CIO Vantage Point

Into the AI Frontier.

The Intelligent Future

ChatGPT, alongside other generative AI prototypes, has gotten the world abuzz with the endless possibilities of how AI can reshape human enterprise.

Promise of Efficiency and Innovation

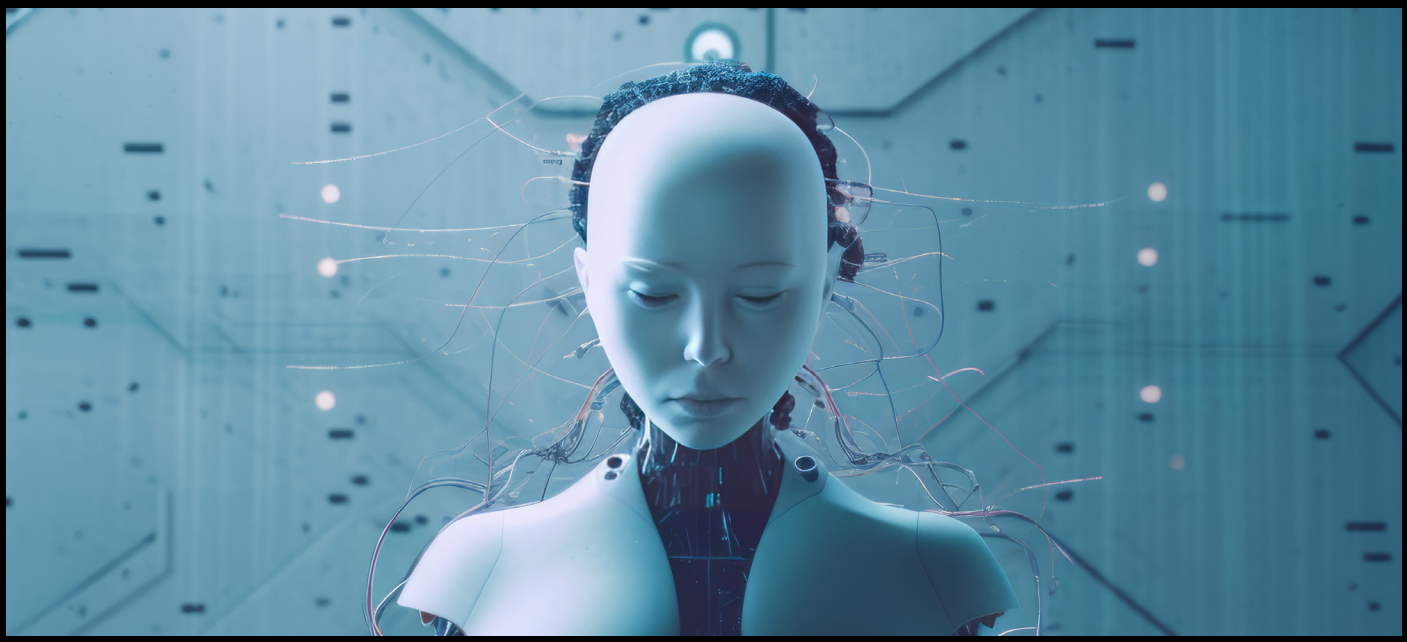
AI is set to revolutionise industries, economies, and processes, birthing new jobs and solutions to some of the world's biggest problems.

Counting the Costs

In breaking new ground, challenges around AI include ethical considerations, job displacement, and a new age of misinformation.

Beneficiaries of the AI Revolution

AI optimism will fuel the tech rally; Big Tech, Cloud Systems, Hardware Manufacturers, and Cybersecurity will be long-term winners of the irreversible AI trend.



DBS

CONTENT

FOREWORD

We stand at the cusp of an AI-driven revolution. What was once science fiction is now a tangible force transforming the world we live in.

AI will present a new realm of possibilities and perils, and a bifurcation of winners and losers among companies across all industries, as the transformative power of AI upends business models.

Despite initial displacements, AI, as in past technological innovations, will drive productivity gains and new employment growth over a longer time horizon. According to McKinsey, AI could potentially deliver additional economic output of some USD13 trillion between 2018-2030, amounting to 16% of global output.

In this CIO Vantage Point, we also identify four major investment themes that would emerge as beneficiaries of this revolution, namely Big Tech, Hardware Manufacturers, Cloud Platforms, and Cybersecurity.

I hope you enjoy the read.

Hou Wey Fook, CFA
Chief Investment Officer

SNAPSHOT

Interest in AI has exploded following the release of ChatGPT and its rapid uptake. With groundbreaking disruption coming at breakneck speed, we believe there is no better time to start preparing for the future of AI than now. We cut through buzzwords, hype, and hyperbole surrounding the AI craze to decipher what it means, and how investors can benefit from this development.

A NEW FUTURE SHAPED BY AI

The latest progress in AI development is transformative, with generative AI models performing multiple tasks, including seemingly creative ones.

DIGGING INTO THE AI TOOLBOX

Generative AI has shown uncanny proficiency in content creation across images, language, coding, and biochemistry, while Cognitive AI is set to elevate technology's potential to replicate humans to the next level.

TWO SIDES OF THE AI COIN

AI's disruption raises concerns on the concentration of power and the displacement of labour; on the flipside, mankind stands to gain productivity, new jobs, and solutions to chronic problems.

BIG TECH, BIG WALLETS

Big Tech is heavily investing in AI and has featured prominently in recent AI-related acquisitions. Network effects and their wealth of resources suggest a "winners-take-all" dynamic benefitting technology leaders.

INTEGRATED CIRCUITS, THE KEY ENABLER

The need to process training data and power data centres will benefit chip designers and semiconductor foundries. An explosion of AI-generated content will necessitate ever-increasing bandwidth and cloud hosting space.

CYBERSECURITY AS FIRST LINE OF DEFENCE

Heavy demand for cybersecurity across all platforms, driven by the proliferation of deepfakes, the rise of misinformation, and the malicious misuse of AI .

1

AI's coming of age

In 1950, Alan Turing – the founding father of modern cognitive science – devised the "Turing test" to evaluate a machine's ability to exhibit intelligent behaviour. For more than 70 years, this remained within the realm of science fiction; but today, Artificial Intelligence (AI) has finally made its definitive transition into reality. 2022 would be remembered as the year that machines successfully conquered Turing's imitation game – with (i) Google's LaMDA being claimed to be "sentient" by one of its engineers, and (ii) OpenAI's ChatGPT taking the world by storm with its human-like natural language outputs.

AI WAS A ONE-TRICK PONY IN ITS PAST.

The term "AI" was first coined half a century ago by American computer scientist John McCarthy – referring to the simulation of human intelligence in machines through programmable algorithms and software. Since then, our world has seen an explosion in AI successfully analysing large amounts of data, making fast calculations, and predicting outcomes with a high degree of accuracy. However, most AI models have only been good at performing just the specific tasks they were trained to do. They hardly exhibited the "intelligence" needed to compete with humans, especially in the creative realm.

'ALWAYS INVENTING, INVENTING, INVENTING': JOHN MCCARTHY AT WORK IN HIS ARTIFICIAL INTELLIGENCE LABORATORY AT STANFORD

John McCarthy, professor of computer science in the artificial intelligence lab at Stanford in 1974. | Photo by Chuck Painter

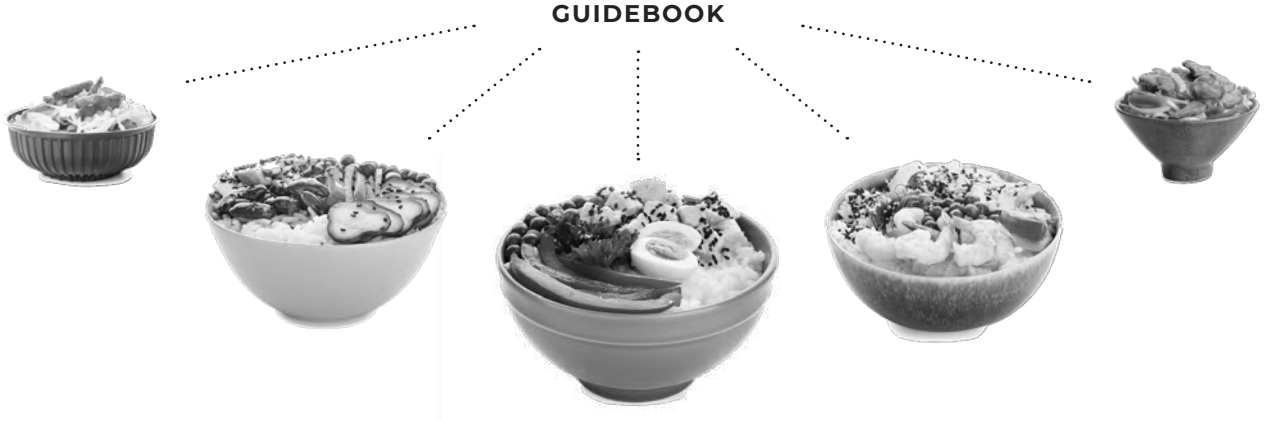
**THE NEXT WAVE OF AI:
FOUNDATION MODELS TRANSCENDING
TASK-SPECIFIC AI**

Traditional AI undergoes supervised learning -

It is trained using specific data for specific tasks and needs to be re-trained for each new task, much like needing a new recipe every time you cook a new dish.

Foundation models present a breakthrough -

A single model undergoes unsupervised/self-supervised learning – It is trained using broad unstructured data to perform multiple tasks beyond what it was trained to do. This can be likened to how a trained cook can use his or her skills to prepare different dishes beyond just following instructions on a recipe.



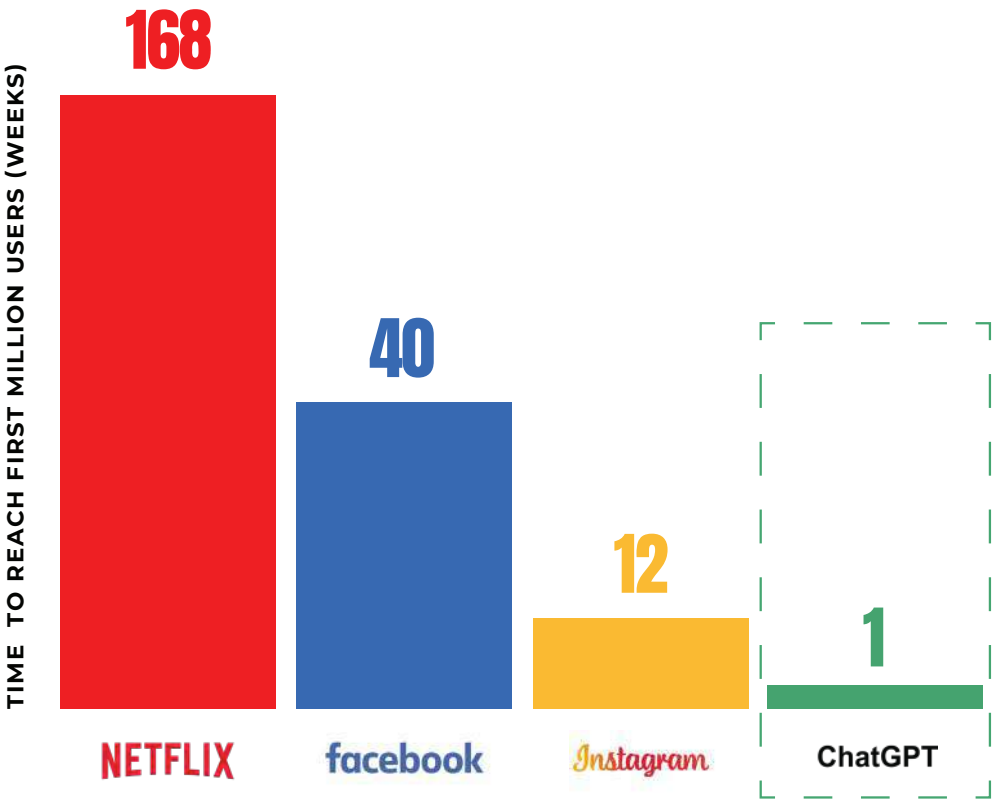
Source: DBS

A NEW WAVE OF AI.

The latest progress in AI development, however, looks set to bring AI beyond the task-specific models that have dominated the landscape to date. For example, using foundation models that are trained on a broad set of unstructured data, generative AI models can perform multiple tasks beyond what they are explicitly trained to do, and even seemingly exhibit their own creativity – marking a great leap forward in AI advancement. To gauge how momentous this development is, one has to look no further than the speed at which ChatGPT took the world by storm, reaching a landmark one million users just five days after its launch.

ChatGPT, alongside other generative AI prototypes, has gotten the world abuzz with the endless possibilities of how this technology can reshape human enterprise.

