Goldman Sachs Research

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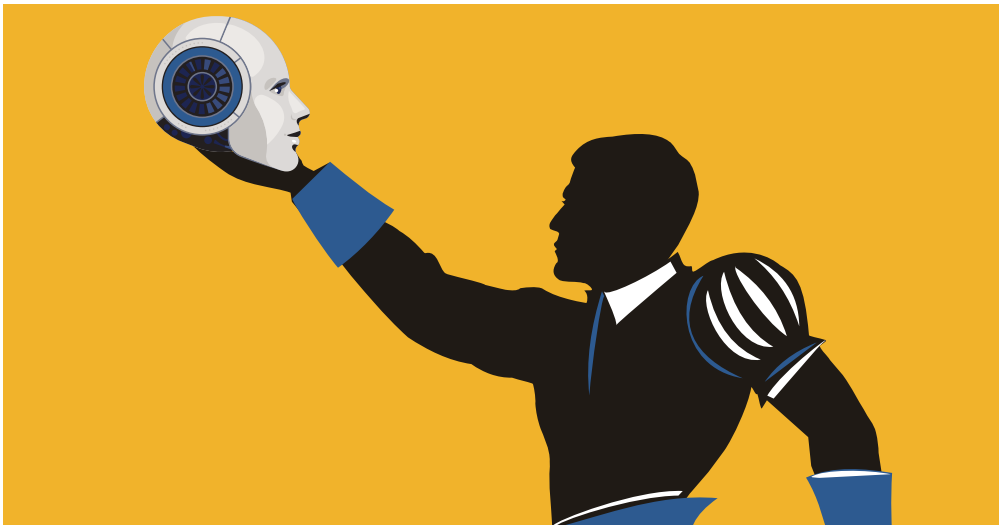
GLOBAL STRATEGY PAPER NO. 70

AI: To buy, or not to buy, that is the question



- The technology sector has generated 32% of the Global equity return and 40% of the US equity market return since 2010. This has reflected stronger fundamentals rather than irrational exuberance. The tech sector globally has seen EPS rise c.400% while all other sectors together have achieved c.25% from the peak pre-GFC.

- The introduction of transformative technologies typically attracts growing investor interest as well as significant capital and new competition. As enthusiasm builds and stock prices increase, the sum of individual company valuations can overstate the total potential aggregate returns; often a bubble develops and bursts.

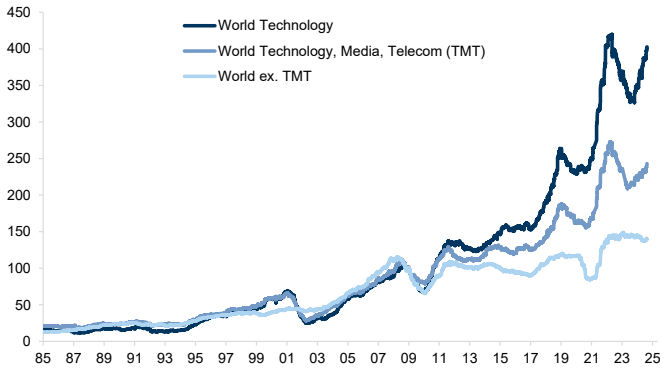
- Historically, investors over-focus on the originators, understate the impact of competition and overstate the returns on capital invested by the early innovators. At the same time, investors tend to underestimate the growth of new entrants to the industry that can piggyback off the capex of others, enabling them to generate new products and services. Valuations often also understate the opportunities that can accrue in the non-technology industries that can leverage the technology to generate higher returns in existing, as well as in new, product categories.

- In our view, the technology sector is not in a bubble and is likely to continue to dominate returns. However, concentration risks are high and investors should look to diversify exposure to improve risk-adjusted returns while also gaining access to potential winners in smaller technology companies and other parts of the market, including in the old economy, which will enjoy the growth of more infrastructure spend.

Tech's Rational Exuberance

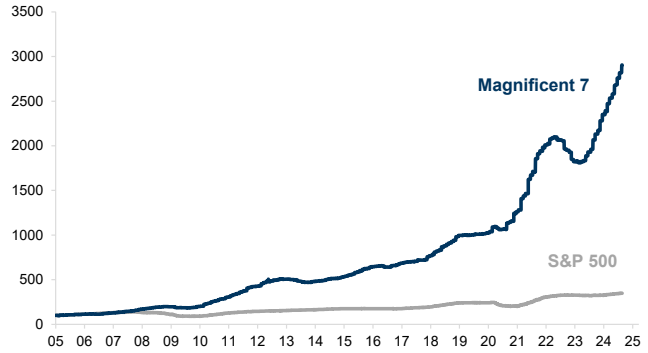
Technology has been the most important driver of returns for the equity markets globally since the end of the Global Financial Crisis. Its **performance has far outstripped other major sectors, and with good justification. Earnings per share have surged while all industries together, outside of tech, have largely stagnated (Exhibit 1).**

Exhibit 1: Tech earnings have outstripped those of the global market
12m Trailing EPS (USD). Indexed to 100 on Jan-2009.



