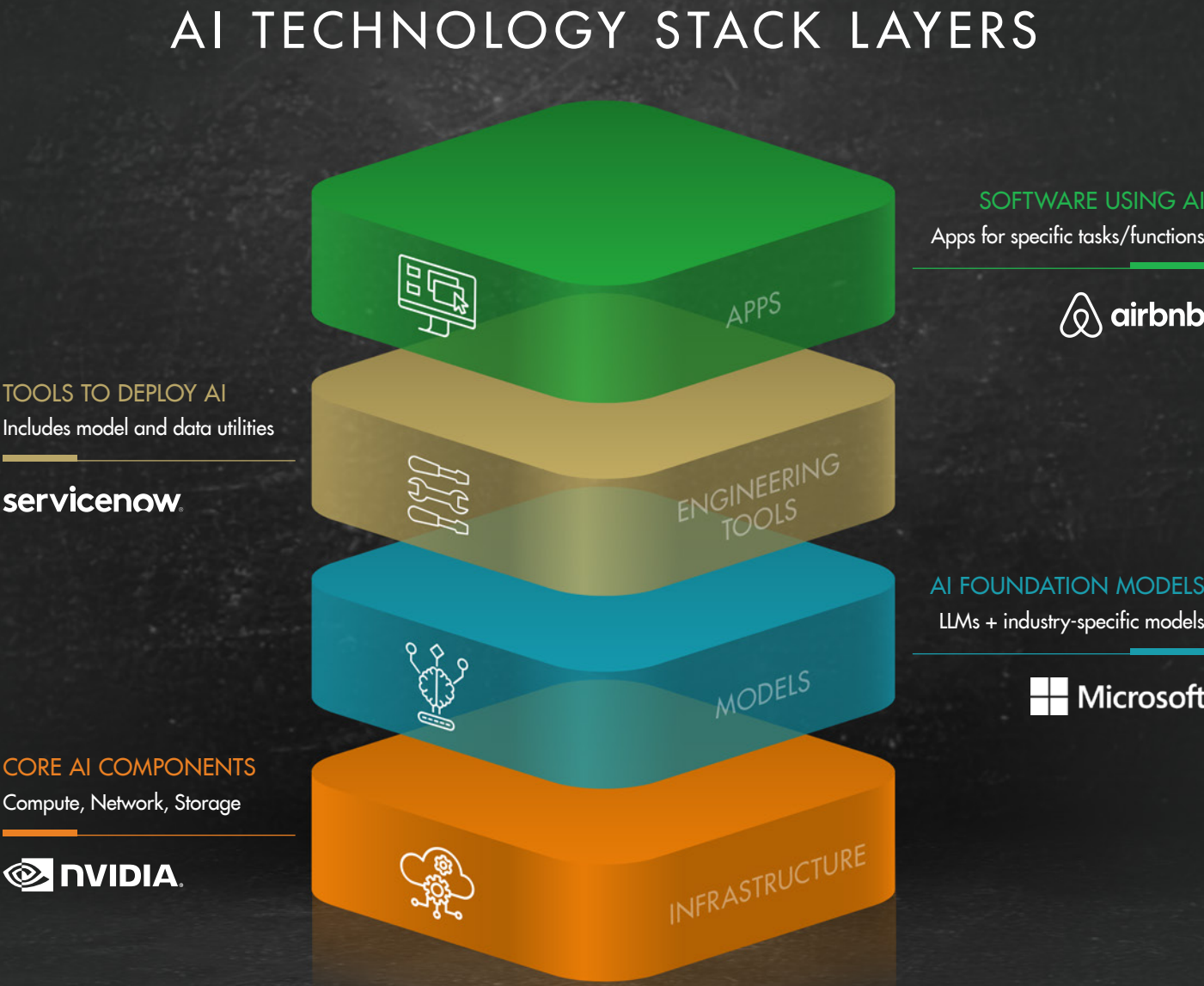
We view investing in AI through the lens of a four-tiered technology stack, which is spurring new investment across the technology sector.

At the base of this stack is the **infrastructure** layer, consisting of semiconductors and associated hardware and software necessary for AI computing, such as accelerated processors, memory, storage, networking and packaging, and the sophisticated machinery and software required to design and produce it all. Nvidia's chips and software are key to this layer, but so too are the offerings of numerous other companies such as Broadcom, Cadence, and ASML.

On top of this infrastructure sits the AI **model** layer. This includes foundational Large Language Models (LLMs) as well as domain-specific models that are tailored to particular industries or use cases such as pharmaceuticals. LLMs are currently led by the large technology companies such as Google, Meta and Microsoft as well as newer players like OpenAI and Anthropic.

Next up are AI **engineering tools** that enable enterprises across the whole economy to operationalise LLMs to harness AI. Companies such as ServiceNow, which is helping businesses deploy generative AI across their operations, are particularly well positioned, as are companies like Snowflake and MongoDB which help businesses organise and use their data for AI-driven tasks.

Finally, at the top of the stack is the **applications** layer, where AI meets its customers to drive prices down and up the quality of products and services, both for business-to-business and business-to-consumer. This is currently led by the likes of Spotify and Netflix through recommender systems, though it is also underpinning a range of other leading consumer-facing businesses such as Uber and Airbnb.



Source: Liontrust, Gartner 2023. All use of company logos, images or trademarks are for reference purposes only

INFRASTRUCTURE LAYER – NVIDIA



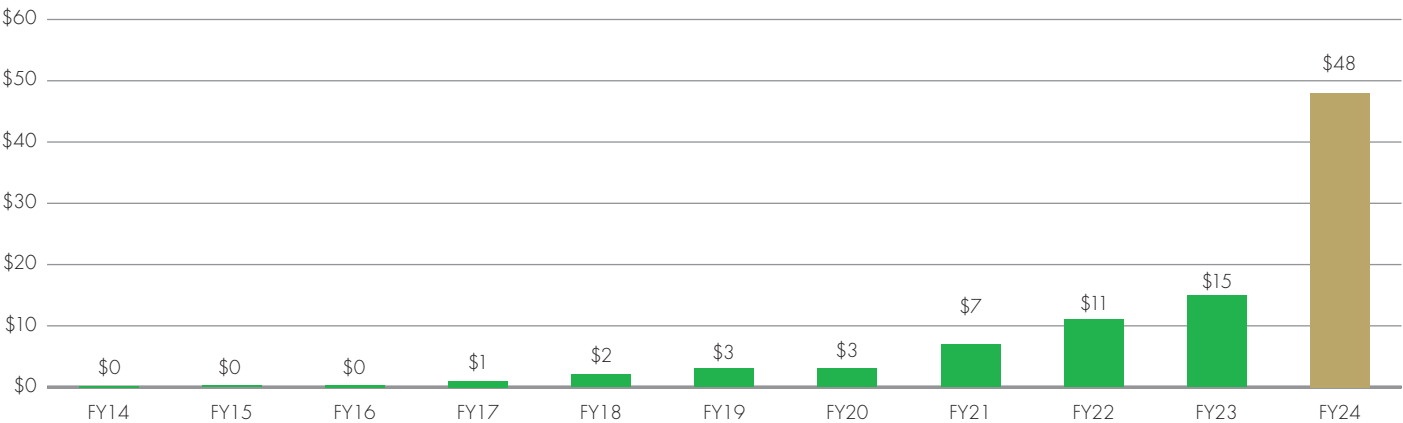
In the past 18 months, Nvidia's CEO and founder, Jensen Huang, has propelled himself into the league of iconic business trailblazers such as Steve Jobs and Bill Gates. Huang has made it clear: Nvidia isn't merely an entrant in the race to infuse AI into the global computing matrix, it's leading the pack and arguably dominating the field.