FACEBOOK TOOK NEARLY A YEAR TO DO WHAT CHATGPT ACHIEVED IN ONE WEEK



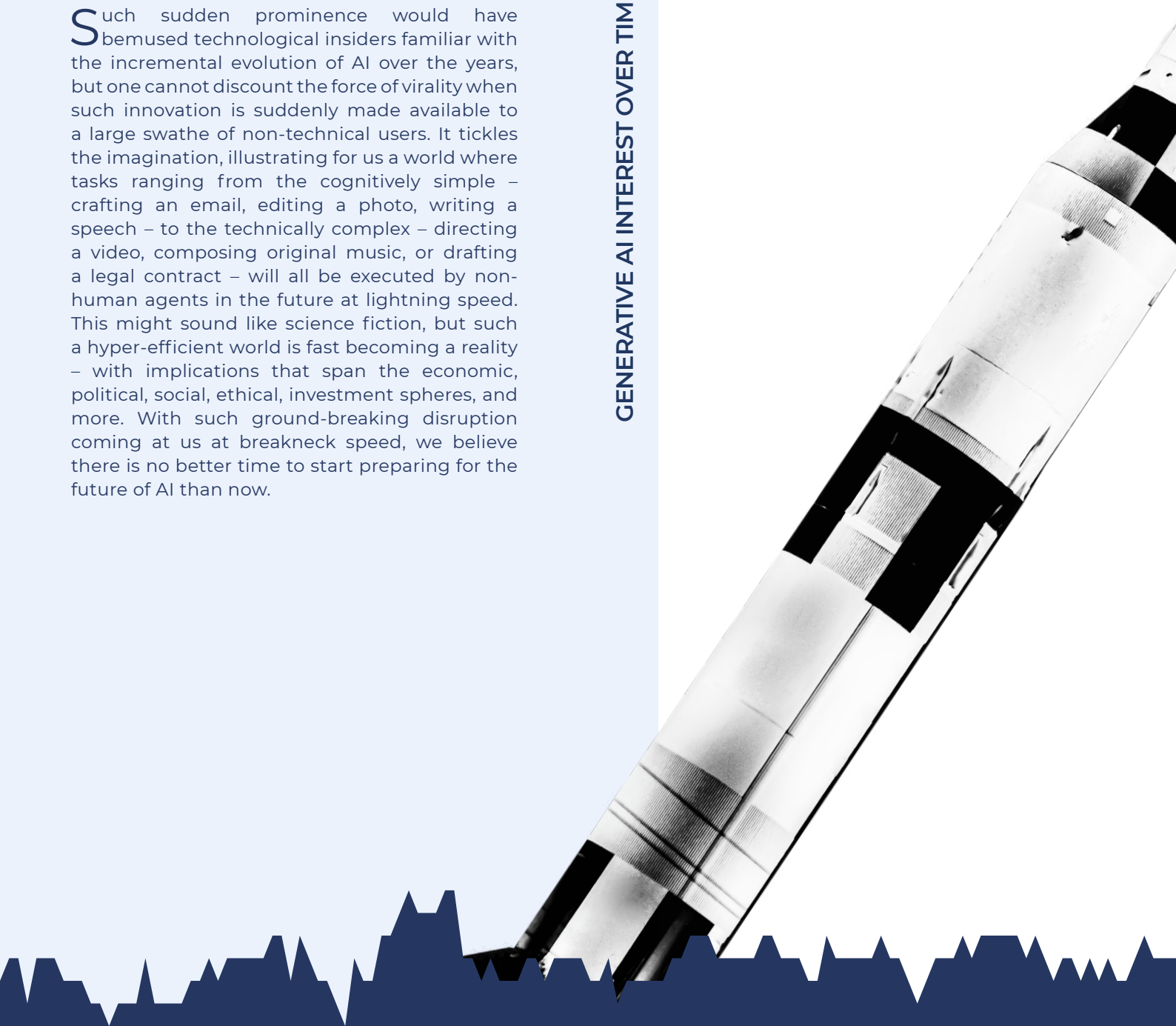
Source: DBS, Netflix, Meta, OpenAI

AI's Future Charged by Superhuman Outsourcing

Such sudden prominence would have bemused technological insiders familiar with the incremental evolution of AI over the years, but one cannot discount the force of virality when such innovation is suddenly made available to a large swathe of non-technical users. It tickles the imagination, illustrating for us a world where tasks ranging from the cognitively simple – crafting an email, editing a photo, writing a speech – to the technically complex – directing a video, composing original music, or drafting a legal contract – will all be executed by non-human agents in the future at lightning speed. This might sound like science fiction, but such a hyper-efficient world is fast becoming a reality – with implications that span the economic, political, social, ethical, investment spheres, and more. With such ground-breaking disruption coming at us at breakneck speed, we believe there is no better time to start preparing for the future of AI than now.

Interest in generative AI has skyrocketed

GENERATIVE AI INTEREST OVER TIME*



Apr 2021

Apr 2022

JAN 2023

Microsoft announces plan to invest USD10b in OpenAI

NOV 2022

OpenAI launches ChatGPT

AUG 2022

Stability AI launches Stable Diffusion

JUNE 2022

Google engineer suspended after claiming AI chatbot LaMDA has become sentient

MARCH 2021

AI announcements from tech giants such as Meta, Microsoft, Nvidia, IBM

*** Interest over time represents search interest relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term**

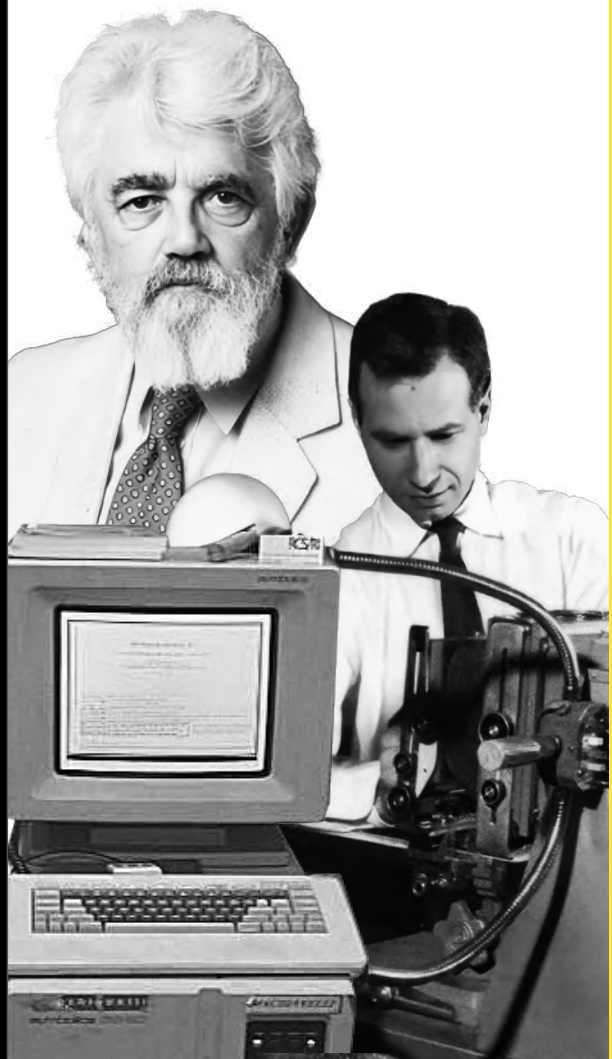
Source: iStock, Google Trends, DBS

Milestones in AI

1950

ORIGINS OF AI

Alan Turing recognised the potential for machines to exhibit intelligence and proposed “The Turing Test”



1956

JOHN MCCARTHY COINS THE TERM “AI”

Dartmouth Conference launched AI as a multidisciplinary field of study

1970

-1980s

FIRST AI WINTER

Development efforts yielded limited results, leading to a decrease in funding and stagnation for AI

1980

EMERGENCE OF EXPERT SYSTEMS

Resurgence in popularity of AI with the advent of expert systems which enabled machines to make decisions

1997

IBM’S DEEP BLUE DEFEATS GARY KASPAROV IN CHESS

Source : John McCarthy, an American computer scientist, Mark I Perceptron, Symbolics3640 via Flickr, Stan Honda/AFP via Getty Images, DBS

2011

APPLE INTRODUCES SIRI

Breakthrough in advanced speech recognition software with one of the first AI-based virtual assistants

2017

ALPHAGO BEATS TOP RANKED GO PLAYER

Using machine learning technology, AI was able to develop intricate strategies and defeat professional Go player, Ke Jie

2018

EU ESTABLISHES AI ETHICAL GUIDELINES

Now

RISE OF GENERATIVE AI

ChatGPT takes the world by storm, portraying the unlimited possibilities of AI

Source : CHATGPT, European Commission, Go Player Ke Jie via Getty Images, Unsplash, DBS

Understanding the AI 'toolbox'

To better understand AI, it is crucial to look at the various subfields that form the building blocks of the discipline. Some AI subfields and their functions include:

Machine Learning: Machine learning is a subfield of AI that allows computers to learn without being explicitly programmed. Machines running statistical algorithms are fed large amounts of data to be trained on. These machines are then used to identify patterns and make predictions or decisions. This subfield is most crucial as it allows machines to evolve continuously and it is hence used in most applications. Examples include product recommendations, image and speech recognition, and fraud detection.

Natural Language Processing (NLP): NLP focuses on enabling machines and software to understand and interpret human language. NLP allows people to interact with AI applications using natural languages like English instead of technical code. This opens unlimited possibilities for a much wider audience to use AI. Applications like chatbots, virtual assistants, and language translation are made possible thanks to NLP.

Computer Vision: Computer vision is the ability for machines to interpret and understand visuals such as images and videos. This involves programming machines to emulate the way humans see and perceive images. Each image captured by the machine will be compared against its database, allowing it to distinguish one image from another. Computer vision is widely used in applications such as autonomous driving and facial recognition.

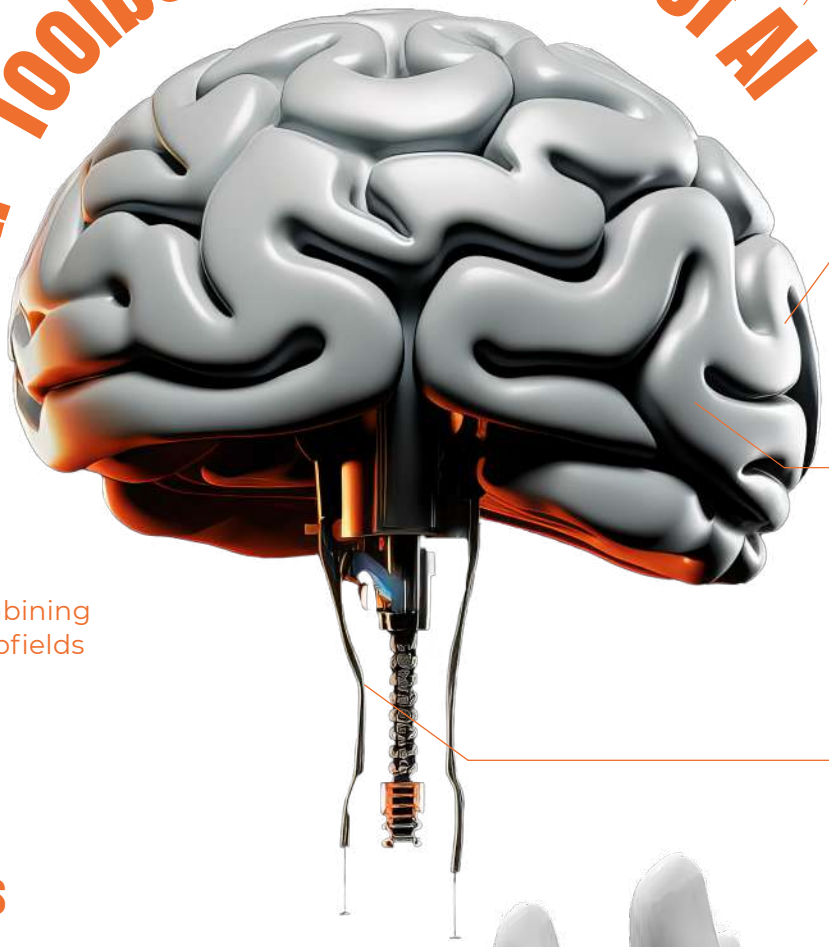
Robotics: Robotics involves the design, construction, and operation of robots. These robots can be programmed to automatically carry out anything from basic repetitive and even dangerous tasks, all the way to humanoids having complex interactions with humans. Today, robots are already being programmed to perform tasks in areas such as manufacturing, production, transportation, and healthcare.

Neural Networks: Inspired by the human brain, neural networks are made up of a vast network of nodes, mimicking the extensive number of neurons in the human brain. Each of these nodes is connected to others by weights which are adjusted as the network learns and adapts. They are trained on vast datasets to identify patterns which can then be used to produce new works like the patterns it learned from training data. Neural networks are widely used in applications such as image and speech recognition, and medical diagnosis.

A majority of popular AI applications are a combination of different subfields. For example, autonomous vehicles use a combination of machine learning, NLP, and computer vision to understand and navigate dynamic traffic conditions and avoid obstacles. Among the multitude of AI applications that exist today, generative AI has risen to recent prominence, driven by the newfound popularity of generative AI models such as ChatGPT and Bard.

