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# Artificial Intelligence

## Investing in AI innovation leaders

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### IN A NUTSHELL

- Recent news coverage around advancements in Generative Artificial Intelligence (Gen AI) and Large Language Models has stimulated considerable investor interest in the breadth and depth of AI to reshape our day-to-day lives.
- Artificial intelligence has the potential to add trillions to global economic growth, with broad influence across all sectors of the economy. Productivity gains are likely to be driven by gains in labour productivity, although labour displacement is also likely.
- While the AI landscape is constantly evolving, dominant AI sub-themes continue to focus on deep learning, natural language processing, image and audio recognition, big data/cloud computing, and cybersecurity.
- Aligning investments to capture AI growth can help investors participate in the transformative potential of Artificial Intelligence.

As Artificial Intelligence (AI) capabilities continue to evolve, the separation between machines and human intelligence is becoming less clear, paving the way for AI to fulfill functions traditionally limited to humans or requiring human input and oversight. Currently, advancements in generative AI are reshaping how AI can replicate human behaviour through the origination of text, image, and audio content that are increasingly indiscernible from human-generated content. Following the historical launch of OpenAI's GPT model, Google and Meta among other major technology players have followed suit with launching their own large language models ("LLMs") to the general public. These LLMs can effectively converse in human-like text, making general connections across vast knowledge domains and almost instantaneously answering queries or prompts across a broader scope than previously thought possible. And LLMs simply represent one facet of AI's potential contributions to our everyday lives and the growth and productivity potential across the global economy.

Experts believe AI growth has the potential to dramatically increase capital efficiency, with the potential to add trillions to economic growth and to shift human labour away from mundane, repetitive tasks. The collection, analysis, and even creation of data has sweeping application across economic and social landscapes. At the same time, sceptics caution against the potential unintended consequences of AI, ranging from mass unemployment and increased wealth inequality to infringement on privacy and other personal liberties. What is inarguable is the increasing importance of AI in our daily lives.

In this paper, we will explore and define the broad categories of AI, illustrating real-life examples of AI application across industries. For investors, considering the effects of AI development on the investment landscape is an important consideration to investing strategically. Aligning AI investments with specific research areas is paramount for accessing the potential investment growth opportunities in the AI space. In this paper, we will dive into the importance of corporate research and development into highly relevant AI areas and the usefulness of patent approval data as measurement of AI development for companies. We argue that while AI research and development represents a less tangible asset than, say, building a factory, developing intellectual capital in the AI space is potentially a much more meaningful contributor to future revenue and profit growth across the most significant areas of AI development.

# 1 / Introduction

## 1.1 Defining Artificial Intelligence

### What is Artificial Intelligence?

Artificial Intelligence ("AI") at its simplest definition refers to the simulation of human intelligence by machines. Human intelligence relies on our ability to not only retain information but to adapt to changing circumstances and apply knowledge to new environments. These functions roughly divide into thought processes/reasoning and behaviors. Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig[1] differentiates these functions across two axes, 1. Thinking and acting and 2. Human and ideal approaches.

Figure 1: Definitions of AI across two dimensions

| | |
|---|---|
| Think Humanly<br>"The exciting new effort to make computers think… *machines with minds*, in the full and literal sense." (Haugeland, 1985)<br>"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning…" (Bellman, 1978) | Think Rationally<br>"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)<br>"The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992) |
| Act Humanly<br>"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)<br>"The study of how to make computers do things at which, at the moment, people are doing better." (Rich and Knight, 1991) | Act Rationally<br>"Computational Intelligence is the study of the design of intelligence agents." (Poole *et al.*, 1998)<br>"AI… is concerned with intelligent behavior in artifacts." (Nilsson, 1998) |

Source: Russell, Stuart, and Peter Norvig (2010). *Artificial Intelligence: A Modern Approach (Third Edition).*

### The Turing test

Introduced by Alan Turing, the father of artificial intelligence, in 1950, the Turing test[1], originally called the imitation game, tests a machine's ability to exhibit intelligent behavior that is equivalent to, or indistinguishable from, that of a human. In practice, this test is conducted by a human evaluator who would blindly interact with both a machine and another human through conversation. The evaluator would judge the responses from both the machine and the human and try to differentiate the machine from the human. If the evaluator could not reliability identify the machine from the human, the machine is said to have passed the test.

While a machine can, in many cases, produce highly accurate or objectively correct responses in a natural language context, it has proven more complex for a machine to mimic or resemble how a human would answer a question. The release of OpenAI's ChatGPT chatbot signifies a tremendous leap forward, as a machine can refine its answers to be more human-like and, in some cases, also indistinguishable from human responses. Ex. ChatGPT relies on techniques from Natural Language Processing ("NLP"), which encompasses spoken and written language, and allows computers to understand language. According to IBM,[1] "NLP combines computational linguistics–rule-based modeling of human language–with statistical, machine learning, and deep learning models. Together, these technologies enable computers to process human language in the form of text or voice data and to 'understand' its full meaning, complete with the speaker or writer's intent and sentiment".

[1] Russell, Stuart, and Peter Norvig (2010). *Artificial Intelligence: A Modern Approach (Third Edition).*

The rapid adoption of large language models across both public and corporate use has renewed investor interest in AI as a "general purpose technology," or an innovation that has potentially broad-reaching economic impact. As with the invention of the steam engine, AI possesses the potential to touch nearly all aspect of our lives, from our consumption behaviors to the way we conduct business. At a high level, the major leap forward for AI technology revolved around the advancement in Generative AI, which can "generate" new and original text, images, and audio while requiring far less data than traditional Discriminative AI models. In a sense, Generative AI has the capacity to "imagine" new "thoughts," an ability previously thought to distinguish humas from machines.