The meteoric surge in Nvidia's stock price over this period calls for a deep dive into its fundamentals. Huang has underscored the vast potential of the data centre market – a \$300 billion opportunity primed for Nvidia's state-of-the-art, cost-effective, and blisteringly powerful computing chips and architecture. Nvidia's bold undertaking to replace the outdated CPU-driven infrastructure with its advanced computing stack will be a decade-long endeavour. As the below chart shows, Nvidia is still in the early days of this journey, with the company achieving \$48 billion of

revenue from the data centre in 2024. Still, this is only around 15% of the overall potential.

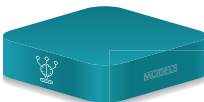
Why not Intel or AMD? By their own admission, both of these giants are finding it more than challenging to surmount the barrier that Nvidia's software offering, CUDA, presents. Over the past decade, Huang has focused on building a robust software ecosystem that now boasts over four million developers around the world. This enormous army of innovators creates software libraries that enable Nvidia's cutting-edge chips (the latest being the H200 Hopper, with the B100 Blackwell currently in the pipeline) to be harnessed in industries across the whole economy, from life sciences and aeronautics to customer service help desks. Indeed, given this ecosystem, Nvidia's leadership in supplying the tools for AI computing may by now be unassailable. This convergence of hardware and software has led Huang to liken it to the "iPhone moment" – a juncture where the supply of technology meets massive broad-based demand and creates an unanticipated revolution.

Nvidia Datacentre Revenues (\$bn)



Source: Nvidia and Liontrust, as at end of February 2024. Past performance does not predict future returns.

MODELS LAYER – LLMs



The fundamental addition to the AI technology stack is the large language model layer, which serves as the brain for generative AI tasks. Like us, you may have used the likes of OpenAI's ChatGPT and other leading models such as Google's LaMDA and Gemini models, Meta's LLaMa models and Anthropic's Claude models through accessible 'chat-bot' style interfaces.

How LLMs understand and generate language: LLMs learn to understand and generate language through the training process. They are fed vast amounts of text data, from which they learn patterns and relationships between words. This training involves adjusting model parameters to optimise the model's accuracy. The more data they are trained on, and the more parameters they have, the better they become at predicting and generating coherent and contextually relevant text.

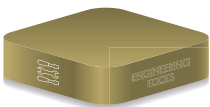
The transformer model: The Transformer Model, introduced in a seminal paper titled "Attention is All You Need" in 2017 by Google researchers, revolutionised the computational analysis and manipulation of natural language. Unlike previous models that processed words in sequence, transformers can process all parts of a sentence simultaneously. This parallel processing capability significantly enhances the model's ability to grasp the complexities of language.

LLMs and context: One of the most impressive aspects of LLMs is their ability to consider context. Large and growing 'context windows', the amount of text they can consider at a time, are enabling LLMs to generate responses that are not only grammatically correct but also contextually appropriate. This ability is crucial for the development of a form of AI that is much closer to human-like intelligence.

Practical challenges: While LLMs are powerful, they are not without challenges. One major issue is the potential for bias in their outputs, as they can only learn from the data they are trained upon or later encounter during inference. If this data are biased, the model's outputs will likely be biased too. Additionally, the environmental impact of training and running large models is a growing concern given their substantial energy requirements.

The future of LLMs: The future of LLMs is both exciting and uncertain in terms of which models and companies will dominate on performance and adoption and the degree of homogenisation or diversity of foundational models over the longer term. But as they continue to evolve, we believe they will become increasingly integrated into industries and our daily lives.

TOOLS LAYER – SERVICENOW



The business-facing technology company ServiceNow may be less celebrated than the consumer giants of Apple, Google and Amazon, but its operational and share price performance over the past decade since its IPO in 2012 stands up to comparison with all of the above names. During this period, ServiceNow has grown annual revenues from \$200 million in 2012 to around \$10 billion today and expanded free cash flow per share by an exceptional 50%-plus a year. It has delivered shareholder returns over the decade at 32% a year. This track record takes some beating.

The shadowy secret of the great digital transformation of the past couple of decades is that much of the spend has not delivered a positive return on investment. But ServiceNow is turning this around and enabling businesses to achieve the long-hoped for productivity gains from digitalisation and automation. Rather than supply companies with just another piece of software to add to the pile, ServiceNow sits above the mess, organises it, stitches it all together and enables different software programmes to talk to one another.

It does this today for close to 8,000 enterprise companies, including 85% of the Fortune 500 like Walmart, CVS, AT&T and JP Morgan. An independent study by the market intelligence firm IDC in 2021 (*ServiceNow Knowledge 2023: AI Advancements Lead Customer and Partner Opportunities for Collapsing the IT and Business Divide*) of a sample of ServiceNow clients found that the average return on investment over five years was around five to six times, with a typical payback period of seven and a half months.

ServiceNow is well positioned to enable its customers to use AI to enhance their business and achieve strong productivity gains over the coming years. Its newly announced products as part of its recent Vancouver software release – which include a large language model based copilot and text to code developer assistant (powered through its partnership with Nvidia) – have reportedly generated strong productivity gains in testing with customers, with an estimated potential 10 times return on investment over time* and will give ServiceNow a 60% base price subscription uplift.

*Company management statement at Mizuho Securities AI in Focus Conference, September 2023.

APPLICATIONS LAYER – NETFLIX AND SPOTIFY



Have you noticed a difference in your daily commute? Instead of laboriously scrolling through our libraries of outdated playlists to find that particular song to kickstart our days, Spotify is doing a pretty good job at predicting what the song might be. Users can even type in details of their mood and a playlist emerges, tailored to the artists they frequently listen to.

This is AI touching our everyday lives. And what's more, we can all experience first-hand the improvements in AI unfolding. Netflix, another direct-to-consumer business, is also enhancing its customer experience through AI deployment. Not only are the movies personally recommended to us powered by AI algorithms, but the actual production of Netflix Original shows is optimised using AI. What this means is a lower cost of content production and shorter time to market, both of which flow through to the benefit of the customer. Put simply, these are two companies using AI to drive automation and create genuine customer value in the process – the cornerstone of what the Global Innovation team looks for in our companies.