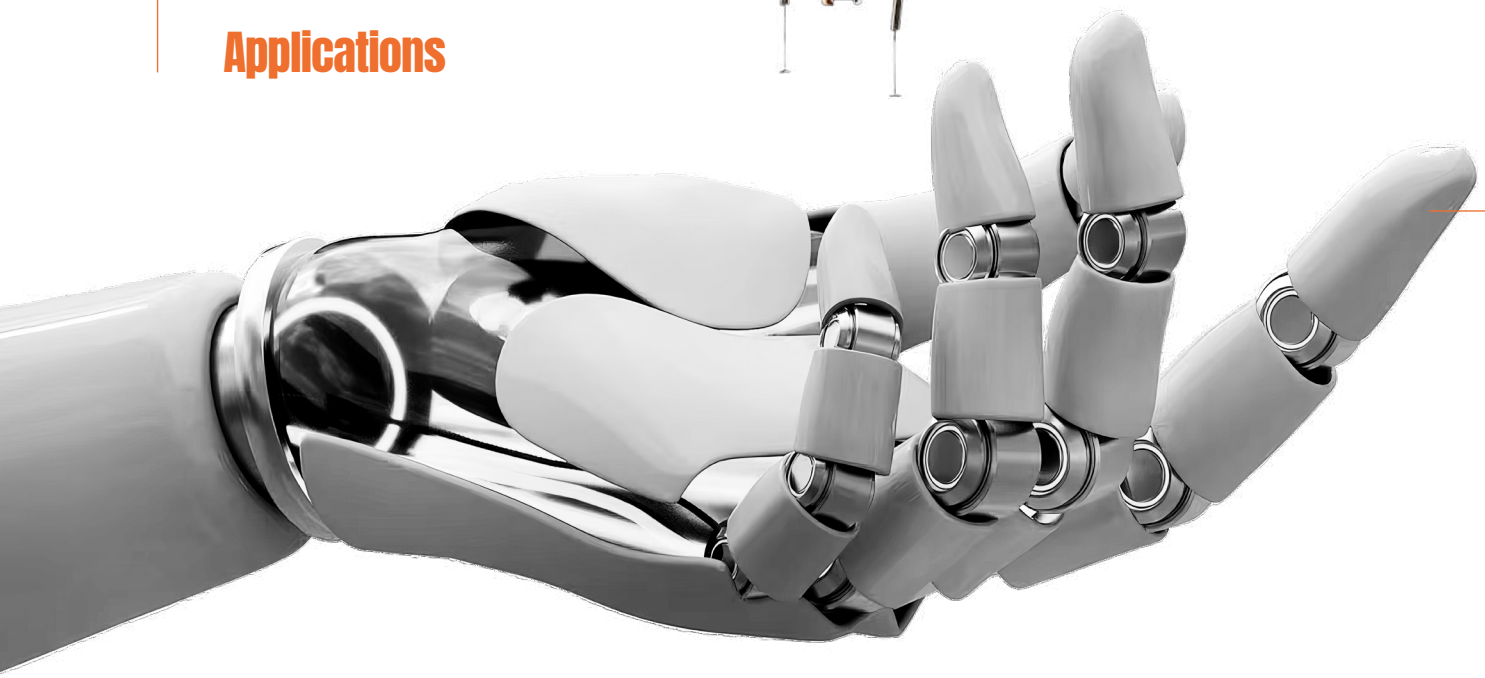
Source: iStock

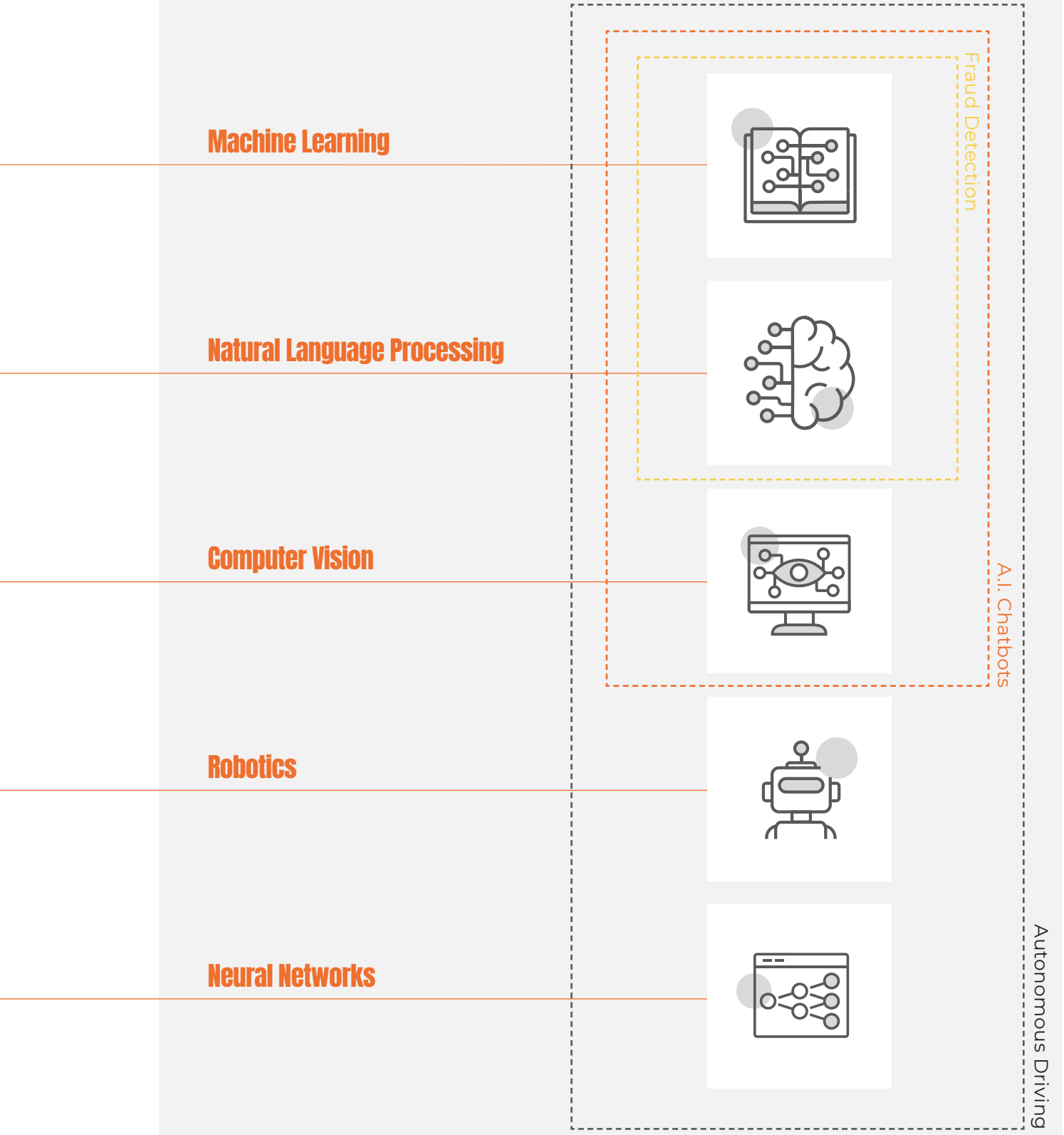
AI "Toolbox" Subfields of AI



Sophisticated applications are possible by combining the different subfields of AI.

Applications

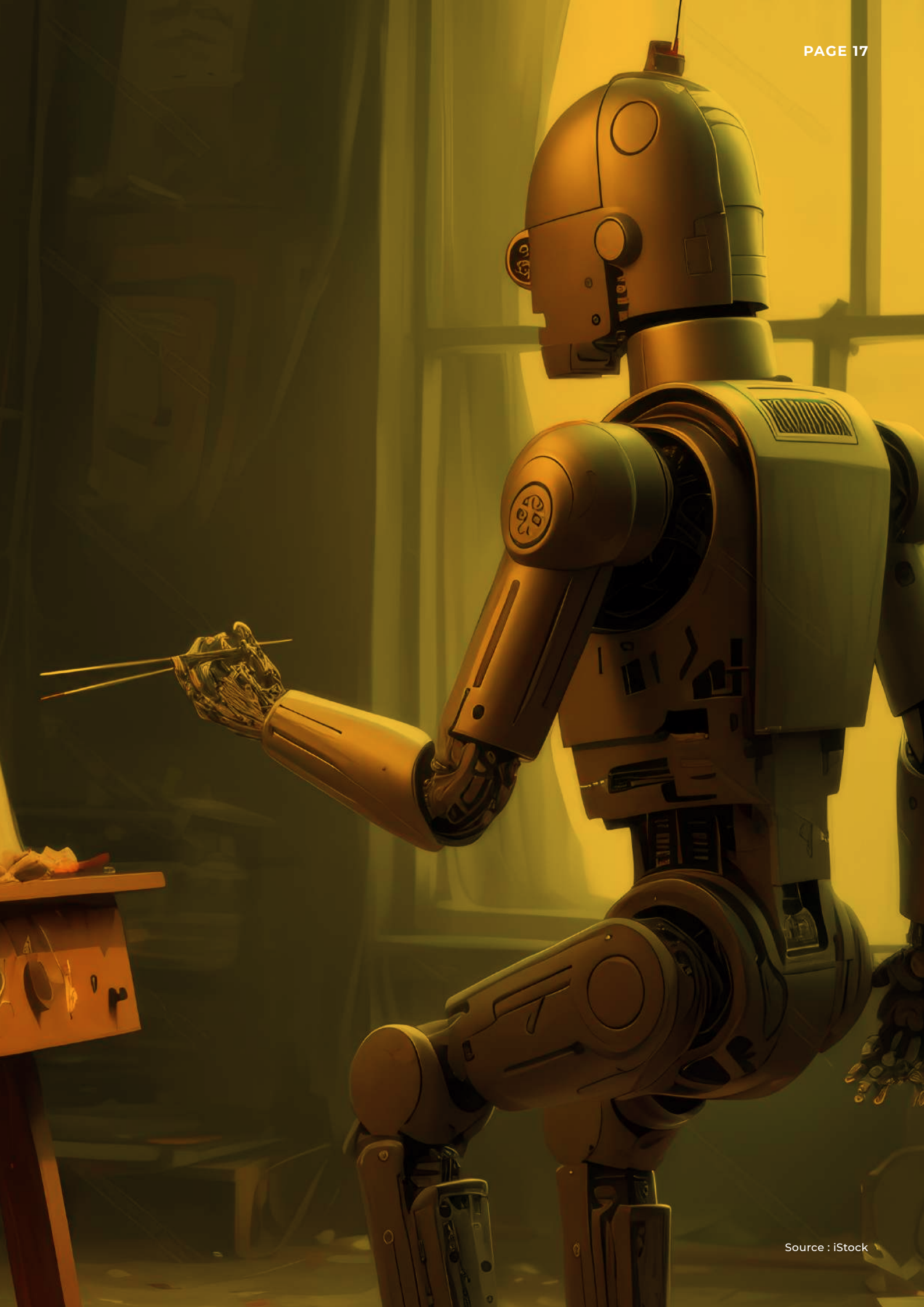




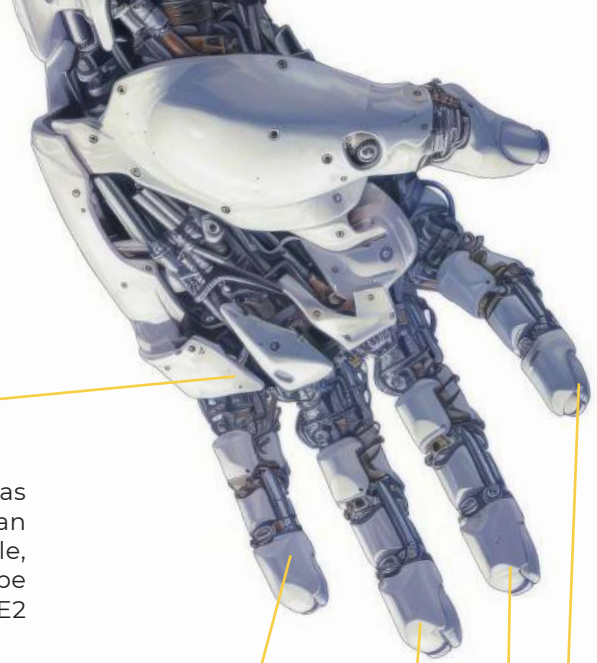
Source : iStock, MIT, IBM, DBS

Generative AI: the rising star

The created has learned to create.