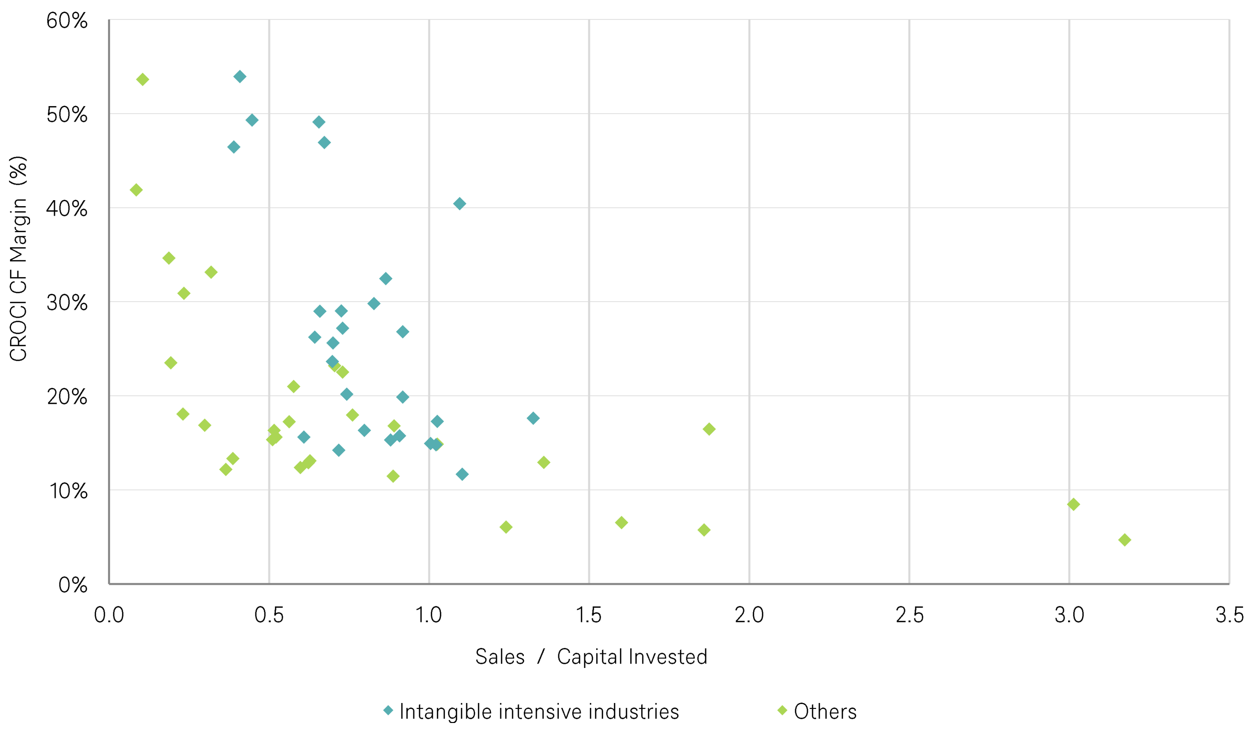
## Generative AI vs Discriminative AI

The main difference lies in their approach to learning. Generative AI learns the underlying distribution of the data, while discriminative AI focuses on learning the decision boundary that separates different classes and categories in the data. Generative models can generate new data that is similar to the input data, even if the generated data does not exist in the original dataset. Discriminative models aim to learn a mapping between the input data and the output label or class.

Generative AI produces content using deep learning algorithms, rather than analyzing or acting upon existing data. Generative AI can create a wide range of content, from written text to images and now even video. This process generally requires less data as compared to discriminative models but also generates more model bias. Gaps in data as well can be "filled" by generative models, as generative AI can be used to generate synthetic data.

One natural consequence of AI and other technological advancements is the rapid growth of capital stock as companies increasingly allocate resources toward technology and away from traditional labor. As a result, we can observe a clear link between capital stock among companies and their improved profitability. According to DWS's Cash Return on Capital Invested ("CROCI") methodology, industries where intangible assets make up more than 10 percent of capital invested have generally generated higher cash returns despite having a lower economic life of assets. This is driven by a better combination of asset productivity and cash flow margins.

Figure 2: CROCI cash return drivers of aggregations of industry group



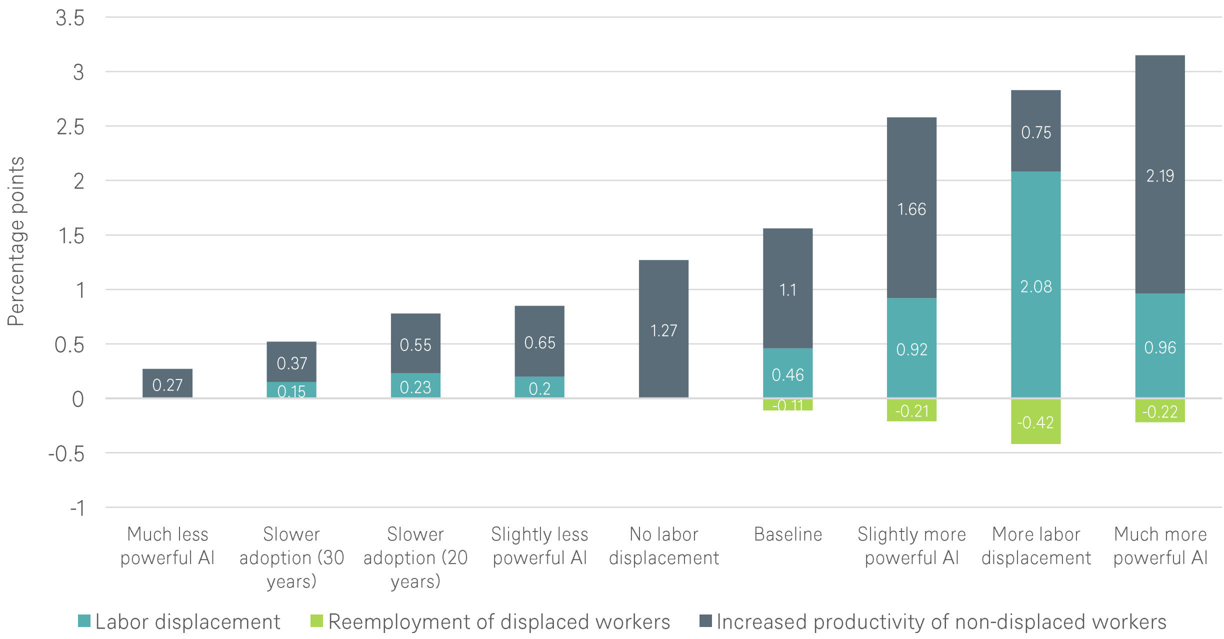

Source: DWS, CROCI. Aggregate 2024E CROCI CF Margin and Sales/Capital Invested grouped by Industry. "Intangible intensive industries" refers to industries where intangibles capitalized by CROCI account for at least 10% of total gross assets. Data as of 1/3/2024.

## 1.2 The scope of AI across businesses and the economy

### Potential impact on productivity and consumption

McKinsey predicts that AI could add roughly $13 trillion to the global economy by 2030,[2] and PwC puts this figure at nearly $16 trillion–or roughly 14% higher global GDP–over the same time frame.[3] Goldman Sachs Research predicts that generative AI alone could drive a 7%, or nearly $7 trillion increase in global GDP and lift productivity growth by 1.5 percentage points over a 10-year period.[4] The impact of generative AI on labor productivity, however, blends labor displacement with improved worker productivity, with estimates of the potential impact shown in Figure 3.

Figure 3: Effect of AI adoption on annual labor productivity growth, 10-year adoption period




Source: Goldman Sachs Research (2023). Generative AI could raise global GDP by 7%.

Labour productivity gains are likely to be concentrated in capital-intensive industries such as manufacturing and transportation given the operational and logistical opportunities for AI-led efficiency improvements, while produce enhancements and greater product and service customization should help to drive increasing consumer demand for higher quality goods and services.