Source: Datastream, Worldscope, Goldman Sachs Global Investment Research

Exhibit 2: The 'Magnificent Seven' earnings have outstripped the broader US market
Magnificent Seven and S&P 500, 12m trailing EPS. Indexed to 100 on Jan-2005



Source: FactSet, Goldman Sachs Global Investment Research

Increasingly, these powerful returns have been accounted for by a small group of dominant companies, mainly in the US. **These, too, have not reflected 'irrational exuberance': their earnings growth has dwarfed that of the broader market**, justifying their performance (Exhibit 2).

The drivers of this success have reflected their ability to leverage software and cloud computing and to fuel high profitability generated by extraordinary demand growth in the period since 2010. But their more recent surge in performance since 2022 owes much to the hopes and aspirations around AI. Despite continued powerful earnings growth, valuations have been rising, led by an increasingly narrow group of 'hyper-scalers'. **The question for investors is whether this is becoming a bubble and, even if it is not, whether the risks of such high concentration are creating a dangerous trap for investors, or possibly an opportunity to diversify into potential beneficiaries of these technologies through cheaper companies outside of the dominant few.**

Story Time

Financial markets reflect and anticipate fundamentals, but sentiment can also play an important role as it does with other fashions and trends in broader life. **In equity markets, narratives have the power to attract and direct much-needed capital. However, they can also amplify interest to the point of monopolising investor attention at the expense of other opportunities, and leading to unrealistic expectations about future profits and leaving companies vulnerable to a sharp de-rating**. In recent years, periods of intense speculation have centered on a variety of narratives, ranging from the dot-com and the internet boom at the end of the last

century, to China growth, Cryptocurrency, the Green transition and, most recently, AI. But history reveals a much longer list, much of which revolves around the emergence of new technologies.

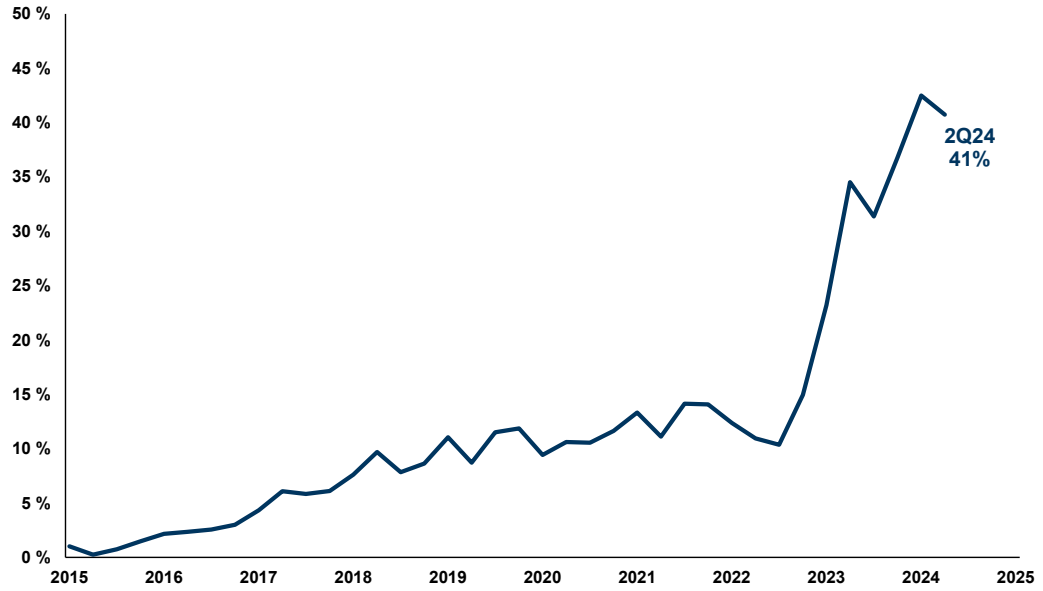
The interest that new innovations receive has been an important part of directing the necessary capital to grow and commercialise innovations. Very often the technologies behind these periods of speculation have proved to be transformational – leading to significant secondary innovations, new products and services, and far-reaching societal changes to the way that we live, work and consume. Along the way, however, the excitement often turns into an obsessive fervor with investors clambering to get exposure to the theme at any price. That's when bubbles emerge and, eventually, burst. A recent study found that in a sample of 51 major tech innovations introduced between 1825 and 2000, bubbles in equity prices were evident in 73% of cases[1].

From an investor perspective, the success and eventual impact of an innovation cannot be known at the outset, and it is even more challenging predicting which competitor is likely to succeed over the long run. Consequently, as more new entrants emerge, investors tend to buy multiple companies as options on their future success, leading to the sum of all valuations to overstate the potential returns that can be generated by a technology or industry. **The challenge for investors is less about whether they recognise an important innovation or market driver when it emerges, but more about whether they value the potential gains correctly and identify the correct winners and losers.**

This question is relevant in relation to the current focus on AI and its potential. While AI is not a new technology, it has captured the imagination of investors and, by association, companies since the launch of Chat-GPT and other large language models. The extraordinary beat on Nvidia investor day in July 2023 sharpened the focus on the potential for the industry. Since then, investors have clamoured for access to the theme and companies have duly responded with record numbers mentioning AI, even in sectors outside of the industry.

[1] Chancellor, E., and Kramer, C. (2000). "Devil Take the Hindmost: A History of Financial Speculation". New York: Plume Books.