In the direct-to-consumer cases of Spotify and Netflix, barriers to competition come in the form of scale economies and network effects. It is hard to overstate the importance of owning the data on a large base of sticky customers when it comes to winning in AI – it's this data that trains the AI model and then constantly improves it. The more customers that feed the model, the more accurate it becomes: recommendations strike a chord more frequently and efficiencies are further enhanced. With 515 million monthly active users in the case of Spotify, and 160 million customers using Netflix, the treasure troves of proprietary data these companies have at their disposal is a unique advantage.

Both of these companies are primed to be beneficiaries of the AI revolution yet neither is a technology company. To access the gains from AI driven automation, you do not have to be confined to investing in the companies creating the infrastructure of Chat-GPT-esque products. AI is a general purpose technology spanning all industries, with the potential to enable much better products, services and organisational design. We believe the emerging winners from this AI transition will be those with the most innovative cultures, who are nimbly adapting to create customer value.

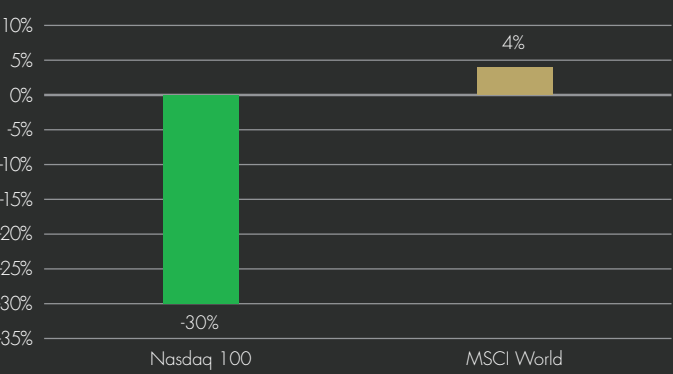
Past performance does not predict future returns.

FROM GROWTH TO PROFIT

Returning from Silicon Valley in October 2022, we were struck by the number of companies we met refocusing their businesses on profitable growth after years of growth at all costs.

This was a seismic shift in the narrative of management, and a necessary one: 2022 was bruising for technology companies who were faced with the sharpest interest-rate hiking cycle in history combined with a climb down from unsustainable Covid-induced demand. Indeed, earnings per share growth for the Nasdaq witnessed a 30% peak-to-trough decline in the 18 months leading up to the first quarter of 2023, while the MSCI World index posted growth of 4%.

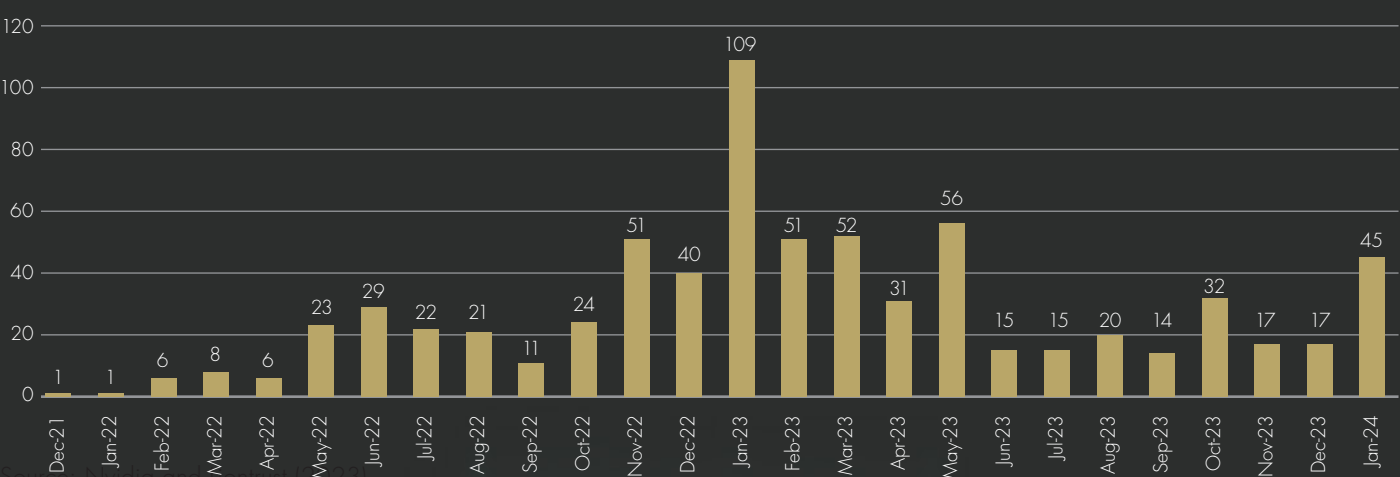
Nasdaq 100 & MSCI World earnings per share growth Q2 2022 to Q1 2023



Source: Bernstein, data as at 31.01.24.

This marked a recession in the technology sector, well ahead of any broader economic weakness. Simply put, technology companies are first in, first out. The technology sector is now firmly in recovery mode and companies have wasted no time in rationalising their cost bases, becoming leaner and more profitable. We have seen over half a million job cuts sector-wide, the optimisation of sales and marketing expenses and prioritisation of R&D projects.

Tech job losses (000s)



Source: Nvidia and Control (2023)

Source: Bernstein, data as at 31.01.24.

Now in 2024, we are starting to see the impacts of this shift come through in improved operational efficiency. The key question we are now asking is whether pivoting to profit sacrifices a company's ability to grow. Does the customer value proposition remain intact when investment dollars are stripped away? We believe that innovators who have not just cut costs but are finding more productive ways to achieve similar growth are excellently positioned to capitalise on the new technology cycle we have just entered.

Past performance does not predict future returns.

Three in the frame: companies that are generating impressive profits



You might not be familiar with MongoDB. Yet while this American company, providing a popular NoSQL database solution, might not always be in the limelight, its impact on the technology world is undeniable.

Directly or indirectly, you will have encountered platforms and services powered by MongoDB. If you've engaged with Adobe's digital platforms, MongoDB plays a pivotal role, powering Adobe Experience Manager to provide consistent digital experiences. Fitness enthusiasts tracking their performance on apps like Strava indirectly leverage MongoDB's efficient data handling capabilities. If you've used the InVision platform for digital product design, MongoDB is at its core, handling billions of daily document reads and writes to ensure a seamless user experience. Meanwhile, shoppers worldwide, browsing through Gap's vast collection, experience a smooth digital journey thanks in part to MongoDB's scalable database solutions.

MongoDB's inception by co-founders Dwight Merriman and Eliot Horowitz was driven by their experiences at DoubleClick, acquired by Google for \$3.1 billion in 2007, where they grappled with the inflexibilities of traditional relational databases. This ethos led to the creation of MongoDB, a NoSQL database tailored for modern demands. Today, MongoDB has established itself as the clear next-generation database leader, fit for AI workloads with features such as vector search, over \$1 billion of annualised revenue and with its core Atlas (database-as-a-service) offering growing 85% year on year.