The potential to increase economic growth will be realized across a number of industries. According to a McKinsey forecast from September 2019, 72% of business experts believe that AI will be the most valuable business advantage of the future. AI techniques are likely to be the most disruptive force for the technology market in the coming decades. However, traditional technology firms are not the only sectors or industries that face potential transformation with the proliferation of AI. Areas of AI expansion include but are not limited to healthcare, self-driving, virtual inventory, virtual reality, and robotics.

Within healthcare, remote patient monitoring capabilities are greatly enhanced with AI's ability to collect, analyze, and interpret thousands or patient data points a day, providing personalized healthcare management and freeing medical professionals up to focus on more complex tasks. Wearables and sensors containing AI software can improve patient outcomes, predicting issues in some cases well in advance of traditional medical monitoring and providing active monitoring that can even prevent medical issues from arising. Beyond patient monitoring and diagnostics, AI also has practical

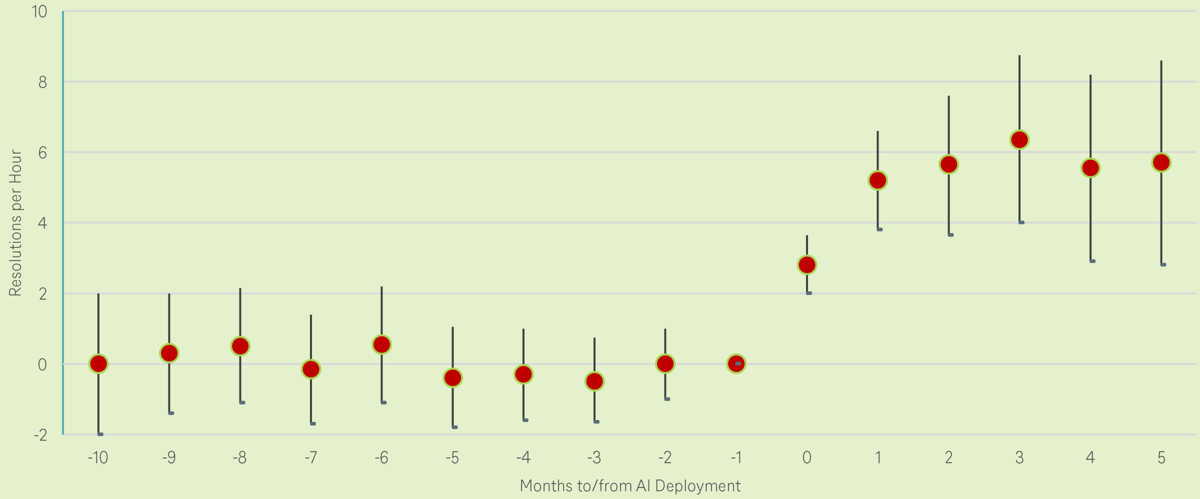
[2] PwC (2017). "Sizing the prize: What's the real value of AI for your business and how can you capitalize?"
[3] McKinsey Global Institute (2018). "Notes from the AI Frontier: Modeling the Impact of AI on the World Economy"
[4] Goldman Sachs Research (2023). "Generative AI could raise global GDP by 7%"

applications in drug development, with the Food and Drug Administration reporting 100 drug and biologic application on submissions using AI/ML opponents in 2021 alone.[5]

## Generative AI improves productivity

A study conducted by Stanford and MIT found that generative AI-based conversational assistant increased average productivity (measured by issues resolved per hour) by 14 percent on average, with the largest productivity improvement for novice and low-skilled workers. Further, the study found evidence that the AI model helps disseminate knowledge from more skilled to less skilled, newer workers, thus accelerating their move down the experience curve. Figure 4 illustrates the improvement in the complaint resolutions per hour relative to the months before and after the deployment of AI for worker training, demonstrating a sharp positive trend in the rate of complaint resolutions in the months immediately following the AI tool rollout to customer support agents.

Figure **4**: AI assistance and customer complaint resolutions




Source: Erik Brynjolfsson, Danielle Li, & Lindsey R. Raymond (2023). Generative AI at Work.

*Thin bars represent 95% confidence intervals

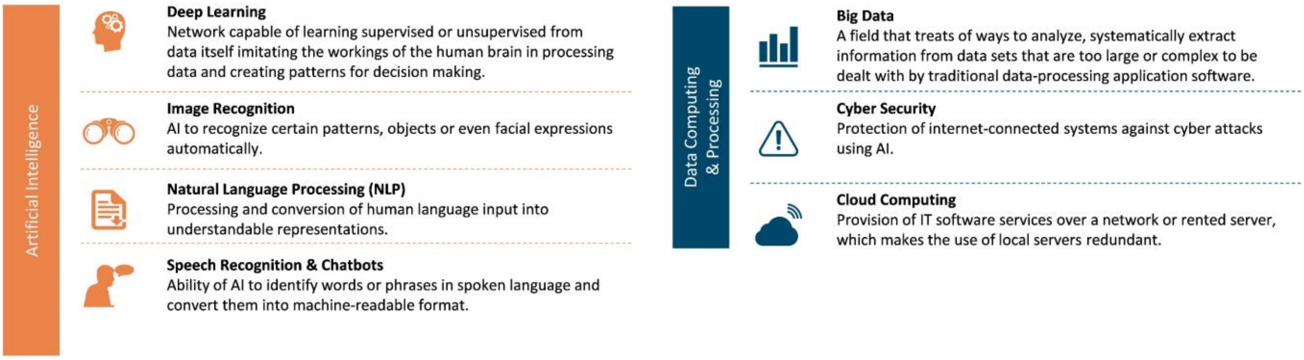
Across the manufacturing supply chain, collaborative robots allow for greater capital efficiency in producing the goods we consume. Inventory management helps to reduce the transactional costs of overstocking and understocking, and warehouse and employee monitoring can help with labour efficiency and even identify factors that help with employee training and retention. IBM finds that supply chain resiliency, accelerated time-to-value, smarter workflows, and intelligent automation will be import drivers of improvement across manufacturing supply chains in the future.[6] According to Maersk chief technology and information officer Navneet Kapoor, generative AI has progressed into more “real” projects. Kapoor states “We are using AI to build what we call a predictive cargo arrival model to improve scheduled reliability for our customers… Reliability is a big deal, even post pandemic, so they can plan their supply chain, their inventories better, and bring their costs down”.[7]

[5] U.S. Food & Drug Administration (2023). “Artificial Intelligence and Machine Learning (AI/ML) for Drug Development”
[6] IBM (2023). I”BM Supply Chain Intelligence Suite”
[7] CNBC (2023). “A.I. could ‘remove all human touchpoints’ in supply chains. Here’s what that means”

# 2 / Investing across the AI value chain

The growth potential across the AI landscape can potentially offer meaningful opportunities for investment across the value chain. While specific areas of AI application are likely to emerge and demerge over time, we can generally categorize AI investment into two broad categories: (i). Artificial intelligence and (ii). Data computing and processing. Figure 4 shows sub-themes within these two categories.