Exhibit 3: Companies citing AI spiked following the release of Chat GPT
Proportion of S&P 500 firms mentioning "AI" during quarterly earnings calls



Source: GS Dataworks, Goldman Sachs Global Investment Research

Lessons from History; the Market Risks and Opportunities in AI

What can history tell us about the 'life cycle' of new innovations and how they impact the stock market?

Although it is difficult to generalise, some common characteristics are:

- A breakthrough technology emerges and reaches commercial scale.
- New companies and capital flood into the space.
- Speculation builds and valuations of companies rise, often resulting in a bubble.
- The bubble bursts, but the technology tends to re-emerge as a principal driver in the economy and stock market.
- The technology/industry becomes dominated by a few large players.
- Secondary innovations emerge, creating new companies and products that leverage the initial technology and its increased adoption.
- Other industries are disrupted by the innovations, forcing incumbents either to adapt or disappear.
- The secondary innovations create new employment opportunities and, with them, new sources of demand as many of the benefits are passed on to the consumer. Productivity tends to rise, but usually only after the full adoption of this new technology and network effects are realised.

Throughout this life cycle there are typically both risks and opportunities for investors. The risks include:

1. **Underestimating the impact of competition in driving down returns.**
2. **Overstating the returns on capital invested by the innovators that are developing the technology.**

The upside opportunities that are often overlooked include:

1. **New companies that can utilise the technology to create new goods and services to drive new sources of demand and growth.**
2. **New markets that open up as a result of the technology.**
3. **Companies outside of the technology space that can benefit from the technology as demand patterns change.**

The impact of competition

When new products or technologies emerge, particularly when they appear transformational, investors tend to underestimate the scale of new competition and its impact on the future returns of the incumbents or originators. There are many useful examples in history that demonstrate the pattern of investor excitement and the promise of high returns leading to a surge of competition and, ultimately, overcapacity that drives down returns. The result is often a large de-rating of companies in the industry and, in some cases, spectacular failures of companies. Nevertheless, this process doesn't usually mark the end of the technology. **Mostly, the infrastructure left behind in the wake of the initial investor surge and capex leads to the emergence of new products and services. These are often underestimated or poorly anticipated.**

Here are some of them:

Books, 16th Century

The printing press was one of the greatest 'enabling' technologies of all time. Following its invention in 1454, its impact was spectacular. According to research by Buring and Van Zanden[2], the number of books published increased from zero to about 3 million per year by 1550 in Europe - more than the total number of manuscripts produced in the entire 14th century. By 1800, 600 million books had been published. As with all technology innovations, the price of books collapsed.

Canals, 18th Century

The innovation of canals for transportation was an important component of the First Industrial Revolution. The first canals built generated strong returns for investors, attracting new inflows of capital that pushed up stock prices and led to a bubble in canal stocks in the 1790s on the London Stock Exchange which peaked in 1793. By the 1800s,

[2] Buring, E., and Van Zanden, J.L. (2009). "Charting the 'Rise of the West': Manuscripts and printed books in Europe; A Long-Term Perspective from the Sixth through Eighteenth Centuries. *The Journal of Economic History*, 69(2), 409-445.

the return on capital in canals had fallen from a pre-bubble peak of 50% to just 5%, and a quarter of a century later only 25% of canals were still able to pay a dividend[3]. Nevertheless, the canal infrastructure became instrumental in reorganising industries and factories, which, in turn, spawned the growth of many new industries, businesses and products. While many of the original companies failed, the infrastructure generated strong growth for others.

Railways, 19th Century

A similar exuberance surrounded the growth of railways in the 19th century in the UK, which were to become equally transformative in terms of economic growth, business organisation and societal change. As capital flooded in, there were nearly 1,240 projects seeking capital by 1845 and the number of miles of network increased from 100 miles in 1830 to 6,123 miles by 1850[4]. A bubble in valuations of railway stocks formed in the 1840s, and by 1850 most stocks had plummeted by an average of 85% from their peak, and the total value of these shares had dropped to less than half the capital spent on them[5]. As with the canals, the legacy of the infrastructure became pivotal to growth cities, changing demands for consumer products and other industries that followed.

The Telegraph, 19th Century

The innovation of the telegraph in the mid-1840s had a similar effect. By 1851, there were more than 50 different telegraph companies competing in the US, across the same lines. As the returns fell, most of the firms failed or were consolidated into larger units. Ultimately, Western Union Telegraph took over its two major competitors and became the first US nationwide monopoly in 1866.

The Telephone, 20th Century

A similar wave of excitement followed the invention and commercialisation of the telephone. The expiration of Bell's original patents in 1894 generated a surge of investment and competition. By 1904, 60% of American cities with more than 5,000 people had two phone networks. The competition drove a wave of consolidation led by AT&T, which was eventually restricted by an antitrust settlement in 1913 that prevented it from taking over independent phone companies and forced it to give up its controlling share in Western Union Telegraph Company. Nonetheless, the constraints on its core business encouraged AT&T to invest in new technologies through its Bell Laboratories subsidiary which became a major innovator in new areas of telecom innovation[6].

The Radio, 20th Century

The periods after World Wars I and II (WWI and WWII) saw massive demand for consumer products that attracted waves of investment as new market entrants

[3] Chancellor, E., and Kramer, C. (2000). "Devil Take the Hindmost: A History of Financial Speculation". New York: Plume Books.

[4] Campbell, Gareth (2014). "Government Policy during the British Railway Mania and the 1847 Commercial Crisis".