Source : iStock



With the recent buzz surrounding generative AI and its explosive growth, we delve deeper into this field. Generative AI is a subset of AI that can create new content, in the form of images, text, audio, or other types of media. It does this by (i) leveraging AI subfields (such as machine learning) to train models to identify patterns from large existing datasets and (ii) using these patterns to produce new and unique content. Some avenues in which generative AI has shown uncanny proficiency include:

Images

Creating images based on existing ones, such as creating a realistic picture from a sketch or an artwork based on an existing style. For example, when prompted to paint a modern city landscape replicating the style of Vincent Van Gogh, Dall-E2 generated the following output:

Notably the generated images feature the signature striking colour and choppy impressionist brushwork apparent in Van Gogh's paintings, such as his "Café Terrace at Night" (below, for reference):

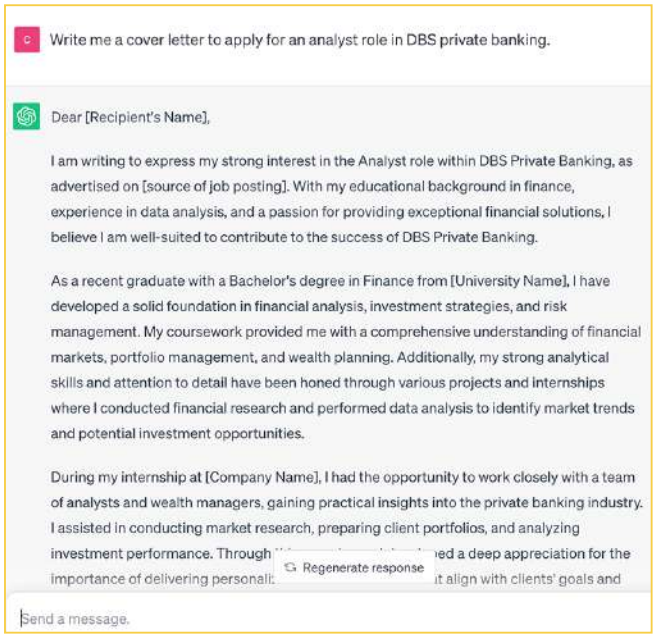
Coding

Writing code in programming languages such as Python

Audio

Composing sound effects, melodies, and even improvising on a specific genre

Language



Generating coherent text based on a designated context, such as writing or editing articles based on a house style, composing scripts, or even creating chatbot interactions. Models can also be trained to translate text between languages, edit tone and grammar, and summarise. For example, ChatGPT is now used by job applicants to draft cover letters:

Biochemistry

Modelling molecular structures to create new antibodies, reducing antibody optimisation time in laboratories

Source : OpenAI, DBS, The Edge, University of Southampton education magazine

GENERATIVE AI USE CASES ACROSS DIFFERENT TYPES OF MEDIA	USE CASES	EXAMPLES
IMAGES	Generating stock images	Stable diffusion Dall-E2
	Image editing	Runway
LANGUAGE	Chatbots and virtual assistants	Boost.AI Quickchat Typewise
	Composition of personalised letters, posts, articles	Copy.AI Copysmith
	Search (e.g. internal search portal within organisations)	ChatGPT Google Glean
	Text analysis (e.g. summary of legal/policy documents)	Viable MLQ.AI
CODING	Generating code for application development	OpenAI GitHub Copilot Replit
AUDIO	Composition of soundtracks	AssemblyAI
	Text-to-voice (e.g. for training videos, social media engagement)	Voicebooking
BIOCHEMISTRY	Molecule design and generation	ProteinGAN BioNeMo
	Synthetic healthcare data (to facilitate clinical research without contravening data privacy)	Syntegra's Medical Mind Datagen

Source : Company websites, DBS

How does Generative AI learn?

ChatGPT's secret sauce.

Behind the human-like spark and almost instantaneous responses of ChatGPT, lies many GPU hours of training and millions of dollars. ChatGPT is powered by OpenAI's GPT (Generative Pre-trained Transformer). This is a type of Large Language Model, a form of Autoregressive Model that produces sequences of words to mimic phrases and sentences produced by humans. This has elements of training the model to guess the next word in a sentence based on the probability distribution of words in its training data. For example, if the input is "Have a nice ..." the language model might guess the next word to be "day" based on the common expression.

This seemingly simple function becomes powerful because GPT's ability to weigh the significance of each part of text is enhanced by something called a transformer. Furthermore, the model can produce human-sounding output as it has learned from a large amount of data from the Internet. Since the initial launch of the first model, GPT-1 in 2018, each iteration of GPT language models has been trained using progressively larger, more comprehensive datasets of Internet text and other data to achieve GPT-4's level of sophistication today.

PROGRESSION OF GPT MODELS

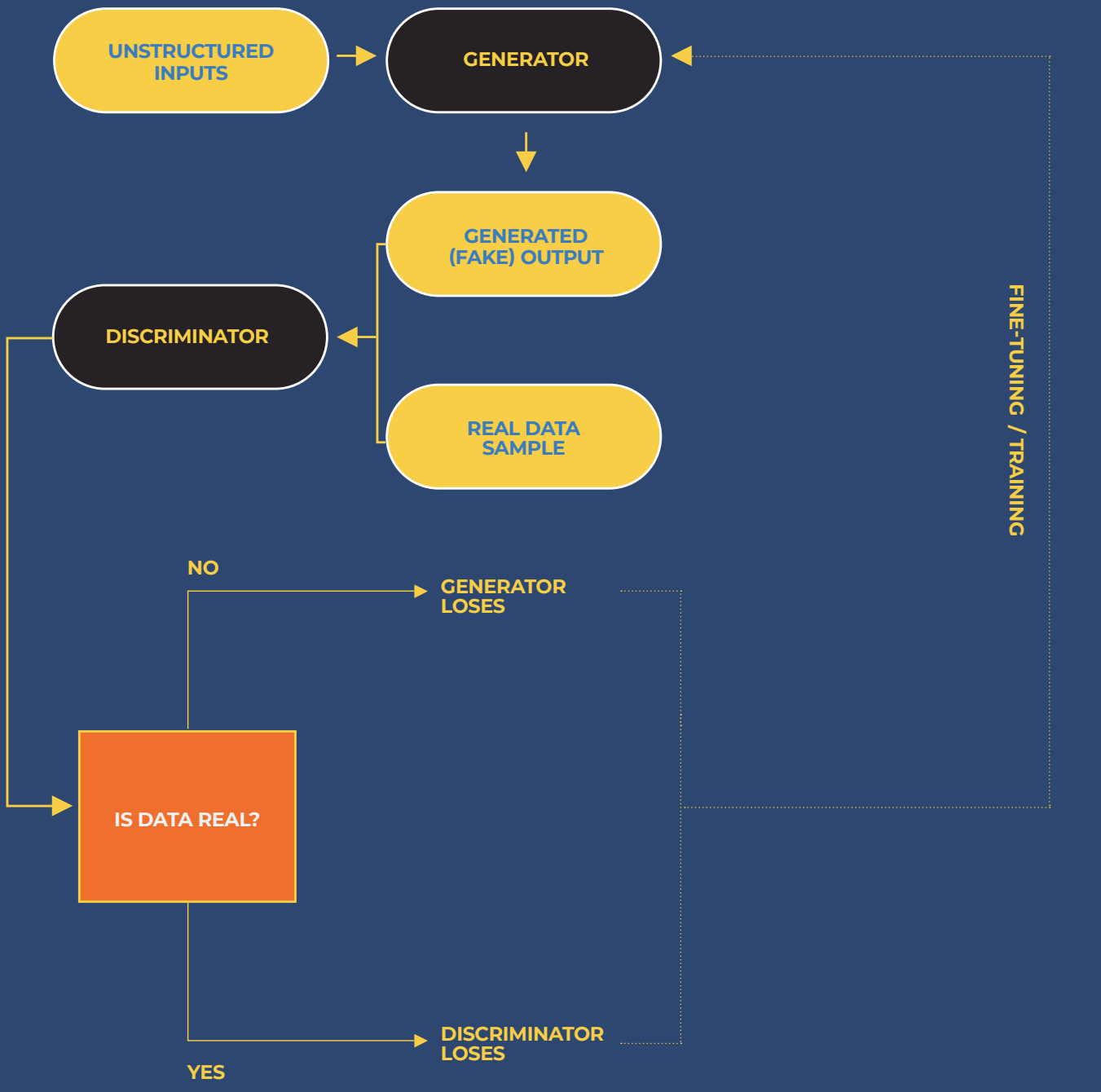
	SIZE OF TRAINING DATA	NUMBER OF MACHINE LEARNING PARAMETERS	CAPABILITIES
GPT-1 **RELEASE DATE JUNE 2018**	BooksCorpus Dataset (5GB)	117 million	Generate human-like text, complete sentences
GPT-2 **RELEASE DATE FEBRUARY 2019**	Text on 8 million web pages (40GB)	1.5 billion	Achieve specific tasks such as language translation, question-answering, summarisation, and text completion
GPT-3 **RELEASE DATE JUNE 2020**	Web pages, Wikipedia, books, others (570GB)	175 billion	Perform most language tasks such as translation, question answering, text summarisation, and content generation, without additional tuning
GPT-4 **RELEASE DATE MARCH 2023**	Undisclosed	Undisclosed, but speculated to have between 1 to 100 trillion parameters	Produce more natural sounding text and solve problems more accurately than GPT-3. Processing, analysis, and description of images. Problem solving and reasoning.

Source: Shutterstock, Alan Thomson, Brenda Gratas, DBS

A word paints a thousand pictures

Other than Large Language Models, the ability of some other AI models to create content in different shapes and forms (such as images and video) is achieved using a form of machine learning known as generative adversarial networks (GAN). A GAN consists of two neural networks: A generator to generate new (fake) data, and a discriminator to evaluate the data and discern the generated fake data from real data.

Generative Adversarial Networks (GAN structure)



Source: Google Developer, DBS

As the AI is being trained, both networks work together in a feedback loop, with the discriminator penalising the generator for creating implausible outputs, and the generator improving its outputs based on feedback from the discriminator. This system aims to create output that is indistinguishable from human-generated content. The following example below illustrates how this is used to train AI to generate images.

While there exists many other types of Generative Models, what is evident is that the computing power needed to support the iterative process is immense and the need for an extensive training dataset is crucial. This suggests that advancements in AI development will likely be led by those with the means to support it.

(1) When training begins, the generator produces low quality outputs

Generated data (Fake data)	Real data	Discriminator
		High accuracy – Can easily identify fake data

(2) As training progresses, the generator gradually improves to produce higher quality fakes, which may fool the discriminator

Generated data (Fake data)	Real data	Discriminator
		Declining accuracy – Becomes more difficult to discern fake data

(3) If the training is successful, the generator's output eventually becomes so realistic that the discriminator unable to distinguish between real data and fakes

Generated data (Fake data)	Real data	Discriminator
		Low accuracy – The generated data is so realistic that the discriminator is unable to distinguish real from fake data

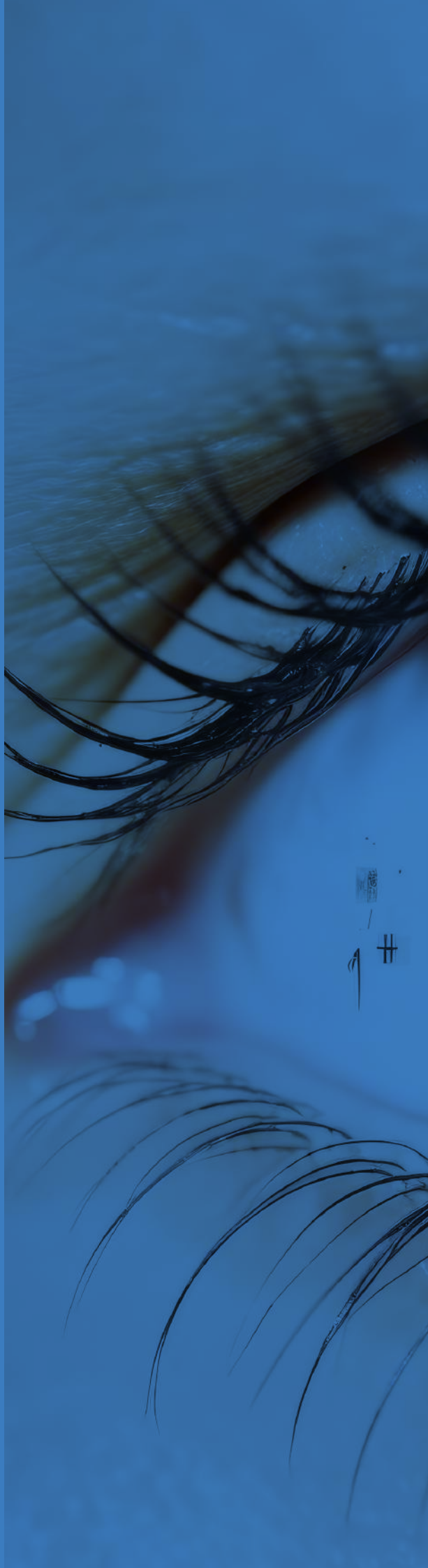
Source: Google Developer, DBS

Cognitive AI - mixing man and machine

THE NEXT FRONTIER IN MACHINE MIMICKING MAN.