Figure 4: Investing in AI: Overview of the sub-themes

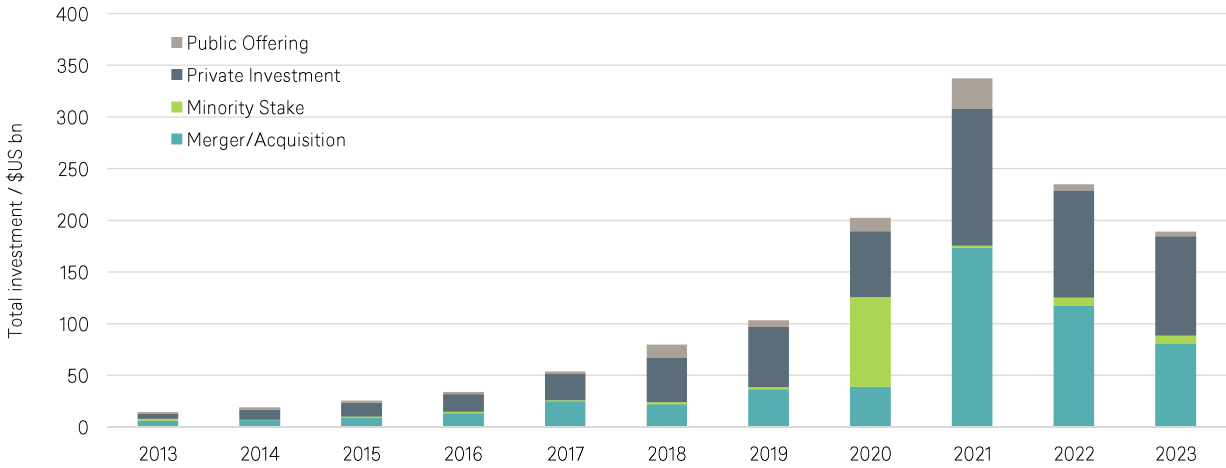



Source: DWS

## 2.1 Trends in corporate investment in Artificial Intelligence

AI, and particularly generative AI, is expected to permeate virtually every sector of the economy, promising to usher in new levels of productivity. AI is expected to rapidly grow to a $3 trillion industry in the next several years[8] and thus it has been attracting hundreds of billions in corporate investments. Figure 5 illustrates the trend in global corporate AI investment from 2013 to 2023, including mergers and acquisitions, minority stakes, private investments, and public offerings. Despite fluctuations due to economic cycles, AI continues to attract record levels of funding. Over the past decade, AI-related investments have increased thirteenfold.

Figure 5: Global corporate investment in AI by investment activity



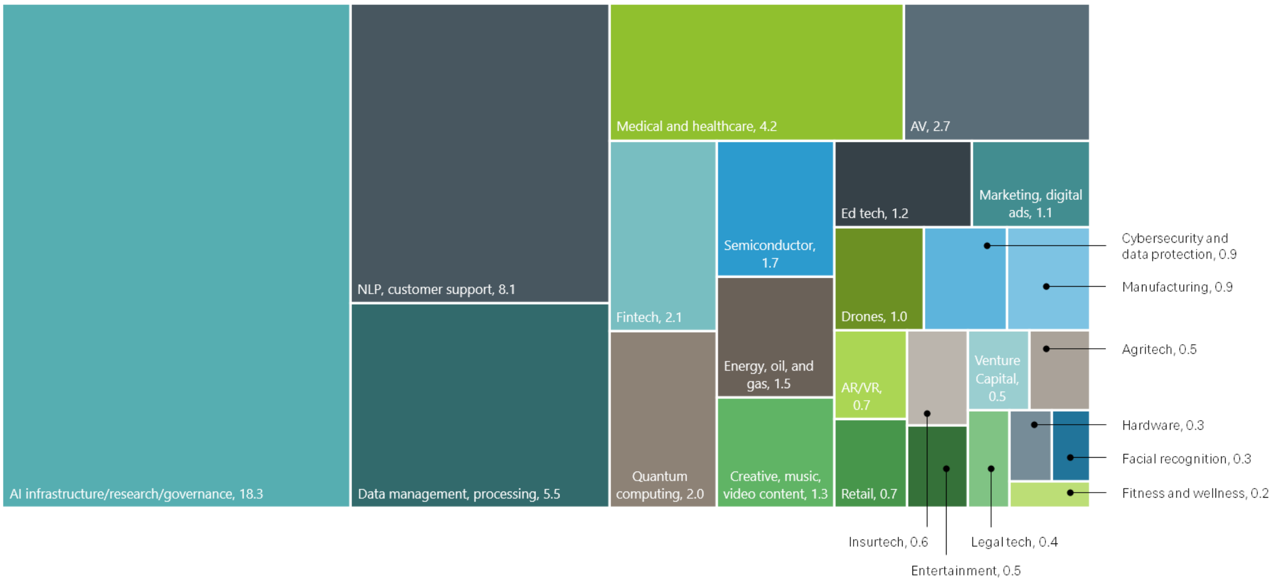

Source: The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024). "2024 AI Index Report"

[8] Morgan Stanley (December 2023). "Megatrends: How to Invest in the AI Boom"

In 2023, the total private investment into AI dropped to $189.2 billion, a decrease of approximately 20% from 2022[9] and was led by a downturn in mergers and acquisitions, which fell by around 30% from the previous year. The deceleration in AI investing can also reflect the fact that during the early part of the AI investment cycle, we saw significant investment into foundation models, which tend to be far more capital intensive than is subsequent investment into AI applications and agents.

Corporate investment into AI is directed across a wide range of emerging focus areas, Figure 6. The focus areas that attracted the most investment in 2023 were AI infrastructure/research/governance ($18.3 billion); NLP and customer support ($8.1 billion); and data management and processing ($5.5 billion). The prominence of AI infrastructure, research, and governance reflects large investments in companies specifically building AI applications, such as OpenAI, Anthropic, and Inflection AI.