[5] Odlyzko, A. (2000). "Collective hallucinations and inefficient markets: The British railway mania of the 1840s".

[6] Starr, Paul. (2002). "The Great Telecom Implosion".

emerged. As broadcast radio took off, for example, demand for radios surged and between 1923 and 1930, 60% of US families purchased a radio. In 1920, US broadcast radio was dominated by KDKA, but, by 1922, 600 radio stations had opened across the US, supported by the growing advertising industry. A bubble developed and the value of shares in the Radio Corporation of America (RCA), for example, rose from $5 to $500 in the 1920s but collapsed by 98% between 1929 and 1932, and most radio manufacturers failed, but the industry continued to grow, supported by advertising and the plethora of new consumer products that emerged.

The personal computer (PC), 20th Century

The PC revolution fueled a similar boom in both the number of companies and the valuations of new entrants in the market. While IBM facilitated the widespread commercialisation of the PC, hundreds of companies entered the market in the 1980s. In 1983, however, several companies in the sector announced losses, including Atari, Texas Instruments and Coleco. A collapse in PC share prices followed and many PC manufacturers went out of business, including Commodore, Columbia Data Systems and Eagle Computer. While several of the surviving businesses took many years to recover, the industry matured and became dominated by just a few companies.

Internet, 21st Century

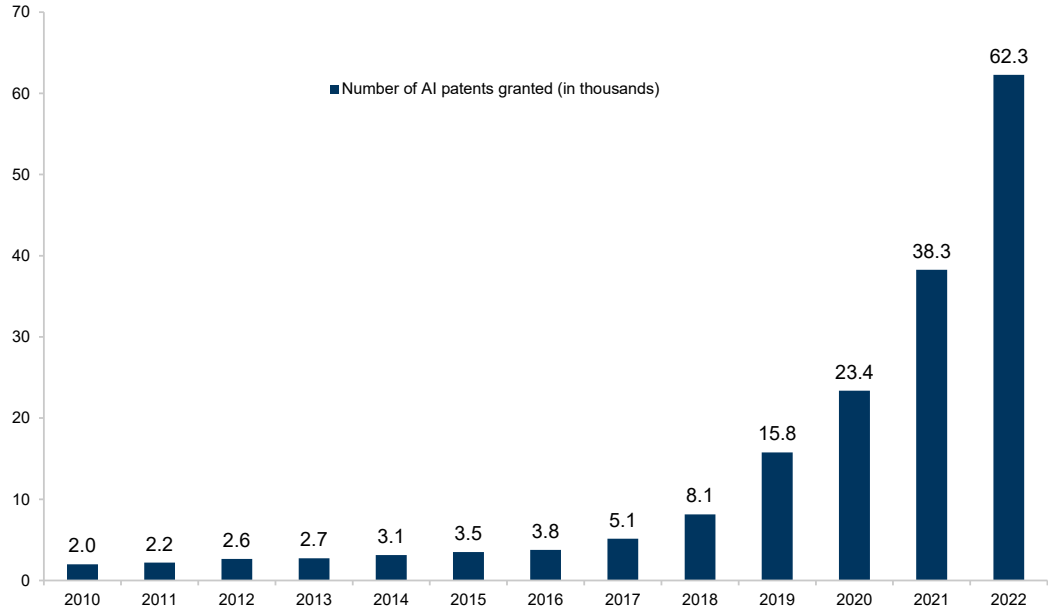
This pattern was repeated during the internet bubble of the late 1990s. Speculation grew rapidly as investors began to see the potential of the internet. When search engine company Yahoo! had its initial public offering, its stock rose from $13 to $33 in a single day. Qualcomm shares rose in value by over 2,600%, 13 major large-cap stocks increased in value by over 1,000% and another seven large-cap stocks each rose by over 900% in 1999. The Nasdaq index increased fivefold over the period between 1995 and 2000. In just a month after its peak in 2000, the Nasdaq had fallen 34% as hundreds of companies lost 80% or more of their value. The Nasdaq itself fell by nearly 80% by the time it troughed in October 2002.

So, there is a fairly consistent historical pattern: radical new technologies tend to attract significant capital and competition. Not all examples in history end with a spectacular bubble, but most do end with a downward adjustment in prices across the industry as returns moderate. Even in cases where a bubble bursts and many companies eventually collapse, this does not mean that the technology itself fails. However, rising competition is central to reducing returns relative to market expectations at the peak of the cycle. Eventually the market for the original technology tends to consolidate into a few large winners, and the growth opportunity shifts to secondary innovations or products and services that follow the original technology.

With the current dominant companies, the conditions are unusual in that most of these were already dominant in the previous wave of technology — in particular software and cloud. The scale of profitability that they achieved resulted in them being in a unique position to be able to absorb the very high costs of innovation in the AI space. While the protective 'moats' around the current AI winners are significant, and valuations are not bubble-like, the number of new patents in this area is growing rapidly, suggesting that

new competitors will emerge and costs will come down. The number of patent families (group of patents that are all related to the same invention or technology) in GenAI has grown from just **733** in 2014 to more than **14,000** in 2023[7].