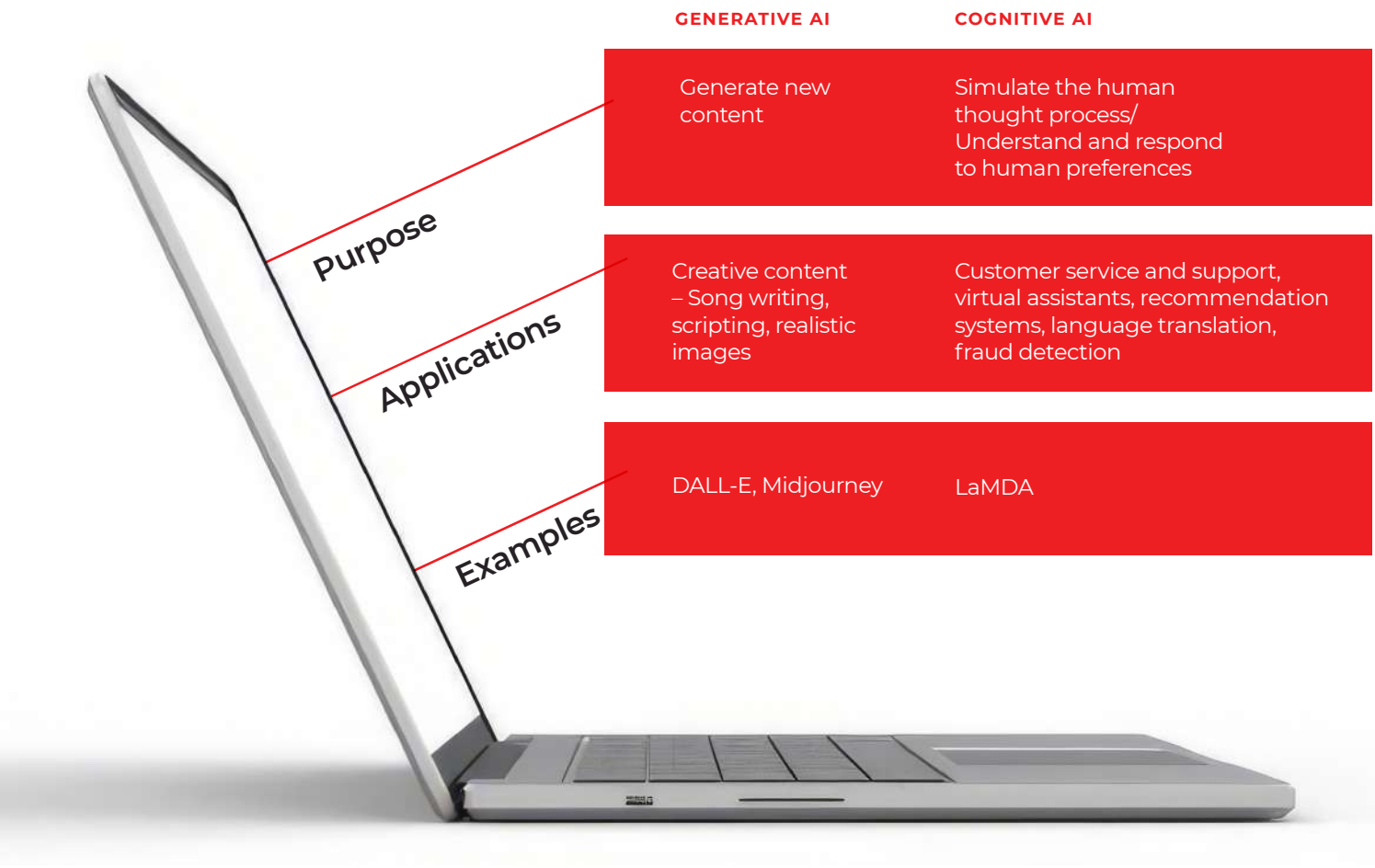
While the possibilities of generative AI have already attracted much excitement, cognitive AI is set to elevate technology's potential to replicate humans to the next level. In fact, many modern and well-known AI applications such as ChatGPT and Bard are primarily known as generative AI platforms, but their humanlike responses are attributable to cognitive AI components in their systems.

Unlike generative models which focus on content generation, cognitive AI further widens AI's capabilities by enabling it to mimic human reasoning and logic capabilities. By simulating the human thought process, cognitive AI models are designed to consume and understand information just like humans. This ability to think and reason in a human-like way enables AI models and applications to work with and adapt to incomplete datasets, which further broadens the horizons of what AI can do.



Source: iStock

Differences between generative and cognitive AI



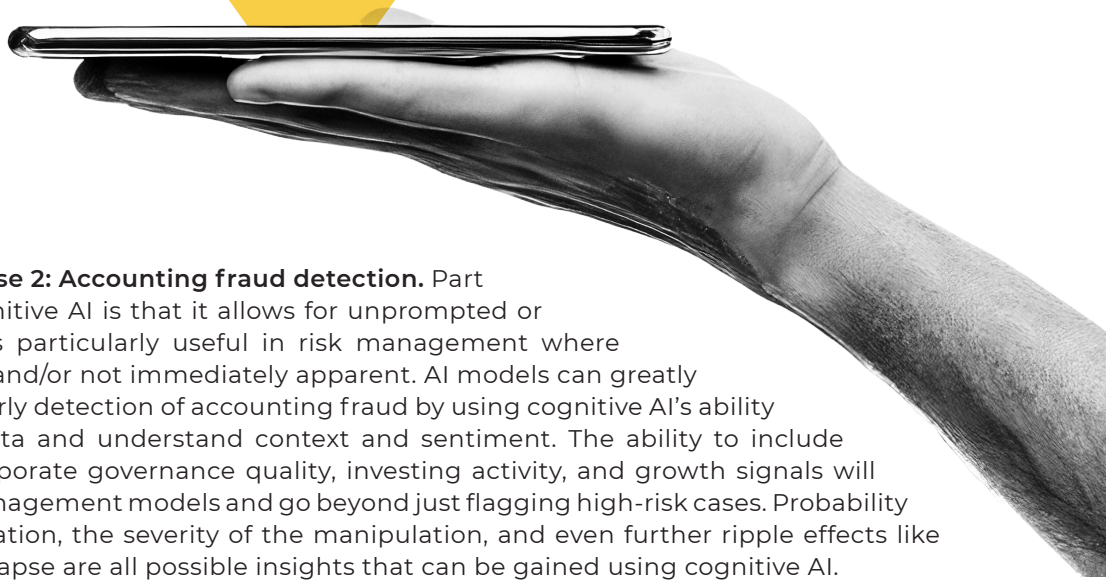
Cognitive AI real world use case 1: Video content curation and marketing. We earlier mentioned that cognitive AI allows AI applications to act and think like humans. This can be illustrated clearly in the video content curation and marketing industry. Take, for example, a video streaming platform that uses traditional machine learning protocols to produce title recommendations for their users. These protocols rely on data called "embeddings" (e.g. tags, text summaries, genre, content type, etc.) to profile their users and establish their preferences, and subsequently curate titles based on these preferences.

However, there are issues with such an approach. First, the recommendations will only be as good as the embeddings are accurate, and secondly, the creation of embeddings is ultimately a manual process that requires time and effort. The use of cognitive AI and its underlying AI subfields such as computer vision and sentiment analysis will allow these existing AI models to bypass the need for embeddings and analyse the source material (i.e. the actual video content). This will allow for more relevant and accurate recommendations as well as save precious man-hours that would otherwise be spent upkeeping databases of embeddings.

Source: DBS, various

Datasets needed for Traditional AI vs Cognitive AI

TRADITIONAL AI	COGNITIVE AI
Video content	Video content
Meta tags	
Genre information	
Text summaries	
Content type	



Cognitive AI real world use case 2: Accounting fraud detection. Part of the "human" aspect of cognitive AI is that it allows for unprompted or non-instructed output. This is particularly useful in risk management where issues are typically concealed and/or not immediately apparent. AI models can greatly improve the accuracy in the early detection of accounting fraud by using cognitive AI's ability to work with unstructured data and understand context and sentiment. The ability to include non-quantitative data like corporate governance quality, investing activity, and growth signals will augment traditional AI risk management models and go beyond just flagging high-risk cases. Probability scores of accounting manipulation, the severity of the manipulation, and even further ripple effects like the likelihood of corporate collapse are all possible insights that can be gained using cognitive AI.

The use cases for such risk management technology extend beyond audit and accounting. Corporate and investment banks can further finetune client screening and onboarding processes, M&A advisers can gain additional insights when conducting due diligence, and financial regulators can improve their surveillance and monitoring protocols through the incorporation of cognitive AI.