Figure 6: Private investment in AI by focus area in 2023




Source: The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024) "2024 AI Index Report"
*AR/VR refers to Augmented Reality/Virtual Reality and AV refers to Audio Visual

## 2.2 Investing in AI companies

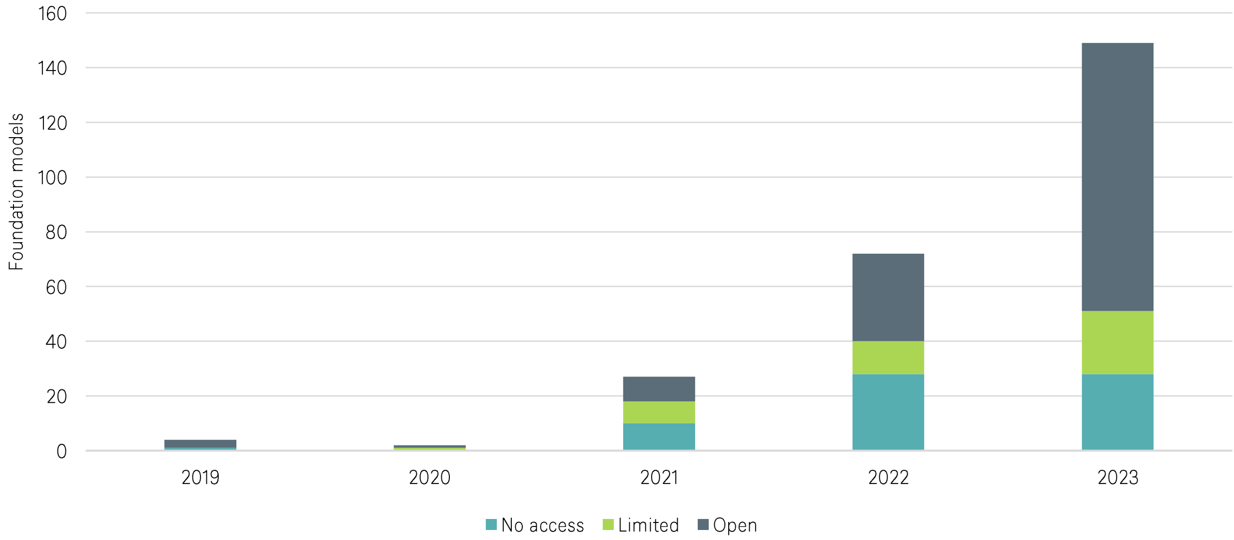
While the commercialization of AI is still in its infancy, there are different business models that have emerged. Some AI companies currently operate similarly to software firms, offering cloud-based AI tools or platforms on a subscription basis. Customers pay a recurring fee to access these services, which might include data analytics, machine learning models, or specialized applications such as natural language processing or image recognition tools. Large corporations are subscribing to more specialized expert services such as consulting, custom development, and integration services tailored to specific business needs. This can include building custom AI models, integrating AI into existing systems, or providing strategic advice on AI implementation.

One noteworthy shift in the AI landscape is toward open-source models, where in the recent years, the number of open-source AI models surpassed the number of limited and no access models. Of the 149 foundation models released in 2023, 98 were open, 23 limited and 28 no access, Figure 7. While monetizing open-source technology is not a new idea—software companies have been using the strategy for years—generative AI models are different from typical software products. Foundation AI models require large quantities of computational power and high-cost talent to develop, train and operate them at scale. The development and eventual monetization of large-scale open-source AI models requires significant capital outlay but with the eventual hope of significant return on capital invested. Considering that we're still only in the early innings

[9] The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024). "2024 AI Index Report"

of AI adoption, we expect the winners and losers among AI-focused companies to emerge in the coming years, where development of intellectual capital will be paramount to sustained success in the AI space.

Figure 7: Foundation models by access type




Source: The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024) "2024 AI Index Report".

Another avenue to investing in AI is to search for companies that use AI and thus have competitive advantages and above-average growth prospects. While many companies talk about AI (FactSet estimated that among S&P 500 companies that conducted earnings conference calls from December 15, 2023 through March 14, 2024, 179 cited the term "AI" during their earnings call for the fourth quarter. This number is well above the 5-year average of 73 and the 10-year average of 45[10]), it could appear difficult to discern the true progress of AI adoption. Besides analyzing companies' earning calls and public statements, one may need to pay attention to their business relationships, acquisitions, investments and R&D focus.

## 2.3 Data computing and processing

### The importance of data collection and security

Data collection is an essential part of the research and business processes. As digital data gathering makes up an increasing proportion of data collected, there are a few essential industries that should benefit from the exponential growth of generated data. "Big data", as it's often called, refers to data sets that are too large or too complex for traditional data-processing applications, thus necessitating developments in data capture, storage, and validation. As AI models become increasingly complex and able to solve substantially more difficult problems, effective collection and quantifying of large pools of data becomes increasingly essential to expand AI capabilities. As Barry Smyth, Professor Computer Science at University College London said so eloquently, "Data is to AI what food is to humans."

While the collection of data is the main area of focus for many investors, secure and accurate data aggregation requires the ongoing development of essential hardware and software as well as the maintenance of strong cybersecurity and data protection networks. These other areas of data collection are critical to the collection, validation, and security of the "food" that AI "consumes" and translates into practical use cases that mimic and approve upon human intelligence.

One of the biggest challenges to deploying and scaling AI is ensuring the data being used to train AI algorithms is of high quality. Using inaccurate or not timely data hampers AI models' ability to predict future trends and make meaningful business decisions. A PricewaterhouseCoopers survey[11] found that while 76% of companies plan to extract value from the data they already have, only 15% said they currently have the right kind of data needed to achieve that goal. Non-tech companies are especially lagging

[10] FactSet (March 2024) "Second highest number of S&P 500 companies siting "AI" on earnings calls over the past 10 years"
[11] PWC (2019) "Trusted data optimization pulse survey"

in terms of data quality, but new tools can help get them up to speed. A growing range of hard- and software for data collection (e.g., computer vision, sensors, natural language understanding or "NLU") can drive significant improvements in the data quality companies require to scale their AI model use.

As data becomes a core component of AI operations, the importance of cybersecurity escalates. The utility of data versus the right to personal privacy is one of the biggest balancing acts faced by the companies. For example, there is tremendous value in using personal data such as health indicators or geolocation tracking for understanding market trends. But many people have a legitimate desire and right to not be tracked. Companies that work with data typically promise that it is anonymized before aggregation, but not all companies have the same data protection standards and cybersecurity to protect individual user privacy. At the same time, cybersecurity can be enhanced using AI-powered solutions by accelerating threat detection, expediting responses, and protecting user identity and datasets.

## AI and data consumption

There are two types of data that are important for AI development and application: human-generated data and machine-generated data. Human-generated data is data that is created by people through human action and can include anything from text data to social media posts to pictures and videos. Human-generated data remains one of the fastest growing and most valuable sources of information for businesses and tech developers.

Human-generated data in the form of images and video is unstructured data and remain challenging for organizations to utilize due to the complexity of building and maintaining cutting-edge algorithms. There are companies that work on unlocking the ability to extract insights from images and video. There are also companies that are specializing exclusively on a particular set of data, for example, geospatial data.

Machine-generated data is data generated by all the systems running in data centers, the Internet of things (IoT) and by connected devices. It consists of all data generated by the applications, servers, network devices, security devices and remote infrastructure as well as through sensors in warehouses, manufacturing devices, and robotics.