Exhibit 4: By 2022, the number of AI patents granted worldwide exceeded 60,000
Thousands of AI patents granted globally



Source: Stanford HAI Research, Data compiled by Goldman Sachs Global Investment Research

While the hyper-scalers have huge scale and ability to invest in proprietary AI models, cheaper open source alternatives are emerging at a very rapid rate. The website Hugging Face, which is a network for enthusiasts, already has around 650,000 models[8], suggesting that the typical pattern of large-scale capital growth and competition is happening in the AI space, just as occurred in previous waves of technology.

Overstating returns on investment - Telecoms in the 1990s

Just as competition is often underestimated, the returns on capital invested by the innovators are typically overstated. Companies at the epicenter of an innovation often fail to achieve the returns that their high valuations imply as the marginal cost of the technology falls and capacity increases over time, while a typical **overlooked opportunity is that investors understate the returns available to new entrants in an industry that emerge after the initial investments are made that can piggyback off the capex of others.**

In the case of most major technological innovations throughout history, while the potential may be obvious, it is rarely clear in the early stages what business models will ultimately dominate to scale and commercialise the technology. This was evident in the early days of the internet. **While there was widespread and broad speculation in any new company that offered potential exposure to the industry, the incumbent**

[7] Venditti, B. (2024). "Ranked: Top Companies by Generative AI Patents". *Visual Capitalist*.

[8] "Big tech's capex splurge may be irrationally exuberant ". *The Economist* (2024).

winners were generally seen to be the telecom companies. They were viewed as a relatively 'safe' route to the potential fortunes that the internet may generate compared to the more speculative unprofitable dot-com companies. Telecoms had the benefit of being well-established companies, in many cases ex monopolies or state-run enterprises, with low volatility earnings and an existing and large-scale client base. They also had tangible assets and owned and developed fibre optic networks, routers, wireless systems and telecoms equipment that were the underlying infrastructure of the internet[9]. It seemed like they were in a perfect place to receive a high share of the future revenues driven by the internet in e-shopping.

But investors significantly overstated the returns on the capital investment that these companies made. This was partly a consequence of new entrants and partly because of the huge scale of capital invested. Competition was stimulated by de-regulation of the industry, led by the US, which introduced the telecoms act of 1996. The act deregulated the broadcast and telecoms industry in order to provide an environment that could take advantage of the technological convergence of these trends and a surge in capital investment followed. According to the Federal Communications Commission, the amount of fibre optic cable laid in the US went from one million miles in 1996 to 10 million by 2000, much financed by debt. When Global Crossing and WorldCom collapsed, they had $25bn and $100bn of debt. A similar pattern occurred across Europe. In the UK, a spending spree occurred after the government allowed 3G spectrum auctions in April 2000 which generated £22.5bn in revenues for the government and similar auctions in Germany raised roughly $30bn. Ultimately, however, the capex boom resulted in severe overcapacity in bandwidth for internet usage. While the fixed costs of these new networks were very high, the marginal costs of sending signals over them was very low[10][11].

Increasingly, competition forced prices down and by 2004 the cost of bandwidth had fallen by more than 90%, despite internet usage doubling every few years. As late as 2005, as much as 85% of broadband capacity in the US was still going unused. Many companies could not repay their significant debts in the US and some of the auctions for 3G licenses in 1999 had to be re-run because the original companies that made the bids defaulted on their bids. When the auction was re-run, the bids were only 10% of the original $4bn raised[12].

Ultimately, the valuation of these companies collapsed, alongside the broader technology bubble. Between 2000 and 2002, the Dow Jones technology index lost 86% and the wireless communications index dropped 89% with 23 companies going bankrupt in the US alone and the failure of WorldCom became the biggest stock market failure in history with a loss of $102 billion in July 2002[13].

[9] Starr, Paul (2002). "The Great Telecom Implosion".

[10] "UK mobile phone auction nets billions". *BBC News,* April 27, 2000.

[11] Osborn, Andrew (November 17, 2000). "Consumers pay the price in 3G auction". *The Guardian*.

[12] See Ted: https://ideas.ted.com/an-eye-opening-look-at-the-dot-com-bubble-of-2000-and-how-it-shapes-our-lives-today/.

[13] Starr, Paul (2024). "The Great Telecom Implosion". *The American Prospect*.

As in other examples in history, the problem was not a miscalculation of the growth potential of the technology, but rather that investors had attributed too much future value to the companies that had built technology and infrastructure to provide it. In this case, like many others before, the ultimate winners were the companies that could 'free ride' off this spending and utilise the capacity to build business models that could leverage the technology and provide new products and services. Many of these winners did not emerge until the onset of the smart phone in 2006 and the onset of apps which then spawned a growing industry of platform companies, ride sharing, social media and so on.

History lessons; the opportunity

While the market for a technology innovation can become dominated by a few very large companies for a long time, the initial transformative technology becomes a conduit that kickstarts a whole range of other innovations and, with this, new companies and market opportunities. At the same time, **one of the other characteristics of technology is that once new innovations become widely used by companies, the main beneficiary is the consumer who enjoys new products and services at lower prices.**

For example, while coal and steam were the foundations of the First Industrial Revolution, a range of other developments quickly followed. Mass migration to cities and the movement away from agriculture resulted in demand for new consumer products. Mechanised looms transformed the textile industry and domestic products such as soaps, which were typically made at home, began to be manufactured in factories. This generated new markets and became the catalyst for the building of consumer brands, advertising and marketing. During the railway boom, the steam engine spawned the development of the railways, and the network effect and connectivity then allowed other technologies to develop.