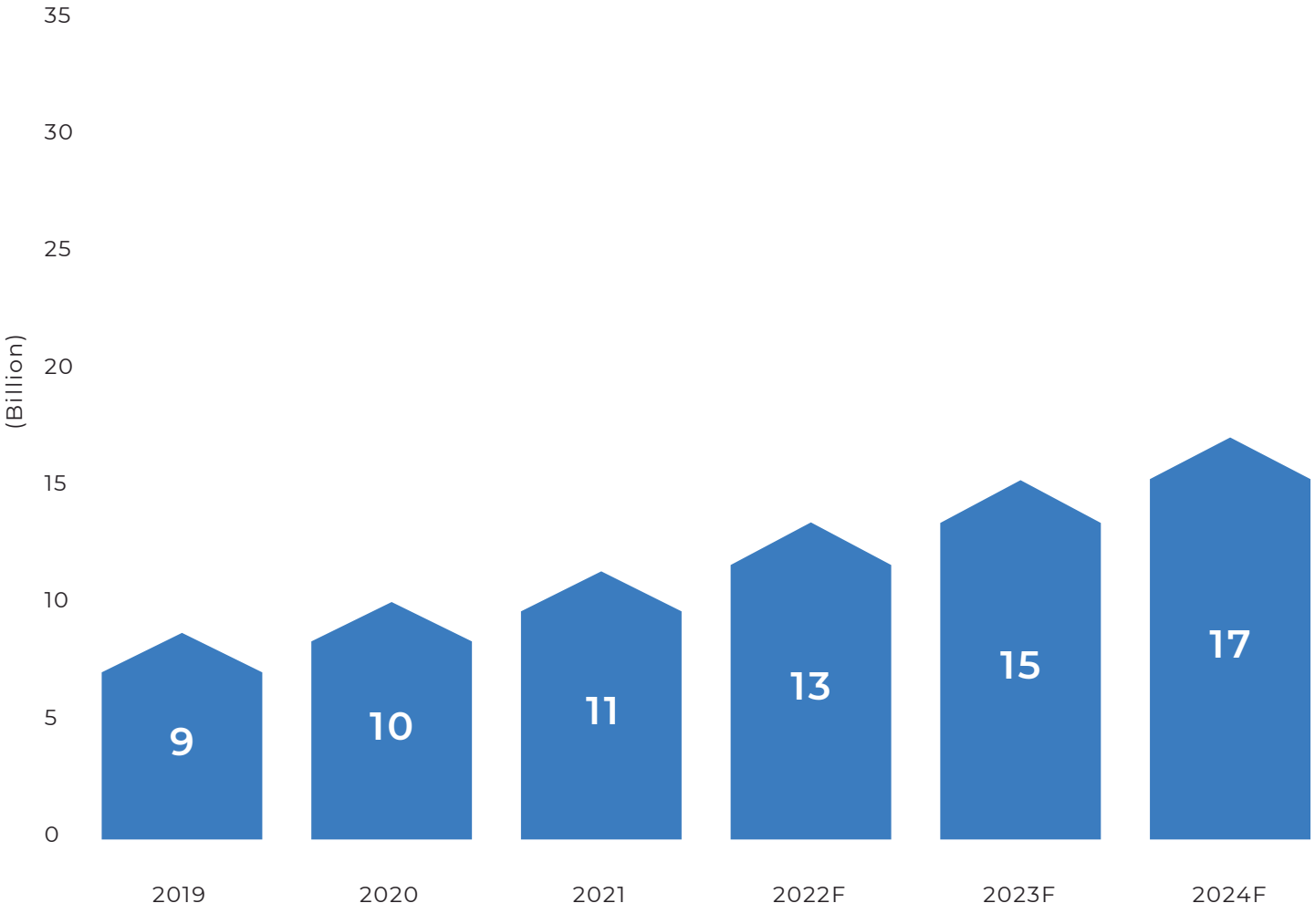
Source: iStock, Cognitive Mill, DBS

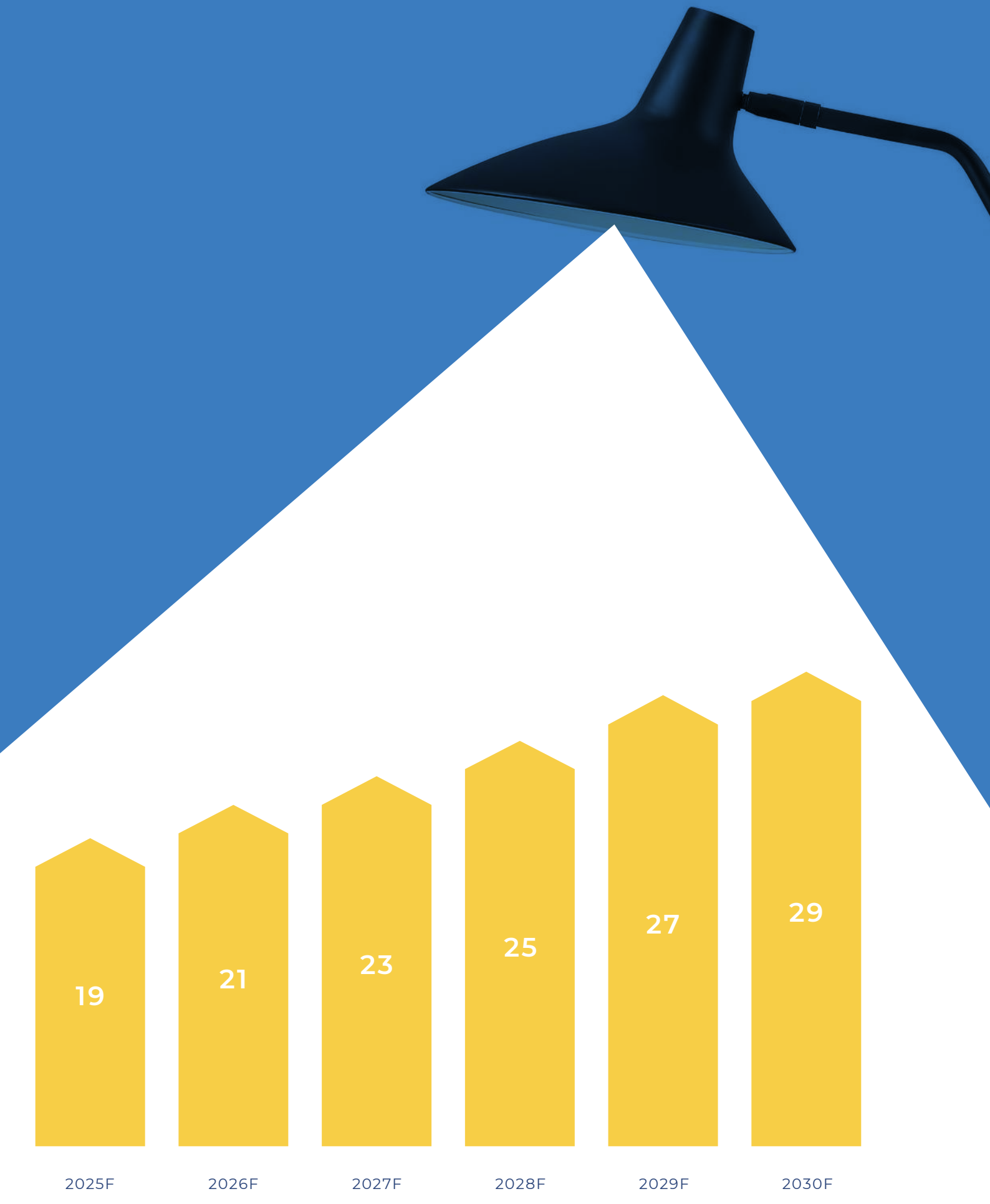
Cognitive AI real world use case 3: Hyper personalisation of the Internet of Things (IoT). The IoT refers to devices embedded with sensors, software, and connectivity, allowing data to be transmitted across the network. The devices can then be monitored and controlled either manually or through predefined rules. With the incorporation of cognitive AI, these devices can gain human-like intelligence. They become capable of analysing data captured by the device's sensors, identifying behaviour patterns, and optimising settings without the need for manual human invention.

Smart home systems are an example of cognitive AI's capabilities. In a traditional IoT setup (without cognitive AI), users will have to manually adjust the temperature settings of their air conditioner and configure schedules for switching on and off their lights. With the inclusion of cognitive AI, these IoT devices can go beyond basic configuration. They possess the ability to learn from the users' routines and consider external variables, such as weather condition, to determine the optimal personalised temperature and light settings.

According to Statista, IoT connected devices worldwide is expected to increase at a CAGR of 12%, from 8.6b devices in 2019 to 29.4b devices in 2030. With IoT devices gaining momentum, the demand for cognitive AI-installed IoT devices will also be on the rise, as users seek hyper personalised devices that can "intelligently" adapt to their evolving needs and patterns.

Growing number of IoT devices globally





Source: Statista, DBS

MACRO

Impact of AI

AI WILL REFORM THE LABOUR MARKETS

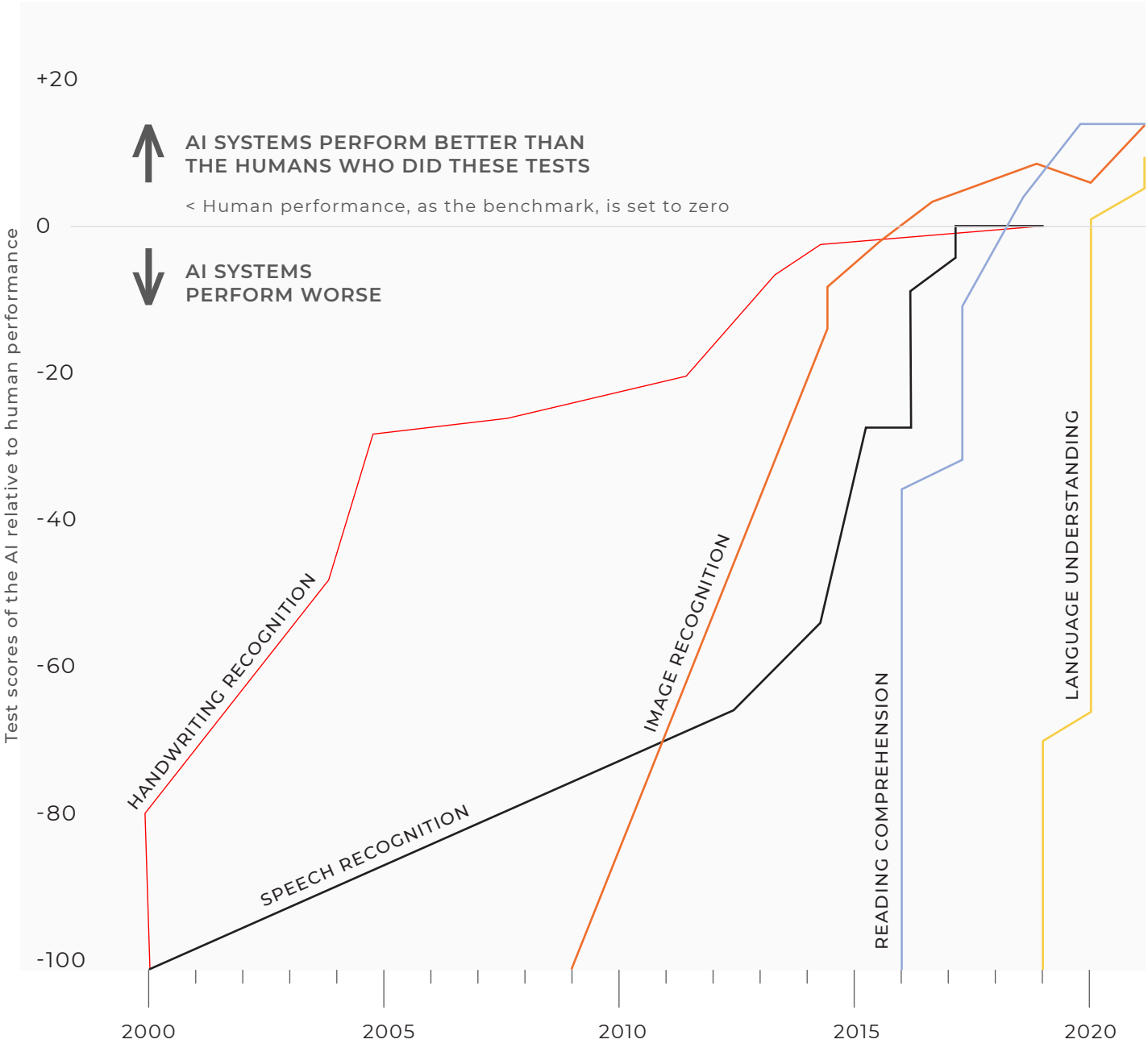
More than human mimicry, AI is fast encroaching on human excellence. No one batted an eyelid knowing that Stockfish (one of the most advanced AI chess engines) recorded an Elo score above 3,500, c.23% beyond the highest score of 2,882 ever achieved by a human player (Magnus Carlsen). So long as machines only exceeded human ability in specialised use cases, we believed that broader human employment would not be under threat. That comfort proved transient when GPT-4 – OpenAI's currently most advanced large language model – performed admirably across a broad range of disciplines, purportedly scoring in the 90th percentile in a simulated bar exam for lawyers, the 93rd percentile on an SAT reading exam, and the 89th percentile on the SAT math exam. This is perhaps why a technological breakthrough of this magnitude is met not so much with praise as it is with wariness; AI undoubtedly feeds an age-old paranoia of whether "robots would take our jobs", dating as far back as the early 19th century when Luddites feared being replaced by textile machinery. It is not without a sense of foreboding that the term "Luddite" is now a derogatory reference to one who is opposed to the adoption of new technology.

> **AI could eventually displace roughly**
>
> **15%**
>
> of workers, or 400 million people worldwide between 2016 to 2030."

If jobs are a function of our intelligence, is any occupation safe? With AI capabilities fast dethroning average human benchmarks of recognition, comprehension, and origination across a variety of media, this section aims to gaze into the proverbial crystal ball to anticipate the potentially disruptive macro implications that could arise.

We have handed machines the Promethean flame. The cold hard truth is that technological advancements have always reshaped labour markets. The invention of the tractor and other farming innovations over the 20th century resulted in agricultural employment declining from c.33% of America's civilian workforce in 1910 to just c.2% today. The difference is that most of these prior waves of innovation augmented merely the physical limitations of human endeavour; the human mind, or so we thought, was a final bastion that the machines could not transcend. With this breakthrough however, AI could eventually displace roughly 15% of workers, or 400m people worldwide between 2016 to 2030, according to a study by McKinsey & Co., a management consulting firm.

AI outclassing humans in cognitive capabilities



The capability of each AI system is normalised to an initial performance of -100.
Source: OurWorldInData, Kiela et al., DBS

Progress

Transforming material

2,000,000 BC

Stone tools

3300 BC

Bronze tools

1200 BC

Iron tools

Transforming energy

Transforming information

Transforming knowledge

1780 1848 1895 1940 1973 2022 Future

Water Power

Steam Power

Electric Power

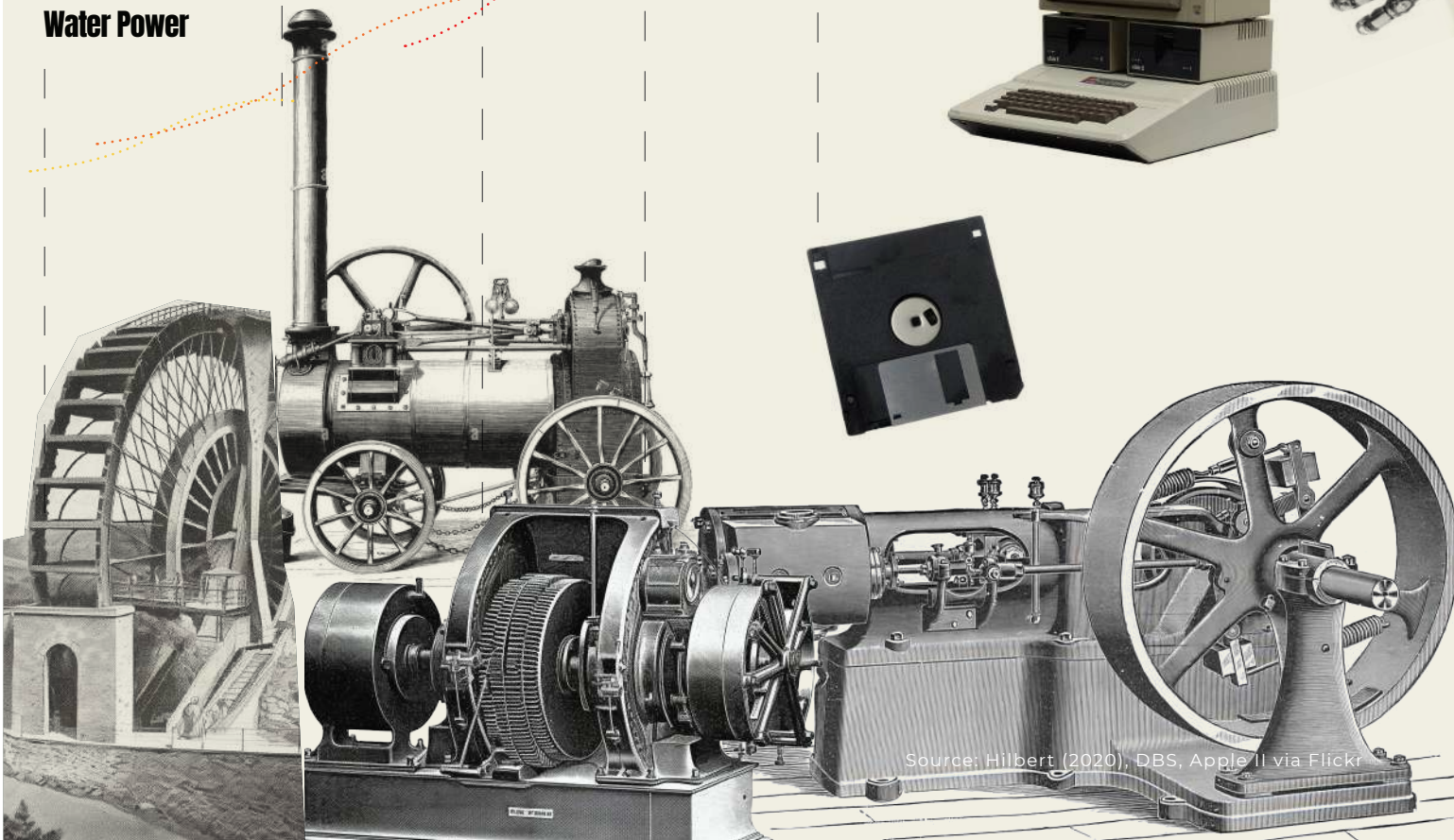
Combustion Power

Communicating & storing information

Computing information

(Knowledge and algorithms)