Recently, there have been rising concerns if AI models can run out of data to further scale and improve their systems. Indeed, a significant proportion of recent algorithmic progress, including progress behind powerful LLMs, has been achieved by training models on increasingly larger amounts of data. It has been noted that foundation models have been trained on meaningful percentages of all the data that has ever existed on the internet. Research from Epoch[12] suggests that these concerns are somewhat warranted. Epoch researchers have generated historical and compute-based projections for when AI researchers might expect to run out of data. They estimated that computer scientists could deplete the stock of high-quality language data by 2024, exhaust low quality language data within two decades, and use up image data by the late 2030s to mid-2040s. Theoretically, the challenge of limited data availability can be addressed by using synthetic data, which is data generated by AI models themselves. For example, it is possible to use text produced by one LLM to train another LLM. However, recent research has suggested that there are limitations associated with training models on synthetic data.

To process massive amounts of data quickly AI systems need access to constantly increasing computing power, often provided by cloud computing platforms. AI models, particularly those involving deep learning, require substantial computational power, which can be expensive and complex to manage on-premises. Cloud computing offers AI systems scalability and flexibility, allowing for the adjustment of resources as needed without the need for significant capital investment in hardware.

As in the case of big data and cybersecurity, there is a symbiotic relationship between AI and cloud computing that is pivotal for advancing both technologies and their applications across various industries. AI can optimize the management of cloud resources through automation, making cloud platforms more efficient. For example, AI algorithms can predict workload patterns, automate scaling decisions, and manage resources dynamically, ensuring that applications receive the necessary resources without over-provisioning. This can lead to significant cost savings and improved performance. AI can also enhance security of cloud platforms, improve data management, and help to automate IT operations.

[12] Epoch AI. "Will We Run Out of ML Data? Evidence From Projecting Dataset Size Trends"

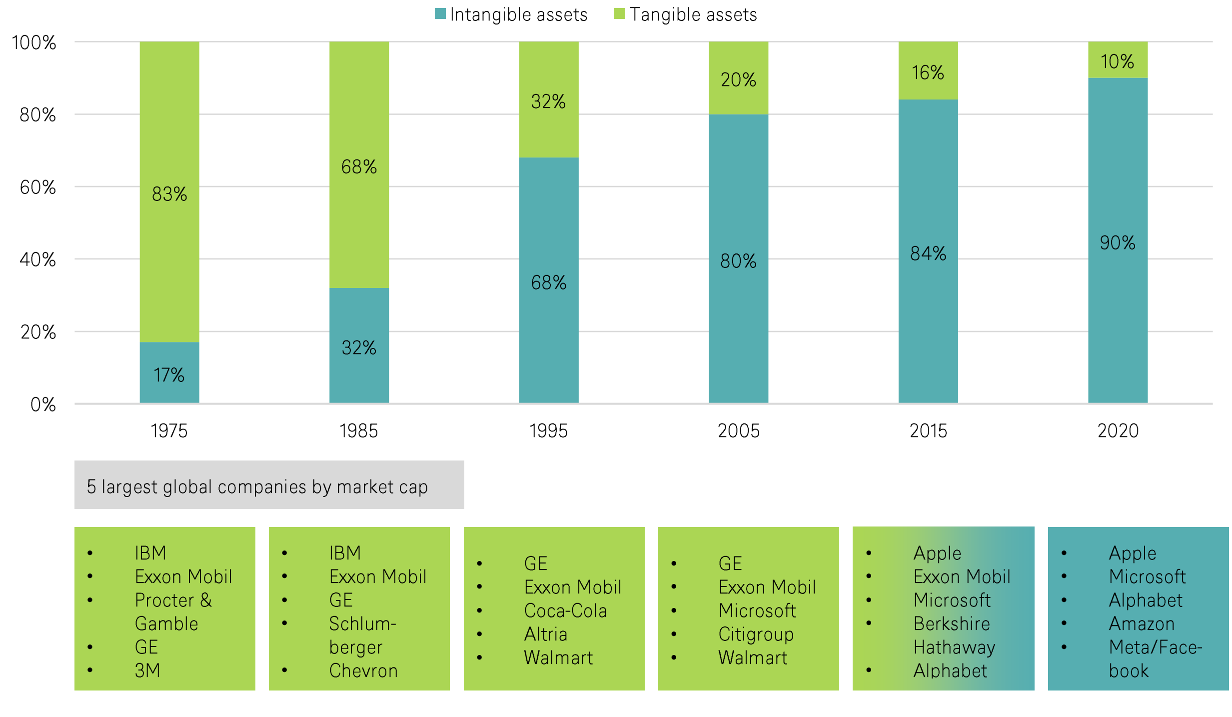
# 3 / Identifying innovation leaders

In such a relatively nascent and rapidly developing area as Artificial Intelligence, picking winners and losers is not a trivial task for investors. Traditional valuation metrics may not provide particularly useful signals, while companies' claims on the efficacy of their AI integration are difficult to judge without concrete details or supporting data. One way to sieve through this ambiguity is to measure a company's spend on the research and implementation of AI or measure the outcome of these efforts through publicly available information such as the intellectual property (IP) generated. In this section, we discuss why applying the research and innovation lens to the investment process may be a suitable approach to AI investing. We also look across the AI patent landscape to gauge where the AI innovation has been concentrating.

## 3.1 Shift towards innovation-based economy

In the current, more intellectual capital-based economy, intangible assets, such as intellectual property, research, technology, and human capital appear to be the new drivers of value, in contrast to the tangible assets such as land, buildings, machinery, and inventory, which were used historically to assess companies' value. In fact, Ocean Tomo, an IP-focused consultant, conducted a study of the S&P 500 and found that in 1975 the value of intangible assets as a percent of the S&P 500 value was only 17%, while tangible assets made up the other 83%. With the shift to our innovation-based economy of today, this has flipped. In 2020 intangible assets commanded 90% of the S&P 500 market value. The trend becomes increasingly clear when looking at the shift in leadership of technology-focused companies which now constitute the largest companies in the world, Figure 8.

Figure 8: Components of S&P 500 market value



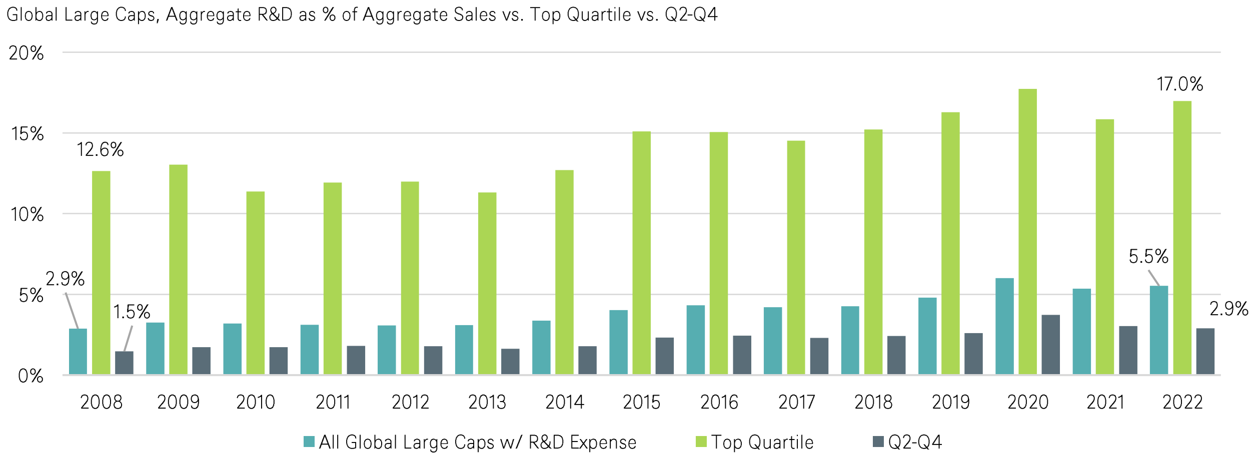

Source: Intangible asset market study, Ocean Tomo, 2020; S&P; DWS.
This information is intended for informational purposes only and does not constitute investment advice, a recommendation, an offer or solicitation.