Moreover, rather than just expanding its customer base, MongoDB concentrated on deepening ties with existing clients, prioritising tailored solutions and retention. In response, the company has achieved net operating profitability with a net operating margin of 6.1% in the last quarter versus -1.5% a year ago. We expect this to be the beginning of MongoDB's path to profitability as the company continues to expand margins along with improving cash flow as it executes this transition at scale.

Past performance does not predict future returns.



'The hotel company without any hotels', Airbnb is often cited as emblematic of technology-led, capital-light businesses disrupting the old guard. Yet over the 14 years since it was founded, it has also often been used as an example of how, for all of their innovation, such businesses can still be lacking when it comes to profits.

Things change. On the eve of Covid, Airbnb generated around \$5 billion of annual revenue and was barely breaking even. Out of necessity due to the devastating impact of lockdowns on the business in 2020 and 2021, effectively all but outlawing the business temporarily, Airbnb dramatically cut costs to keep the lights on, including halting all marketing expenses. Many of these cuts were kept as the business rebounded strongly on reopening, unleashing a meaner and leaner company. Today, Airbnb generates around \$9 billion of annual revenue and around \$4 billion of free cash flow, a phenomenal 40%-plus free cash flow margin. This is what capital-light innovation looks like at scale, and it is a thing of beauty.

Past performance does not predict future returns.



Uber has long been a disruptive force in the transportation industry, revolutionising the way we think about getting from point A to point B. Its technology-driven, on-demand model has made it a household name in over 900 metropolitan areas worldwide. We have all experienced the convenience of Uber's value proposition yet Uber did not make a profit for a long time. Then Covid struck and the world stopped moving. Fast forward and we are confronted by a very different picture. The company has reported profits capturing the attention of investors who see long-term value in its transformative business model and ceaseless focus on innovation.

At its core, Uber's business model is an amalgamation of brilliant simplicity and intricate logistics. The company is a classic example of a platform business that connects riders and drivers through an accessible, user-friendly mobile app. The genius lies in its scalability: without owning a single vehicle, Uber expands by acquiring more users and drivers, who are essentially the assets that make the model so lucrative. This asset-light strategy has enabled it to rapidly enter new markets and diversify its services, which now range from food delivery (Uber Eats) to freight logistics (Uber Freight).

Uber's recent profitability is particularly remarkable given its historical cash burn. A combination of driving efficiencies across its organisation, scaling back on less profitable endeavours, and increasing revenue from high-margin services have contributed to this positive financial turnaround. The shift to profitability is not merely a short-term achievement; it's a fundamental change in business dynamics that enhances the company's viability and we believe makes it an increasingly appealing investment option.

THE COMING IMPACT OF AI

AI – helping to speed up drug discovery

Can you imagine your employer enrolling every single one of your colleagues into a mandatory AI learning academy? Healthcare giant Moderna has done precisely this, tasking its entire workforce, all the way up to the CEO, to become fluent in AI.

It might be surprising that a healthcare company is pursuing AI with such fervency, but Moderna is really a technology company. It produces mRNA molecules, which, just like the software of a computer, carry sequences of code. While computers follow instructions in the form of the binary coding system of a series of 0s and 1s, the building blocks of life, proteins follow code in the form of the four letters (or nucleotides) carried in mRNA. Four letters might sound like a short and limited alphabet but it provides a near infinite number of possible sequences with which to produce proteins – and so drug discovery is really a mathematical problem, which is ultimately cracked with data.

Wherever data is key, AI may be a powerful solution. Bringing a drug to market can take over a decade, with only 8% of drugs making it through Phase III clinical trials. One of the reasons commercial success is so scarce is the challenge of predicting the correct protein structure (for drugs to bind to in order to work) and identifying the right compounds that bind to the specific protein site. Yet AI is helping to predict the design of molecules that will achieve the desired results in fighting illnesses from flu to cancer – leading to potentially lifesaving outcomes for patients. Take Moderna's RSV vaccine candidate as an example (expected to come to market in 2024, representing the company's first non-Covid commercial opportunity): using AI to forecast and ID for clinical trial enrolment helped move the vaccine from the idea development phase to phase III trials in just two years. This process typically takes six or seven years.

It is early days for AI's application in pharma, but we are starting to see the benefits of improved production processes from early adopters. No sector sees more R&D spend go to waste. R&D consumes over 25% of sales on average in the industry, yet 92% of drug approvals fail. At the same time, no other sector holds more potential to change lives and the economy in the 21st century. This makes the potential of AI to drive this sector forward all the more exciting.

MODERNA ANDREW GIESSEL, DIRECTOR OF AI AND DATA SCIENCE



Dr. Andrew Giessel is Director of AI and Data Science at Moderna, where he oversees the team applying machine learning and statistical techniques to improve the company's mRNA medicines, including the Covid-19 vaccine. Prior to Moderna, Andrew served as Director of Data Science at Sense AI, a startup developing a platform for geospatial mobile sensor data. He holds a PhD in Neuroscience from Harvard Medical School and a BS in Biochemistry & Computer Science from the University of Kansas



Where in the healthcare industry is the greatest potential for AI to accelerate innovation and create customer value?

The space of potential opportunities is so big. Traditional, more physics-based approaches to problem solving require a good understanding of the rules of the system. But often the things that matter in biology are combinations of different factors that can be very hard to describe, making it difficult to come up with a simple set of rules for the system. AI and Machine Learning (ML) allow for a different, more data-driven approach, helping make sense of such a complicated domain.

The impact that LLMs are having is incredible and substantial, especially on the research side of things where we have been working on trying to understand the relationship between the sequences we use for our mRNA and how effective they are in the body. This is a huge, dual level problem because mRNA encodes for proteins and proteins are the molecule that your body then makes, leading to a therapeutic effect in a person.

There's LLM-driven optimisation in picking the right protein sequence, which is important as this determines effectiveness. In the case of a vaccine, you're picking a protein sequence for part of a virus – but as the virus evolves, the protein changes, so if you have picked the wrong protein then the vaccine won't be as effective. There's also optimisation in picking the right mRNA sequence. There are effectively an infinite number of mRNAs that could code for a given protein, and these can vary in terms of the amount of protein they make and how stable they are. It is hard to approach this process from first principles as these are difficult rules that are not yet well

understood. The traditional approach is to use a combination of rules and heuristics, which can get you quite far, but we are increasingly seeing benefit in pursuing a more data-driven approach.

This starts with "experimental screening": testing a range of variants, applying rules to generate examples, and then testing these. This generates experimental data that is used to build a model, with the input being the exact mRNA sequence and the output being performance. This modelling allows us to repeat the process multiple times to pre-screen further rounds of possibilities, helping constrain the design space which is mindbogglingly large.