Generative AI

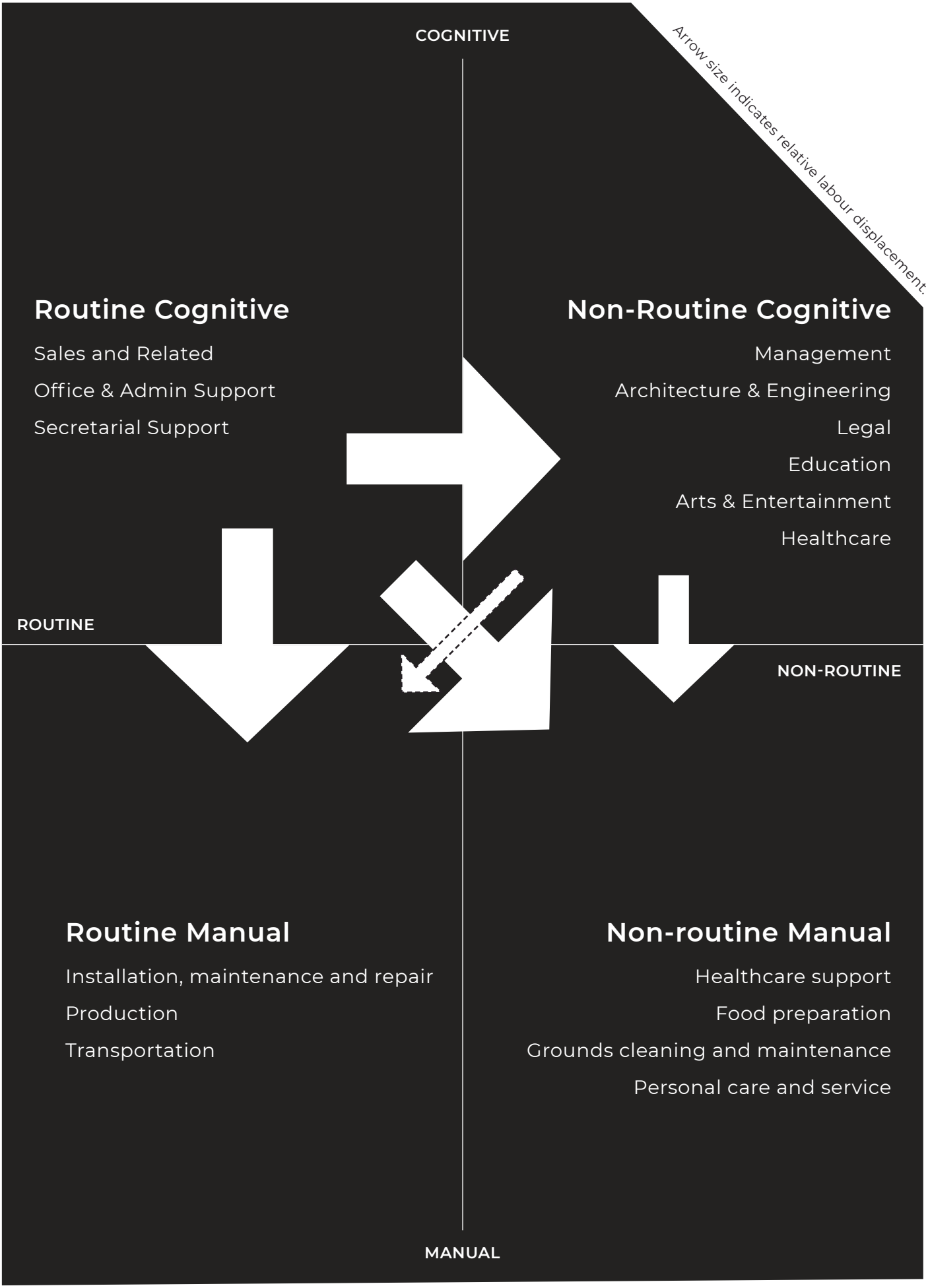


Source: Hilbert (2020), DBS, Apple II via Flickr

THE MACHINES ARE COMING FOR OUR IVORY TOWER.

Even so, the composition of such an employment disruption does not seem to follow the norms of yesteryear. It is well understood that 20th century technologies accelerated the migration of tasks from physical to cognitive, of habitat from rural to urban, and of demand from goods to services – resulting in a general decline of blue-collar jobs for white-collared alternatives. With AI now putting a chink in the armour of human's cognitive capability, we could see a complete transformation of those familiar structural labour market trends, giving way to:

THE GREAT LABOUR MIGRATION



Source: DBS

WHITE-COLLARED JOBS MOST SUSCEPTIBLE TO DISRUPTION BY AI...

Source: Ed Felton (Princeton), Manav Raj (University of Pennsylvania), Robert Seamans (NYU), DBS
*AIOE score measures degree of disruption of AI, with a higher score indicating higher degree of disruption

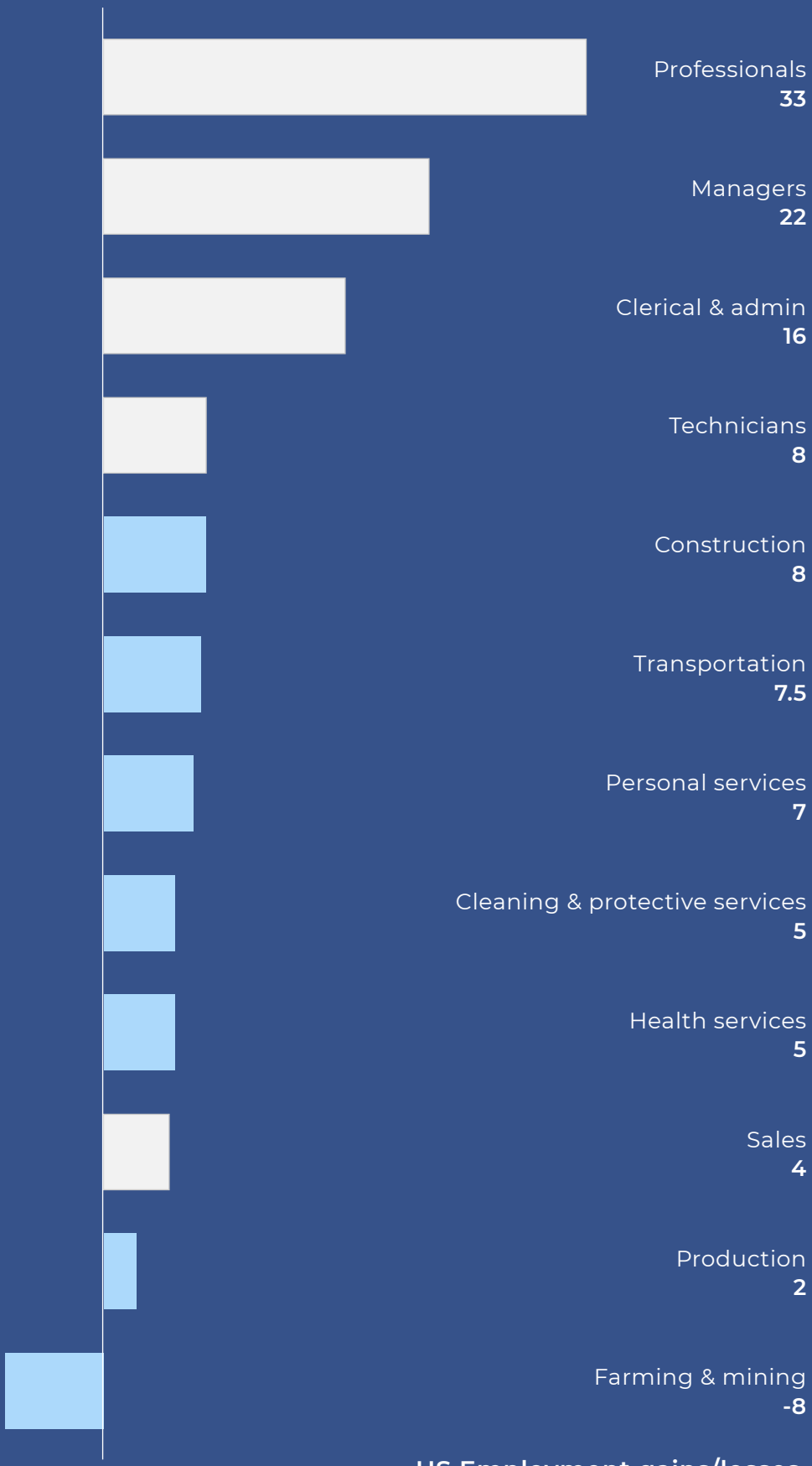
1. WHITE-COLLAR (COGNITIVE LABOUR) RECESSION.

We believe that the greatest threat remains for routine cognitive tasks that can simply be automated with AI, resulting in stagnating or even declining wages for labourers. McKinsey estimates that by 2030, the share of the total wage bill of this group could decline from 33% to 20%, while non-routine cognitive jobs (requiring high digital skills) would see its share of employment rise from some 40% to >50%. A direct consequence of this widening gap in employment and wages would be an intensifying competition for individuals skilled in developing and utilising AI tools, while a structural surplus would emerge for most other cognitive workers. Nonetheless, even non-routine cognitive occupations would not prove entirely unscathed, given that AI is expected to displace a host of higher-order professions including researchers, scientists, teachers, paralegals, programmers, content creators, doctors, etc.

2. BLUE-COLLAR (MANUAL LABOUR) RENAISSANCE.

The shortages of blue-collared labourers in developed economies in the post-Covid era of deglobalisation was a boon for manual worker salaries, having suffered stagnation for decades. Coupled with the structural surpluses in the cognitive-focused labour force above, there is a possible renaissance of employment gains in sectors involving both manual routine and non-routine tasks. This segment, however, faces longer-term challenges from other innovations related to robotics/automation, the scope of which is beyond the focus of this discussion. The corollary remains that labour's share of income would not see an enduring revival so long as tech-dominance persists.

... POTENTIALLY REVERSING THE BLUE- TO WHITE-COLLAR TRANSITION (1940-2018)



US Employment gains/losses, 1940 - 2018 (millions)

Source: Autor et al., DBS

THE NIGHT WILL DARKEN BEFORE THE DAWN.