## 3.2 R&D leaders outperform laggards and non-spenders

To identify innovation leaders, we can analyze trends in research & development (R&D) spending or gauge the effectiveness of this spending by tracking patents (filed or granted) or even patent-forward citations. While patents in AI, where an increasing proportion of research efforts are shifting toward open-source models, may not precisely measure the value of IP going forward, patents can be categorized in a far more precise way that general R&D spending and can also give a broad sense of the "track record" of R&D spending as it translates into tangible products and services.

Figure 9 shows R&D spending across Nasdaq Global Large Cap Index universe of companies between 2008 and 2022 (only the companies with some level of reported R&D were included in the analysis, in 2022: 438 reported out of 1,194 companies) Firstly, we can see that annual R&D as % of Sales has steadily grown from ~3% in 2008 to ~5-6% in recent years among this group. Total R&D across global large caps is up from $342B in 2008 to $916B in 2022. Secondly, the Top Quartile of R&D spenders reinvest ~5-6x more as a % of Sales vs. Quartiles 2/3/4. The Top Quartile has increased R&D from ~12-13% of Sales to ~16-18% in recent years, while the rest of R&D spenders (Quartiles 2/3/4) have increased from ~1.5% to ~3-4%.

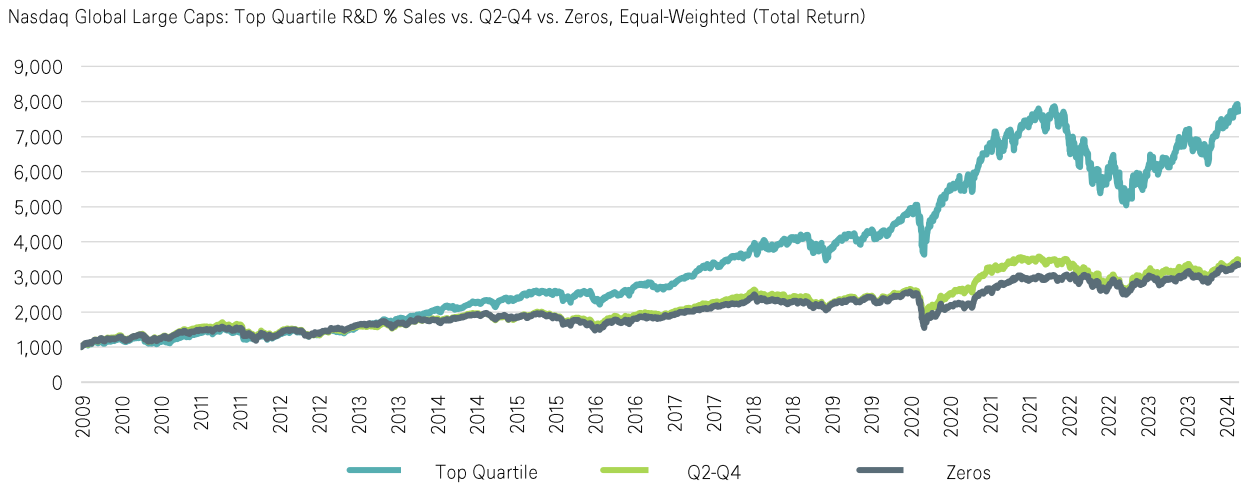
### Figure 9: R&D spending among global large caps




Source: Nasdaq, Factset as of 3/19/2024. Index data as of each year-end from 12/31/2008 to 12/30/2022.

Figure 10 shows Sales growth for the companies across quartiles of R&D spending. Top Quartile companies have realized faster Sales growth compared to R&D laggards (+107% since 2008 vs. +30% for Quartiles 2/3/4). Interestingly, R&D laggards (Quartiles 2/3/4) did not experience higher sales growth as compared to companies with zero R&D expense (Zeros).

### Figure 10: R&D leaders outperform laggards and non-spenders




Source: Source: Nasdaq, Factset as of 3/19/2024. Index data as of each year-end from 12/31/2008 to 12/30/2022.
Companies are ranked on prior full-year R&D expense as % of Sales on a 6-month lag (June 30) to allow for disclosure of reported financials. Baskets rebalanced annually 3rd Friday of July.
*Top quartile refers to the top 25% of companies in terms of R&D spending where Zero refers to companies with zero R&D expense. Equal weighted shows the portfolio where all stocks have the same starting percentage weight.

## 3.3 Patents in AI

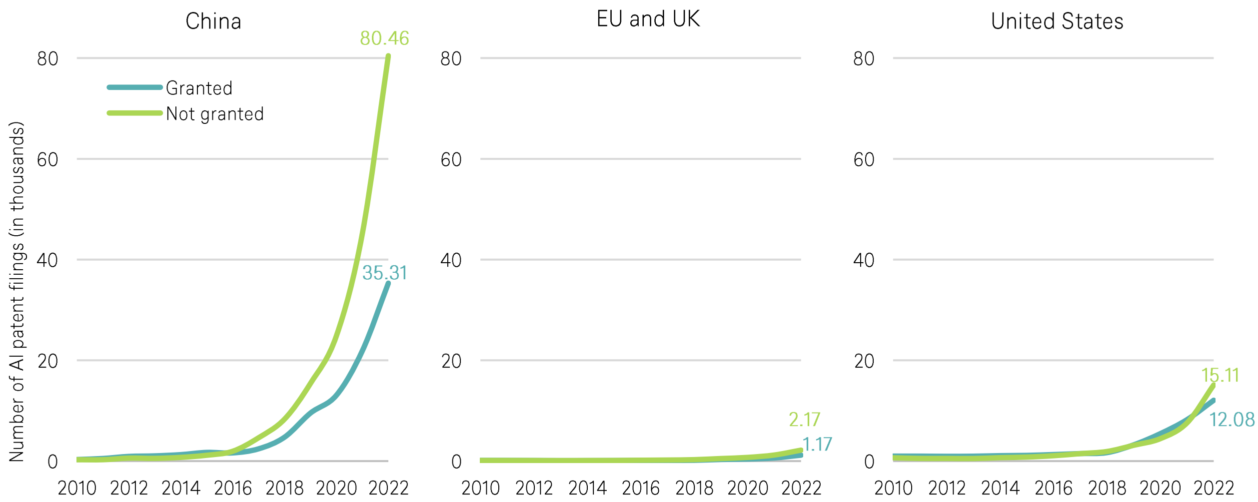
One way to gauge the effectiveness of companies' R&D spend is to look at intellectual property, such as patents, generated by companies. In some areas such as pharmaceuticals, assessing a patent value via a number of quantitative methods is a common practice. In contrast, in rapidly developing software and tech, assigning a concrete monetary value to each piece of IP is less common. However, patents still serve as a good indicator of companies' commitment to remain at the frontier of research and innovation and can be analyzed to identify specific areas of R&D focus within and across technology areas such as AI.