Similarly, during the Second Industrial Revolution, the harnessing of gas and oil to create electricity was one of the key driving inventions. But this, in turn, enabled the mass production of steel, the development of the internal combustion engine and the automobile. The start of the modern assembly line in factories became a further innovation, transforming the production and distribution of a range of new products. Similarly, the network impact of the railway boom and the telegraph fostered a host of new market opportunities and companies.

With the computer age of the Third Industrial Revolution came the rapid acceleration of service industries. The first transistorised consumer products started to appear in 1952, opening new markets as consumers were willing and able to pay a premium for low power consumption and portability. By the mid-1950s, prototype silicon devices were developed in Northern California. Plastics and lighter materials also generated significant new growth markets, while the growth of multinational companies opened new market opportunities.

A similar pattern emerged with the internet as its rapid roll-out and adoption enabled the development and penetration of the smartphone. This, in turn, spawned an industry of

companies based on the 'apps' used on these phones (think of the revolution in taxi and food delivery services, for example) and the 'internet of things' (a world of connected appliances and devices).

So, while the leading tech today will most likely remain dominant in their respective markets, rapid innovation, particularly around machine learning and AI, will likely create a new wave of tech superstars. It is probable that AI and robotics will not only create new faster-growing innovative companies but also raise the prospect of major restructuring gains in non-technology sectors.

AI Is Still Not in a Bubble... but Diversification Is Important

Despite the significant interest that AI has generated, it still does not appear to have driven a bubble in valuations which sets it apart, so far at least, from previous narrative investment cycles like the internet in the late 1990s. The dominant companies are less likely to be in a bubble if we compare their valuations to other periods. Current valuations are much lower than have been typical in other recent bubble periods, stretching back to the Nifty 50 era of the early 1970s, the Japanese bubble in the late 1980s and indeed the technology bubble in 2000 (Exhibit 5). For example, the median PE and EC/Sales of the 7 biggest technology companies today is roughly half that of the dominant 7 at the peak of the technology bubble in 2000.

Exhibit 5: Dominant companies today are not as expensive as those in previous 'bubble' periods in history

	Size		Valuation	
	Market weight	Market Cap ($ Bn)	*24m fwd P/E	*24m fwd EV/Sales
Magnificent 7 (2024)				
Apple	7.3%	3387	26.5	7.7
Microsoft	6.6%	3043	25.7	9.4
NVIDIA	5.7%	2649	24.1	13.2
Amazon	4.0%	1850	25.4	2.5
Alphabet	3.9%	1808	16.6	2.0
Meta Platforms	2.4%	1118	19.2	5.5
Tesla	1.4%	672	55.4	4.9
Magnificent 7 (2024) Aggregate	**31.3%**	**14527**	**23.9**	**5.0**
Tech Bubble Leaders (2000)				
Microsoft	4.5%	581	53.2	19.2
Cisco Systems	4.2%	543	101.7	17.5
Intel	3.6%	465	42.1	11.5
Oracle	1.9%	245	84.6	19.0
IBM	1.7%	218	23.5	2.3
Lucent	1.6%	206	37.9	4.1
Nortel Networks	1.5%	199	86.4	6.4
Tech Bubble Leaders (2000) Aggregate	**19.0%**	**2457**	**52.0**	**8.2**
Japan Financial Bubble (1989)				
Nippon Telegraph and Telephone	6.9%	157	100.1	
Industrial Bank Of Japan	4.6%	105	154.2	
Sumitomo Mitsui Banking	3.4%	77	49.2	
Bank of Tokyo-Mitsubishi	3.3%	75	49.8	
Fuji Bank	3.1%	71	52.8	
Dai-Ichi Kangyo Bank	2.9%	65	44.0	
Sakura Bank	2.8%	62	62.1	
Japan Financial Bubble (1989) Aggregate	**27.0%**	**613**	**67.0**	
Nifty 50 (1973)				
IBM	7.1%	48	35.5	
Eastman Kodak	3.6%	24	43.5	
Sears Roebuck	2.7%	18	29.2	
General Electric	2.0%	13	23.4	
Xerox	1.8%	12	45.8	
3M	1.4%	10	39.0	
Procter & Gamble	1.4%	9	29.8	
Nifty 50 (1973) Aggregate	**19.9%**	**135**	**34.3**	

*Actual (LTM) P/E and EV/Sales data from 02/01/1973 for Nifty 50. **LTM P/E data and EV/Sales from 27/12/1989 for Japan Financial Bubble. ***24m fwd P/E and EV/Sales data from 24/03/2000 for Tech Bubble.

Source: Datastream, Factset, Goldman Sachs Global Investment Research

Perhaps more importantly, however, the current dominant companies are much more profitable and have stronger balance sheets than those that dominated during the tech bubble (Exhibit 6).