As a platform company, this is compelling. If we make a model that is general enough to predict mRNA stability, for example, we can then reuse it for the next mRNA we make. These models generate better data, which can be used to improve the model further, in a virtuous circle. And this is why we are leaning into this approach, as these models can identify complicated relationships that would otherwise be difficult to capture. This is helping overcome fundamental design problems and accelerating the drug discovery process.



What is the rate of progress in AI that you are seeing currently, and how should we expect the healthcare industry to transform going forward?

Modelling approaches have been around in fields like small molecule drug discovery for a while. It's a very similar concept – instead of designing a protein via mRNA, you're screening many small molecule compounds. What's newer and more revolutionary is leveraging LLMs that can understand and generate natural language.

Much of the daily lifeblood of companies like ours relies on text – emails, clinical reports, standard operating procedures that detail manufacturing processes. A huge hurdle in getting new medicines to patients is navigating the arduous clinical trial and regulatory approval processes. Phase 3 trials can have 30,000 participants – tracking everything that happens requires vast amounts of data. Regulations aren't designed to slow things down, they are there to ensure that things are being done the right way. Accelerating these processes by using computer programs that can understand language is amazingly helpful.

One simplistic application is accelerating responses to questions posed by regulators. These questions happen throughout the development process, and come in the form of an email with something like 100 questions. Each question requires its own entry, and traditionally these must be manually entered into a database system with metadata tagging it to the appropriate part of the process – for example, this question is about manufacturing, this is about clinical trials, and so on. AI and LLMs can automate this by predicting metadata based on the question text, and pre-fill everything for review and submission. This compresses an entire day of work into five minutes, freeing up considerable time.

Deeper applications include expediting the research and response processes. We are a platform company and most of what we have done so far is vaccines, so we get the same types of questions repeatedly. The raw material to answer these questions is already in text form in our systems. But having someone find and read a 500-page document to find one thing, and repeating this for probably the 20th time because this is a question we get regularly, is inefficient and tedious. This can be accelerated dramatically with AI and LLMs, and this novel technology only continues to improve.

These models could once only handle a limited amount of text at a time – state-of-the-art used to be 100,000 tokens (word parts). But we are seeing rapid progress such as Google's most recent model which can process 10 million tokens in a research context. This increased capacity means you can chuck in all the information and documents that you have collected as part of this regulatory process and get to a first draft very quickly. Validation is still needed, but this takes closer to 30 minutes compared to 10 hours for manual draft creation. It's not perfect, but this is a massive time saving, and these models are only going to get better from here. This is going to rapidly change every part of the development process.



How does AI impact the competitive dynamics of the industry? Will companies who have embraced AI be in a better competitive position?

AI is one of the most powerful technologies that will emerge in our lifetimes and will eventually be completely pervasive. From our perspective, mRNA is a new technology. We have ambitious pipelines and a relatively small workforce, so need to be as efficient as possible, and this is why we've essentially run towards AI/ML.

Many companies just like us have banned these tools. We're on the opposite end of the spectrum: not only do we encourage people to use it, we also want to educate our people to be able to use it effectively. We want to change the way they think about doing their job. I supervise two software teams dedicated to building capabilities so this can be embedded into everything we do.



How are you seeing AI advance in your business?

There's not a part of the business that isn't touched by AI/ML. I've already touched on how we are using it in drug design in areas like optimising our mRNA sequences, protein sequences, and formulations, and how we are using generative AI and LLMs for optimising communications with regulators.

We are also using it in clinical trials for forecasting enrolment to help us understand exactly how long a trial will take and how to optimise advertising spend and targeted community outreach to drive engagement. In manufacturing, we are using it extensively for schedule optimisation. One example of where we apply this is for our personalised cancer vaccines, where the turnaround from patient biopsy/tumour sequencing to us producing a bespoke medicine for them is incredibly short – around 45 days – so efficiency and process optimisation is crucial when we do this at scale. We also use it earlier in our research process when doing things like animal studies. From a commercial perspective, as we continue to grow, there are also plenty of opportunities to use AI/ML to optimise areas like marketing. ML first got traction in e-commerce and digital marketing spaces; this approach is applicable to our products too.

Internally, we deployed an application called mChat which is essentially an internal ChatGPT, and we are hearing many stories of people finishing tasks in 20 minutes instead of entire days. This transformation is happening across every department and knowledge worker.



What has it taken as an organisation to fully embrace AI? What do companies need to do to be on the right side of this in terms of investment and resource building?

A major thing is simply making AI available, not banning it. Given all the capabilities this unlocks, it will change how people use computers, so effective change management is needed. At Moderna, we have 12 "mindsets" which are aligned with a culture of curiosity-driven innovation, and this has helped our speed of adoption.

Internal outreach is important. We have held townhalls, run workshops, and set up a special interest group dubbed the Generative AI Champions Team. These folks are constantly surprising us with novel applications they can find, and act as advocates for generative AI within their own business departments. Investing in and empowering these people to demonstrate the value of AI and spread adoption through word-of-mouth is really important. You reach this point of no return where people can't imagine going back to their jobs without AI. But it takes effort and investing in your workforce to get there.

Companies will also need to hire for this capability. This is an emerging skillset that hiring managers are going to need to pay attention to really get the most out of these tools in their teams.



Do you see potential drug discovery use cases for AI in modalities beyond mRNA?

In general, this is a tool that eventually everyone is going to adopt in various ways. But there are some applications that are unique to our modality and the specific problems that we are trying to solve in mRNA and protein sequencing and engineering. There's no shortage of interesting problems that we can apply it to. Our platform approach gives us a good ROI on these types of early innovation investments, and that has been really important for our success.

RECURSION MICHAEL SECORA (PHD), CFO



Michael Secora, PhD, is CFO of Recursion Pharmaceuticals, a biopharmaceutical company reshaping drug discovery using artificial intelligence and machine learning. Dr Secora holds a Ph.D. from Princeton University in Applied and Computational Mathematics and a B.S. in Mathematics and Physics from MIT.



How transformative an impact do you see AI having on the healthcare industry?

I believe that it is becoming increasingly clear that AI and ML will inevitably touch various aspects of our lives, including healthcare. I do not see any part of the value chain where AI and ML could not have an effect.

I think it is worth highlighting a publication that the Food and Drug Administration (FDA) released last May, which delves into the application of AI and ML across the spectrum of drug discovery and development, starting from target identification to next-generation manufacturing processes. I believe seeing such a leading regulatory body outline the applications of AI and ML was an important moment.

More broadly, there are several sources which frame that the volume of data generated worldwide is doubling every year or two. Think about that. Over a short period of time, we are producing more data than has been generated in human history. How do we begin to make sense of this vast amount of information? I believe that it is evident that AI and ML are no longer a luxury, but will become the norm for parsing, understanding, and finding insights in this data deluge, and I believe that this trend will be true for healthcare as well.



How do you see the value creation of data and AI emerging through the healthcare value chain?