The dynamic nature of AI industry can be seen from the trends in patent origination (geography and industry vs academia). Over the last decade, there has been a significant rise in the number of AI patents, with a particularly sharp increase in recent years. Since 2010, the number of granted AI patents has increased more than 31 times, and from 2021 to 2022 by more than 60%.[13]

China dominates AI patents. In 2022, China led global AI patent origins with 61%, significantly outpacing the United States, Figure 11. The share of AI patents originating from the United States has declined from 54% in 2010 to 21% in 2022.

Industry races ahead of academia. Until 2014, most significant machine learning models were released by academia. Since then, industry has taken over. In 2022, there were 32 significant industry-produced machine learning models compared to just three produced by academia. Building state-of-the-art AI systems increasingly requires large amounts of data, computer power, and money—resources that industry actors inherently possess in greater amounts compared to nonprofits and academia.

**Figure 11: AI patents by application status by geographic area**




Source: The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024) "2024 AI Index Report"

[13] The Stanford Institute for Human-Centered Artificial Intelligence (HAI) (2024) "2024 AI Index Report"

# 4 / Conclusion and outlook

*The development of AI is as fundamental as the creation of the microprocessor, the personal computer, the Internet, and the mobile phone. It will change the way people work, learn, travel, get health care, and communicate with each other. Entire industries will reorient around it. Businesses will distinguish themselves by how well they use it.*

-Bill Gates

Artificial intelligence is perhaps the most important technological trend of this century, with the potential to add trillions to global economic growth and to transform the way companies conduct business. The capabilities of AI to sense, comprehend, and act are transformative to operations across all sectors of the economy, and most experts already agree that AI will be the most valuable business advantage of the future.

It is important to recognize that we are still in the early innings of AI adoption which present both potentially compelling opportunities and notable challenges for investors and industries alike. As AI technologies mature and new capabilities are developed, we can expect a surge in AI integration into business processes, consumer products, and large-scale industrial systems. This expansion is likely to spur a wave of new businesses and business models, akin to the growth seen with the advent of the internet.

At the same time, the rapid development of AI comes with unpredictability. The technologies that are leading today may be superseded by more advanced innovations tomorrow. Additionally, regulatory and ethical frameworks surrounding AI are still developing, which could lead to shifts in how AI can be used and commercialized. Investors and companies must navigate these uncertainties carefully, balancing the pursuit of innovation with awareness of potential regulatory changes and societal impacts.

What we can be certain of is the unavoidable impact that artificial intelligence will bear in transforming industries over the coming decades. AI will play an integral role in reshaping the way that we operate day-to-day, with significant implications for corporate profitability. By aligning investments to capture the changing landscape for the AI megatrend, investors can participate in this tremendous growth and ensure they do not miss out on the transformative potential of AI, which is likely to reshape entire industries, drive innovation and shape the future of our interconnected world.

As the AI landscape evolves, the gulf between leaders and laggards will naturally grow. Empirical evidence suggests that significant performance differentiation between innovation leaders in terms of R&D spending and laggards, the latter of whom have demonstrated little differentiation versus AI non-investors. Capturing AI leadership relies on properly identifying and aligning to companies with a strong track record of developing AI intellectual capital.

# Glossary

Anthropic: Is a U.S.-based artificial intelligence startup public-benefit company, founded in 2021. Anthropic has developed a family of large language models (LLMs) named Claude as a competitor to OpenAI's ChatGPT and Google's Gemini.

Artificial Intelligence (AI): Is the theory and development of computer systems able to perform task normally requiring human intelligence.

Big data: Refers to the large data sets that can be studied to reveal patterns and trends to support business decisions. It's called "big" data because organizations can now gather massive amounts of complex data using data collection tools and systems.

ChatGPT: A large-scale AI language model developed by OpenAI that generates human-like text.

Data mining: Is the process of sorting through large data sets to identify patterns that can improve models or solve problems.

Deep Learning: A subfield of machine learning that focuses on training neural networks with many layers, enabling learning of complex patterns.

FactSet Research Systems Inc. is an American financial data company that provides integrated data and software.

Foundation Models: Large AI models trained on broad data, meant to be adapted for specific tasks.

Generative AI: A branch of AI focused on creating models that can generate new and original content, such as images, music, or text, based on patterns and examples from existing data.

Image recognition: Is the process of identifying an object, person, place, or text in an image or video.

Inflection AI: Is a technology company which has developed a machine learning and generative artificial intelligence hardware and apps, founded in 2022. The first product released widely by Inflection AI is a chatbot, Pi, named for "personal intelligence," that is intended to function as an artificial intelligence-based personal assistant.

Internet of Things (IofT): Refers to a network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity. These devices collect and share data with each other and other systems over the Internet or communication networks.

Large Cap: refers to a company with a large market capitalization value relative to other publicly traded companies.

Large Language Model (LLM): A type of AI model that can comprehend and generate human-like text and is trained on a broad dataset.

Machine Learning: A type of artificial intelligence that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

Nasdaq Global Large Cap Index is a float adjusted market capitalization index designed to track the performance of securities in NASDAQ Global Market Index that comprise the Large-cap segment of companies.

Natural language processing (NLP): Is a subset of artificial intelligence, computer science, and linguistics focused on making human communication, such as speech and text, comprehensible to computers.

Natural language understanding (NLU): is a field of computer science that analyzes human language meaning.

OpenAI: Is an American artificial intelligence research organization founded in December 2015 and headquartered in San Francisco. OpenAI has developed several large language models, advanced image generation models, and previously, released open-source models. Its release of ChatGPT has been credited with catalyzing widespread interest in AI.

Research and Development (R&D): refers to a company's expenses directly associated with the research and development of a company's goods or services or related intellectual property.

S&P 500: An index that includes 500 leading U.S. companies capturing approximately 80% coverage of available U.S.

Turing test: The Turing test was created by computer scientist Alan Turing to evaluate a machine's ability to exhibit intelligence equal to humans, especially in language and behavior. When facilitating the test, a human evaluator judges conversations between a human and machine. If the evaluator cannot distinguish between responses, then the machine passes the Turing test.

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