Exhibit 6: The current dominant companies are much more profitable and have stronger balance sheets than those that dominated during the tech bubble
Next 12 month estimate for Big Tech & last 12 months for Tech Bubble

	Market Weight (%)	Fundamentals			
		Cash as % of Market Cap	Net Debt to Equity	Return on Equity (%)	Net Income Margin (%)
Magnificent 7 (2024)					
Microsoft	6.6%	3.0%	-20%	27%	35%
Apple	7.3%	1.8%	-32%	146%	27%
Nvidia	5.7%	3.7%	-61%	65%	53%
Amazon	4.0%	8.6%	-21%	17%	9%
Alphabet	3.9%	4.0%	-29%	27%	28%
Meta Platforms	2.4%	4.2%	-23%	27%	34%
Tesla	1.4%	4.3%	-25%	12%	9%
Magnificent 7 (2024) Aggregate	**31.3%**	**4.2%**	**-30%**	**46%**	**28%**
Tech Bubble Leaders (2000)					
Microsoft	4.5%	3.0%	-63%	35%	39%
Cisco Systems	4.2%	0.4%	-17%	22%	17%
Intel	3.6%	2.5%	-33%	26%	25%
Oracle	1.9%	1.0%	-61%	39%	15%
IBM	1.7%	2.7%	111%	39%	9%
Lucent	1.6%	0.9%	38%	36%	9%
Nortel Networks	1.5%	1.1%	-3%	-1%	-1%
Tech Bubble Leaders (2000) Aggregate	**19.0%**	**1.7%**	**-4%**	**28%**	**16%**

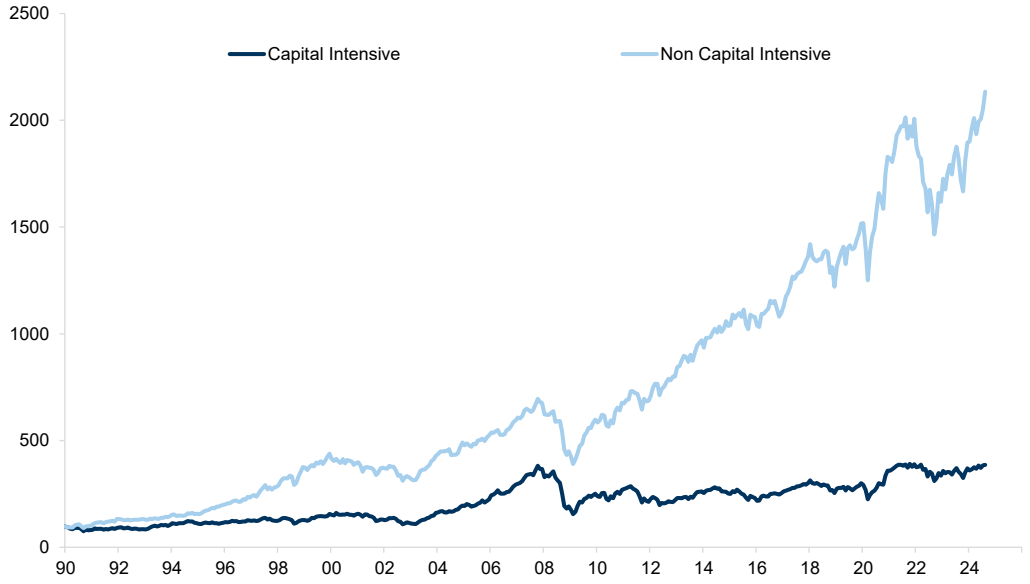
Source: Datastream, Factset, Goldman Sachs Global Investment Research

Over-investment risks

While the dominant companies may have justifiable valuations based on their current and expected cash flows, there remains a risk that they will not achieve the returns on their investment that the market currently assumes.

From the late 1990s, software and, later, cloud computing were able to be highly effective in leveraging the technologies with very high margins and low capex. The era of ultra-low interest rates following the financial crisis rewarded these business models relative to traditional industry that had very high capital invested but achieved low returns (see Exhibit 7). Most of the AI 'hyper-scalers' emerged out of these successes and have the scale and cash flows to invest. **Nevertheless, the AI winners of today are no longer capital-light businesses. Just as we saw with the networking companies of the internet, AI is driving a major capex boom and threatens to stifle the high rates of returns that have characterised the sector over the past 15 years and which current valuations imply will continue.**

Exhibit 7: Capital-light businesses have significantly outperformed those that employ heavy capital
World Capital vs. Non-Capital intensive. Price return (USD) - Capital intensity based on: Assets / Employee, Assets / Net Income, and CAPEX / Net Income.

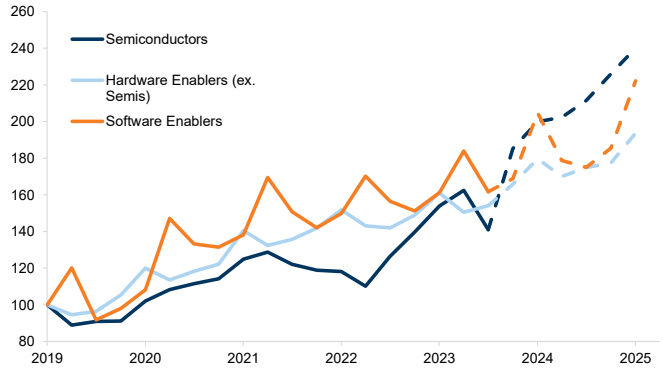


Capital-intensive: Electricity, Industrial Materials, Automobiles and Parts, Gas, Water and Multi-utilities, Industrial Metals and Mining, Telecommunications Service Providers, Leisure Goods, Construction and Materials, Oil Equipment and Services. Non-capital-intensive: Technology Hardware and Equipment, Medical Equipment and Services, Pharmaceuticals and Biotechnology, Household Goods and Home Construction, Beverages, Food Producers, Retailers, Tobacco, Software and Computer Services, Personal Goods.