Perhaps I will address this question in the context of what Recursion does. By generating, aggregating, and integrating vast amounts of reliable biological, chemical, and patient data, compiled with attention to standardisation so that every experiment conducted can connect with every past and future experiment, one adopts a technology company philosophy within a biotechnology context.

With an approach focused on mapping reliable biological, chemical, and patient data, one can explore in an unbiased manner what novel targets could be implicated in a given disease. In so doing, this process begins to resemble more of a search problem. For example, given an indication, one could search for the top 10 potential targets implicated in that disease as well as the top 10 compounds that could interact with those targets, prioritising and filtering by target novelty and chemical and clinical tractability. One can then experimentally validate hypotheses with which one also improves the overall process, one's understanding of biological mechanisms, and the design of chemical matter. Furthermore, invoking patient-centric data (like we have with Tempus), one can start to connect cellular-level insights to patient-level understanding, thus generating causal rationale for drug design.



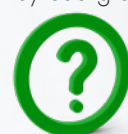
What is going to be the impact of all of this on us as healthcare consumers?

For healthcare consumers, I believe that the impact could unfold in two main ways: increased efficiency

in drug development, which could lead to faster and potentially cheaper access to therapies; and the discovery of novel treatments for diseases that were previously untreatable. It is about pushing the boundaries of known science and opening up new possibilities for treatment, which is incredibly exciting.

In terms of efficiency in drug development, when thinking about the process, one should start by surveying a wide area of biology, and use aggressive science to terminate weaker hypotheses early. This design choice should help minimise dollar-weighted failure by focusing resources on the most promising programs and seeking to reduce costly late-stage failures. Using this approach has led Recursion to advance programs about twice as fast and for about half the cost compared to the industry average.

Another critical aspect is novelty. The vast majority of biology is still unknown. By using AI/ML to differentiate targets and chemical compounds within large proprietary datasets, one can then compare these insights to the corpus of scientific literature and identify opportunities not only to validate known biology and chemistry but also to uncover unknown relationships. This is what Recursion is doing which has led to novel relationships that we have been advancing internally and for our partners. As a scientist by background, I see this as scientific exploration at scale.



What has got you most excited so far about AI's long-term potential in healthcare?

I believe that with greater data analysis, as enabled by AI/ML, all disease increasingly becomes rare disease and all medicine increasingly becomes precision medicine. With greater access to large-scale, reliable data, I believe that we can start to understand the unique causes of a disease itself, and what this means on a patient by patient basis.

Take pancreatic cancer for example. It is not just one condition; there are many forms of it, each with its own nuances. The complexity is immense, and can involve significantly different genetic or epigenetic factors. But whether we're talking about different types of cancers or other diseases, this level of detail allows us to understand and address these diseases in a much more tailored way. With more data, you can aim to solve the precise problem for the right patient with the right drug at the right time.

As we look to the future, maybe 10 years or so ahead, I believe we could move from multiomics data to "my-omics" data. The idea could be to profile each individual across various omics disciplines – phenomics, genomics, transcriptomics, proteomics, etc. – at a particular stage in their life, and then provide the precise treatment needed at that time. As omics technologies become more advanced, widespread, and cost-efficient, this could allow us to profile ourselves in depth. This could lead to a situation where healthcare is personalised to the extent of "just in time diagnosis, just in time treatment", mirroring the immediacy we see in consumer product delivery but applied to healthcare.



How could this alter the competitive landscape? What do you think will be the defining criteria of winners from this AI revolution? What types of companies run the risk of being disrupted?

I believe that the intersection of technology and biotech is an inevitability and starting to play out. I am confident that in 10 years or so, the biopharma industry is going to resemble Recursion more than the other way around. Biopharma is a trillion-dollar industry where success rates from preclinical stages to the market are less than 10%. There are lots of opportunities for driving greater efficiencies.

I believe that the technology companies have started to move into this space, leaning in with their strengths. For example, you have Microsoft with OpenAI – it launched BioGPT. Amazon was involved with a Phase 1 clinical trial and has acquired companies like One Medical and PillPack – it is leaning into its strength in logistics and getting to know the consumer. Oracle acquired Cerner, which I believe highlights a desire to be a system of record for patient data. And then you have Google which has incubated companies like Calico, Verily, and DeepMind's Isomorphic Labs which was tied to breakthroughs like AlphaFold.

As biopharma and technology companies evolve, I believe this biotech space will be dependent upon companies that can build and command proprietary data sets built for the purpose of training AI/ML models to uncover novel insights. And that is what Recursion has been able to build itself – arguably one of the largest such datasets.



What about regulation – how do you view the stance of regulators towards AI in the healthcare industry?

I think it is incredible to see regulators such as the FDA being so forward-thinking. When you consider the

potential of LLMs, for instance, I believe that they can immediately begin assisting regulatory bodies. Imagine LLMs providing a preliminary review of investigational new drug (IND) submissions. These tools could provide a first pass, helping to scale the review process for the burgeoning number of therapeutic potentials. This kind of technology could be beneficial for regulators in navigating the complex interplay of science, regulation and commerce.



What are you most excited about in the year ahead?

I believe that this is going to be an impactful year. Seeing LOWE (our LLM-Orchestrated Workflow Engine) connect many of our experimental and computational modules with proprietary and public data as well as perform next-generation digital chemistry calculations live, in a non-code way, has been fascinating. Moreover, I believe that tools like LOWE can help scale the productivity of teams working in drug discovery where an ability to code is not a barrier for adoption. I increasingly believe that the programming language of the future is human, where we will just talk to a computer as we would with a person to carry out increasingly complex tasks.

The growing use of AI/ML in drug discovery and development is not a hypothetical – it is real and right before you – that is what LOWE represents to me. And I think that sentiment is increasingly being felt by large pharma companies. You see some companies like Roche and GSK starting to build their own LLMs. I believe that this is a notable shift. Complementing Recursion's software tools is the integration and scaling of new capabilities within our platform (the Recursion OS), progression of our partnerships, and advancement of our pipeline programs through clinical trials and to data readouts.

AI – tried and tested by the Global Innovation team

Not only is AI improving productivity by enabling people to accomplish more with less, but it is also helping open up new markets and stimulating growth.

Key to this growth is the concept of democratisation: by utilising AI-powered technologies, people are being empowered to engage in activities that were previously out of reach, ranging from coding and app development to writing and creative design. To test this idea out, members of the Global Innovation team looked to experiment with various AI applications in a hands-on way – such as Microsoft's Copilot, Adobe's Firefly and Open AI's ChatGPT.

What Copilot means for Microsoft and us

"We believe Copilot will fundamentally transform our relationship with technology and usher in the new era of personal computing."
— Satya Nadella.

1 November 2023 was a momentous day for technology, for consumers of technology and for investors in technology. It was the day that Microsoft announced the general availability of Copilot for the enterprise, its generative AI tool designed to enhance productivity across computing tasks. Why was this so significant? Two key reasons. Firstly, because Microsoft has so successfully become the operating system of computing for the vast majority of humanity, Copilot has the potential to meaningfully impact us all in our day-to-day lives. Most of us use Microsoft in some capacity, whether using Microsoft word documents, building spreadsheets in Excel, using GitHub to develop code, or Bing to shop. Copilot is being infused into all of these products – Microsoft is democratising access to this new generation of technology. We are all going to have access to our own generative AI assistants.

Secondly, the productivity gains being delivered by Copilot are eye-watering. Data just released from customers of Copilot's early access program (who used Copilot for eight months leading up to November) demonstrate that generative AI-driven productivity gains are both real and, even more notable, realisable from day one of use. 70% of Copilot users said they were more productive (by a factor of 55% for developers), 68% saw an improvement in the actual quality of their work, and 77% said once they used Copilot, they didn't want to give it up.



Naturally, when faced with a customer value proposition as striking as this, the Global Innovation team wanted to test out Copilot ourselves. We decided to build our very own website using Copilot in Microsoft Power Pages, which lets users rapidly give natural language prompts to generate relevant content, code, Cascading Styling Sheets (CSS), and images into a webpage, as well as embed their own chatbots in their websites. However, we fell at the first hurdle. Copilot in Power Pages has not quite made its way onto our computers yet. Undeterred, we set upon building our website using Wix's ADI (Artificial Design Intelligence) tool, the company's own version of Copilot, which we thought would provide a similar enough experience.

Concluding thoughts: 'more for less'

The ascent of low/no code development (such as developing this website) is hard to overestimate in terms of its impact on developer productivity, and this is being driven by generative AI. The average developer spends approximately 50% of their time writing code, but a 55% productivity infusion from coding assistants such as Wix ADI and Copilot can save up to 2.20 hours per day, freeing up their time for design and enhancing both the output and quality of their work. If the Global Innovation team can create a website using simple natural language prompts in under 20 minutes, just think of the collective productivity gains that can be realised as copilots and AI assistants accelerate their global rollout.

Firefly – a small step for AI, a giant leap for Global Innovation

In the field of creative image design, we decided to experiment with Firefly, an exciting new generative AI model released by one of our current portfolio holdings, Adobe. This model can recognise connections between text and images to generate image outputs, and now powers an array of tools across Adobe's creative software suite. Leveraging Adobe's vast scale and IP, the latest version – Firefly 2 – was trained on over 500 million images and videos

from Adobe's stock catalogue and the public domain, meaning all images are safe for commercial use with no IP infringement concerns. With that peace of mind, we used Adobe's online Photoshop application to embark on a creative mission: send the Global Innovation team to outer space.

The final image, which you can see on the previous page, is far from perfect, but it is a giant leap from what we could have achieved without Firefly's AI assistance.

What did we learn about Firefly? Firstly, the time savings are real: tasks that would have taken hours – such as mastering various tools, sourcing and uploading content, assembling the final image, and colour correction – were accomplished in less than a lunch break thanks to Firefly's AI assistance. Secondly, it was easy to achieve quality: tools were not only intuitive and required minimal technical skill, but also produced high-quality images. The precision of AI tools like 'select object' ensured clean and accurate details (no jagged edges or missing ears), while the text-to-image generation simply required written prompts to create images that were fully contextually appropriate (heads fit in space suits, everything was on-theme). Lastly, these tools fostered creativity: Firefly's generative image capabilities allowed us to overcome creative blocks, offering the flexibility to either guide the AI with detailed prompts or explore new ideas with more open-ended suggestions. This blend of efficiency, simplicity, and creativity not only saved time but also made the creative process more accessible and enjoyable.

These elements help bring to life how Adobe's Firefly AI model can boost productivity while also democratising the creative process. Its intuitive design, ease of use, and overall efficiency not only save time but also lower barriers to entry, making creative endeavours more accessible to a wider audience. This is a boon for consumers and a strategic win for Adobe: improved productivity leads to increased user engagement and retention.

Meanwhile, democratising technology in this fashion expands Adobe's user base beyond professional designers, opening up new markets for growth. The tangible impact of Firefly is already evident: over three billion images have been generated since its beta launch in March, with a remarkable 90% of Firefly web app users being newcomers to Adobe products. This statistic not only highlights the customer value creation of these AI tools in general, but also underscores AI's role in driving a new wave of growth for companies such as Adobe in the years ahead.

Animal Spirits: using LLMs to forecast the economy

"Not everything that counts can be counted. And not everything that can be counted really counts", Albert Einstein is believed to have said. Indeed, in this industry of investing in which we ply our trade, numbers rule. And no more so than in the immensely difficult, usually hated, but often unavoidable task of making forecasts.

Managements' formal quantitative guidance on future revenues and earnings weighs heavily in analysts and investors' expectations for companies. When it comes to the overall economy, investors and economists obsess over the US Federal Reserve Federal Open Market Committee (FOMC) members' dot plots (the committee's expectations on interest rates over time) and other such metrics from the Fed and other major central banks.

The tyranny of numbers is well illustrated by a story the late, great Nobel Prize winning economist Kenneth Arrow used to tell about his first ever job as a weather forecaster in the US Air Force during World War II. After a while, Arrow determined that his forecasts were not much better than pulling predictions out of a hat and wrote to his superiors asking to be relieved of the duty. He received the following reply: "The Commanding General is well aware that the forecasts are no good. However, they are required for planning purposes."

Indeed, numbers are usually at their best when they are supported and enriched by qualitative detail and colour. How well are the newest products being received by early adopting customers? How is the order book shaping up? Where are the snags in supply chains, are they improving or getting worse? Are customers feeling the pinch? Are they trading up or trading down?

Enter LLMs, which are not just about processing vast amounts of data. They excel in understanding and interpreting language. This means they can analyse qualitative information with a degree of nuance and insight previously unattainable and hold the promise of finally putting due weight on the detail and the colour with forecasts.