Source: Datastream, Worldscope, Goldman Sachs Global Investment Research

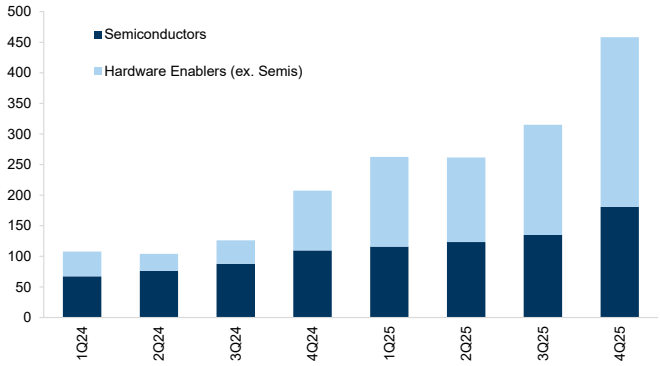
Many leading tech companies are now ramping up their spending at an extraordinary rate. According to Alphabet, spending on capex was $12bn in Q1 2024, driven 'overwhelmingly by investment in our technical infrastructure, with the largest component for servers, followed by data centers'. For the year it expects a similar run rate, so close to $50bn. A new forecast from the International Data Corporation (IDC) Worldwide Artificial Intelligence Spending Guide shows that global spending on AI, including software, hardware and services for AI-centric systems, is expected to grow at a compound annual growth rate (CAGR) of 27% over the 2022-2026 forecast with spending on AI-centric systems expected to surpass $300 billion in 2026. Nvidia has predicted that $1 trillion will be invested by 2027 in data center upgrading alone. The hyper-scalers alone now represent 23% of total S&P 500 capex and R&D.

Exhibit 8: AI investment has surged over the past several years
Global actual and forecast revenues by AI-exposed sector, 4Q2019=100



Source: FactSet, Goldman Sachs Global Investment Research

Exhibit 9: The market has significantly upgraded its AI investment expectations across the AI hardware stack
Change in consensus global revenue forecasts since March 2023, $bn, annualised

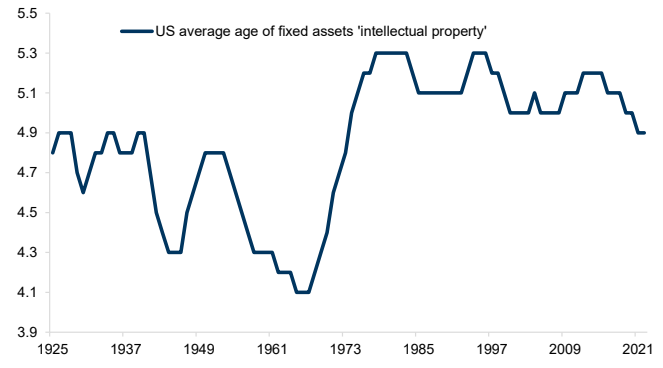


Source: FactSet, Goldman Sachs Global Investment Research

Investors have become increasingly confident about the future revenues in both semiconductors and hardware 'enablers'.

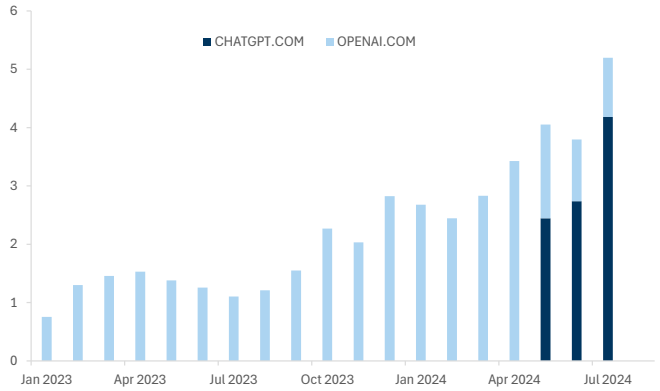
Perhaps surprisingly, despite all the capital invested in technology, there is little evidence that the age of the intellectual property assets are rising. Indeed, since the start of this century, estimates suggest the age is declining (Exhibit 10). Usage of ChatGPT has continued to grow, whether looking at numbers of visits or time spent (Exhibit 11).

Exhibit 10: US average age of fixed asset 'Intellectual Property'



Source: Datastream, Goldman Sachs Global Investment Research

Exhibit 11: ChatGPT, total minutes spent by users
openai.com (old chaptgpt website) and chatgpt.com (new website), Worldwide data on comScore (total minutes spent, in billions)



This chart replaces the one included originally in this report, which was based on number of visits rather than minutes spent, and did not include the new website data. As such, it inaccurately showed a fall-off in ChatGPT visits.

Source: comScore

The risk is that as competition increases, the returns and margins begin to fade, and the growth rates of many of the current dominant companies will likely adjust lower. Nevertheless, there are some reasons to be more hopeful that in previous technology cycles. Importantly, while capex is rising sharply, our US strategy team notes that capex relative to cash flows is less alarming. At the height of the Tech Bubble, TMT stocks were spending more than 100% of cash flows from operations (CFO) on capex and R&D. Today, the capex and R&D as a share of CFO equals 72% currently in