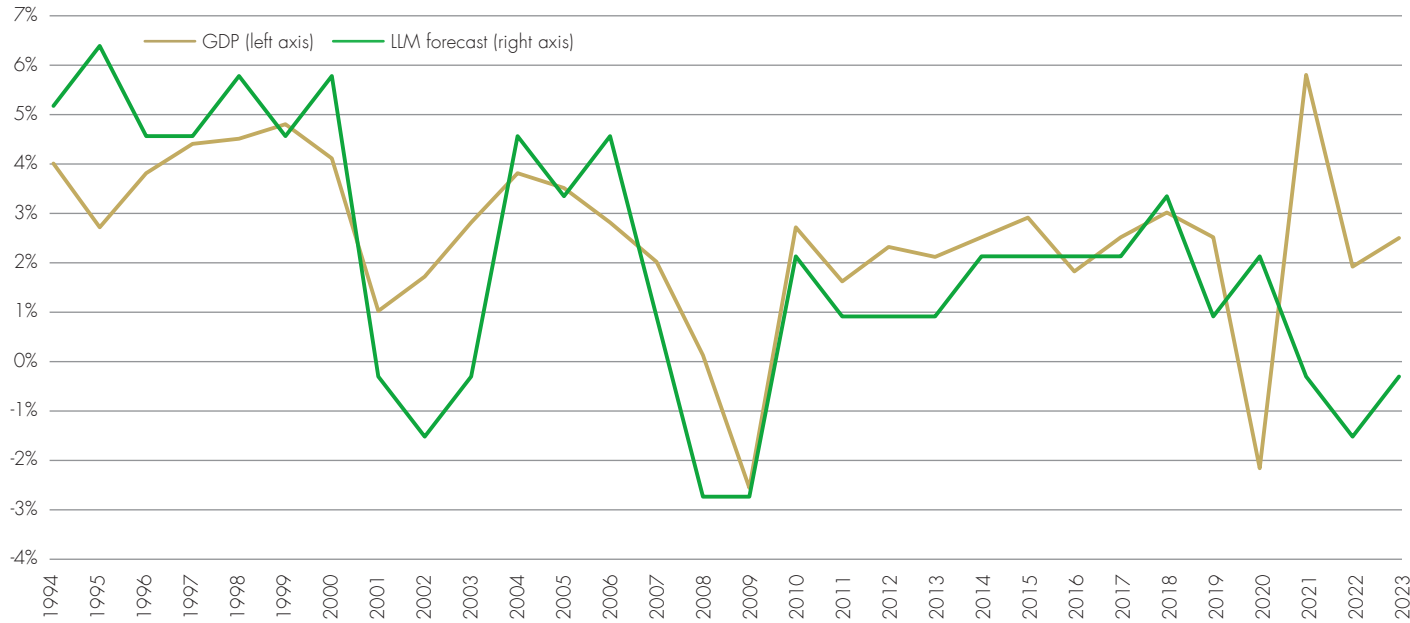
Furthermore, the beauty of LLMs is that they are simple to use. Certainly, we found that building a basic version of a forecasting model that incorporates qualitative information is achievable with less than an hour's work.

We are bottom-up investors and spend most of our time researching individual companies. Nevertheless, an accurate and balanced view on the economy is very helpful. To illustrate our point, we took the US Federal Reserve's FOMC minutes (which contain the committee's detailed discussion and debate on economic conditions and the outlook) and fed them into an LLM (Open AI's ChatGPT-4) to build a simple model to use to forecast US economic growth.

In terms of the specifications, we took each set of December meeting minutes (the committee meets eight times a year) from the past 30 years and asked ChatGPT to score the FOMC's outlook for economic growth over the year ahead on a scale of 0 to 10 based on their broad qualitative discussion of macroeconomic conditions.

The chart below shows US real GDP since 1994 and our LLM outlook score taken at the end of the prior year. While of course far from perfect – the model, for example, failed miserably to navigate the volatility of the Covid period – the forecast is surprisingly good given the simplicity of the approach.

US GDP and LLM Forecast 1994–2023



Source: Liontrust research and Bloomberg, as at end of January 2024.

The obvious next step, and beyond our ambitions for the exercise, would be to add the LLM forecast into a broader forecast framework, such as adding it as an explanatory variable alongside others in a regression model to combine the quantitative analysis and qualitative debate in harmony.

But one could also go much further than we have here to incorporate qualitative information into the forecast using LLMs. In particular, the potential to measure and weigh sentiment from online text in the news, financial analysis and social media using LLMs is interesting. Existing approaches using natural language processing are well known, but LLMs are likely to prove significantly better due to their far superior handling of language and context. They may finally

The two series have a correlation of 0.58, which is quite a good correlation with GDP growth for a forward looking variable. Indeed, the same correlation for the prior year-end Bloomberg consensus US GDP forecast was 0.63. So it appears that using an LLM one can build a pretty respectable economic forecasting tool within the hour.

provide a suitable way to incorporate the economic impact of Keynes's famous though long-elusive "animal spirits" into forecasts.

Moreover, the example of such a simple application within a domain of expertise with a non-trivial payoff serves as a small indication of the power of LLMs to drive productivity in the coming years. LLMs' accessibility plus their efficacy and extremely wide applicability is a powerful economic formula.

Forecasting will no doubt remain a difficult and perilous job, but LLMs may help drive the frontier forward as they are beginning to do for many challenging tasks across the economy.

CONCLUSION

This report has explored the potential of AI to drive a new cycle of innovation and investment returns. In our view, AI meets the necessary criteria for both value creation, through innovative applications that lower costs and improve quality across sectors, and value capture, with leading technology companies well positioned to profit from AI's benefits.

Across the new technology stack, from infrastructure companies such as Nvidia providing the chips and software foundations, LLMs becoming the new AI "brain", to ServiceNow building AI tools for companies across the whole economy, we are focused on investing in businesses that are building and harnessing AI tools to drive productivity. We are also invested in leading innovators such as Spotify and Netflix, where AI meets the public, enhancing the customer experience.

Beyond technology, AI is poised to transform major sectors like healthcare and unlock vast potential, with companies such as Moderna and Recursion pioneering its use in drug discovery. We believe the strongest growth and strong shareholder returns will ultimately accrue to companies that fully commit to AI-based reorganisation. Firms including Airbnb, MongoDB, Uber and Shopify are already making this profitable pivot.

While risks exist around factors such as regulation, bias and job losses, we believe AI's economic promise outweighs the pitfalls,

 We are still only five minutes into the football game

especially if governance keeps pace. As this report has shown, AI is driving real value today while opening up new frontiers for creativity and innovation.

We are still only five minutes into the football game. We believe the next decade will be defined by the rise of AI across the economy.



IMPORTANT INFORMATION

Key risks

Past performance does not predict future returns. You may get back less than you originally invested.

The Funds managed by the Global Innovation Team:

May hold overseas investments that may carry a higher currency risk. They are valued by reference to their local currency which may move up or down when compared to the currency of a Fund.

May have a concentrated portfolio, i.e. hold a limited number of investments. If one of these investments falls in value this can have a greater impact on a Fund's value than if it held a larger number of investments.

May encounter liquidity constraints from time to time. The spread between the price you buy and sell shares will reflect the less liquid nature of the underlying holdings.

Outside of normal conditions, may hold higher levels of cash which may be deposited with several credit counterparties (e.g. international banks). A credit risk arises should one or more of these counterparties be unable to return the deposited cash.

May be exposed to Counterparty Risk: any derivative contract, including FX hedging, may be at risk if the counterparty fails. Do not guarantee a level of income.

The risks detailed above are reflective of the full range of Funds managed by the Global Innovation Team and not all of the risks listed are applicable to each individual Fund. For the risks associated with an individual Fund, please refer to its Key Investor Information Document (KIID)/PRIIP KID.

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