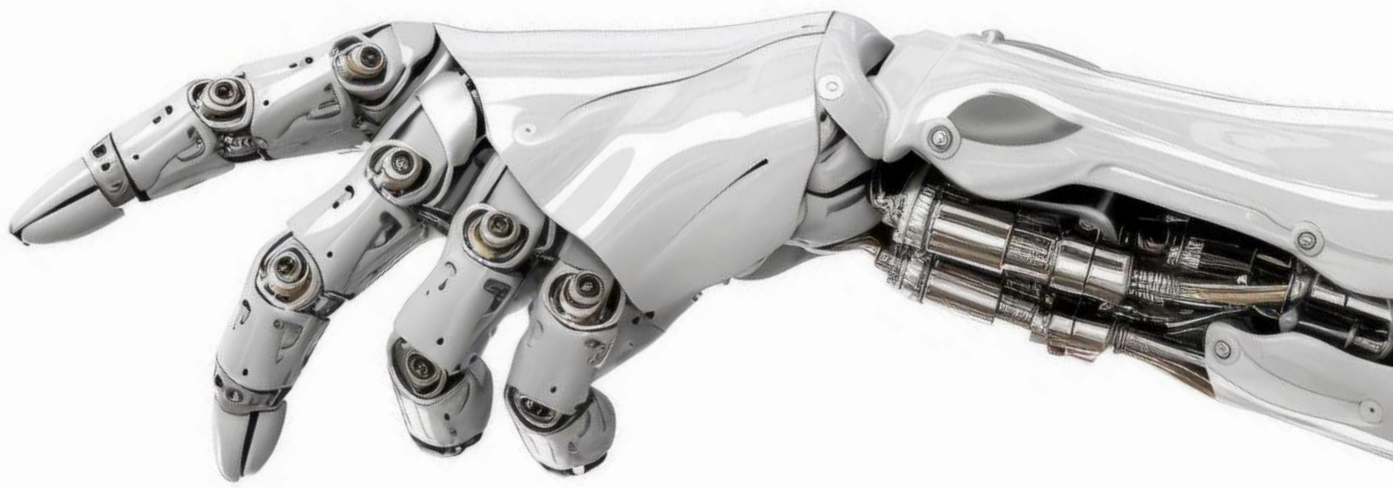
Unfortunately, between the excitement of a new technological innovation and its promised opportunities, often lies a difficult workforce transition that can span decades. Such a period was also observed in the late 18th century – known as Engel's pause – when British working-class wages stagnated despite per-capita GDP expanding rapidly during the technological upheaval that was the industrial revolution. With AI disruption, the economy would likely face a stretch of transitionary consumption decline, both (a) cyclically through lost expenditure as workers are furloughed or retrained, and (b) structurally as labour's share of income stays depressed for the reasons mentioned before.

THE STATE TO THE RESCUE.

Government support is thus imperative to bridge the transition in the form of education/retraining, social provision, or unemployment benefits. We must be prepared however, for an outcome that sees efforts for reskilling to be less effective than prior eras, given that there would be millions who would not be able to keep pace with the trainability of AI due to their exponential learning curves. Should this be so, there may be a greater need for unprecedented state-level policies including (a) four- or even three-day workweeks to maintain higher levels of employment and thus safeguard social stability, or (b) the implementation of a universal basic income (UBI) to ensure that a subsistence level of wages is at minimum still available for the bulk of the displaced population. Regardless, this implies that higher taxes are a near certainty – for both top-income earners and owners of AI capital – in the age to come, unless governments are prepared to go even deeper into debt than they already are.

BIG TECH, BIGGER GOVERNMENT.

Speaking of governments, it was Russian president Vladimir Putin who recognised that “Whoever becomes the leader in this sphere (AI) will become the ruler of the world”. The prevalence of cognitive-enhancing technology would amplify the divergence between nations that are AI-equipped and those who are not, where the former gets the lion’s share of competitive advantages in trade, military, innovation, and education, while the rest lag behind. In this regard, developed economies would likely capture more economic benefits than emerging economies due to first-mover advantages. Yet, being a first mover is a much less crucial factor compared to the accessibility, quantity, and quality of data – which has further implications on the core western rights of freedom and privacy.

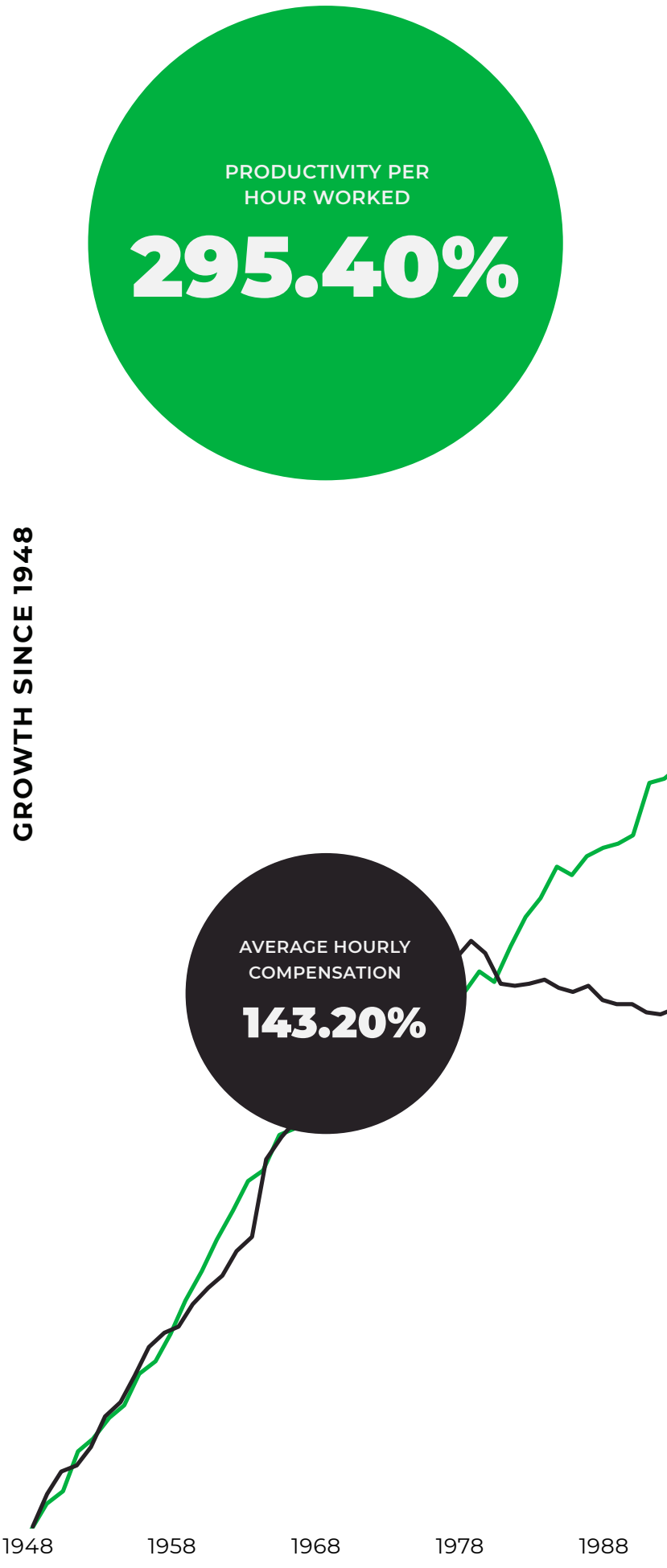


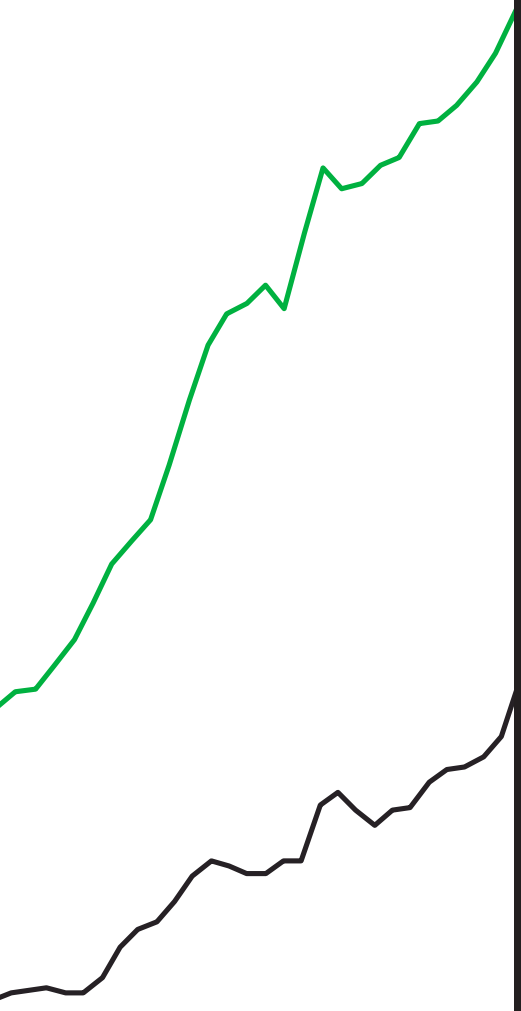
REBALANCING THE “WEST VS THE REST”.

It is difficult to argue against the notion that the western world had such disproportionate gains from the scientific and industrial revolutions due to the openness of their societies and the transatlantic exchange of ideas and competition. In contrast, the Chinese, Russian, and Ottoman empires – which had shifted towards an inward-looking bias all around the 15th century – faced centuries of comparative stagnation. AI has the potential to now tip this balance of power over. If research and idea generation can now be done by non-human agents, would the same freedoms of the exchange of ideas still be necessary for exponential growth in the next millennium? It could even be said that governments with stronger state control, along with large digital datasets and low data privacy policies, allow for quicker data collection and synthesis, allowing AI to dominate in truly Orwellian fashion. Most Western societies on the other hand, with their antitrust laws, privacy protections, and individual rights, may see them eventually cede control of AI superiority despite their present technological advantage.

Productivity soars, wages stagnate

The nature of AI technology also concentrates power in firms. AI enables rapid real time analysis of immeasurably large datasets to produce informative outputs to users, who would be willing to sign over data to companies because of potential benefits exceeding costs of data privacy. Such platforms profit from network effects and are likely winner-takes-all monopolies, as we have already observed with the Tech giants of the 21st century. With technological ownership concentrated among just a handful of firms, the bulk of productivity gains are unlikely to accrue towards the individual. As such, the post Reagan/Thatcher era of deregulation and de-unionisation and its associated trends remain entrenched, with wage stagnation and inequality as likely features under the persistence of industrial supremacy.





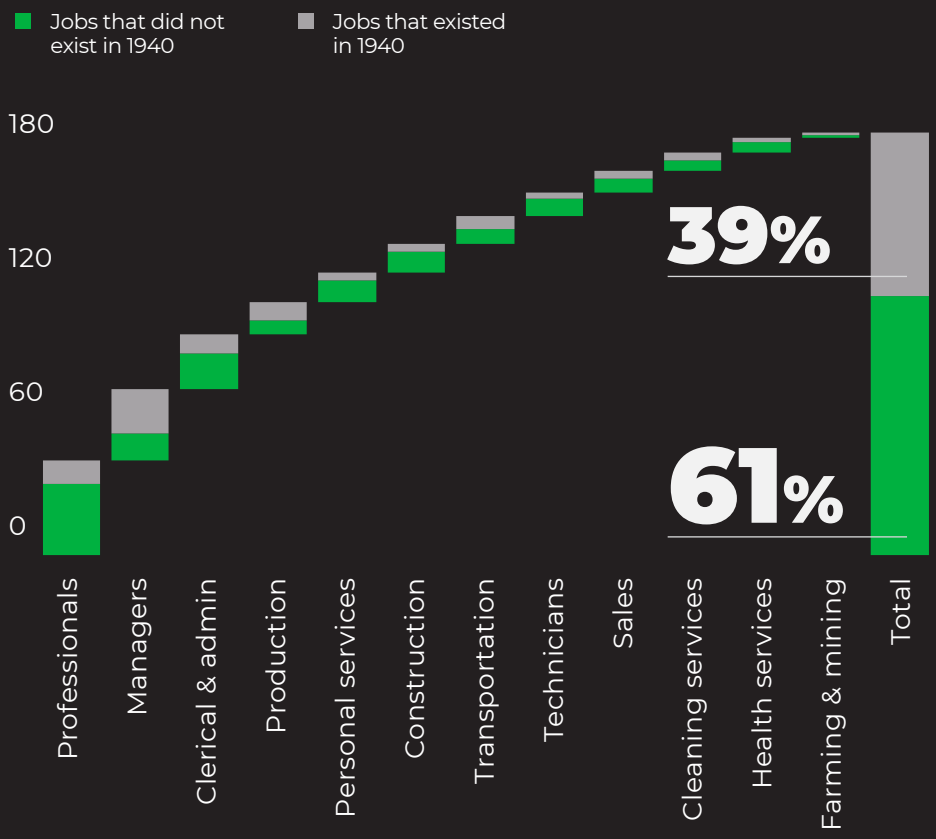
1998 2008 2018

Source: Economic Policy Institute, DBS

Not all disruption is dystopian. All that said, we would be remiss to exclude the potential benefits of the AI revolution. Despite some initial displacement, technological innovations can drive employment growth over a longer horizon – according to a study by economist David Autor et al. Using census data, they illustrated that c.60% of workers today are employed in jobs that did not exist in the 1940s, implying that technology can in fact give back to labour markets more than it has taken away. In other words, even as the world had bid farewell to elevator operators, horse carriage coachmen, and most human assembly lines, it gave rise to analysts, programmers, and other forms of analytical professions to flourish in the modern era.

Letting AI speak for itself. As with all technology, it is often difficult to envision the forms of latent professions that can emerge when they are still years in the making. Just imagine how tough it would be trying to explain the work of a TikTok influencer to a person living in the pre-2000s. It is perhaps most apt then that we let AI itself imagine for us the variety of jobs that it could enable for mankind in the future. Needless to say, this is still a highly speculative exercise; artificial intelligence isn't clairvoyance (or so we think).

"NEW" JOBS ACCOUNT FOR MORE THAN 60% OF OCCUPATIONS TODAY



Source: Autor et al., DBS

QUESTION TO CHATGPT:

WHAT NEW JOBS COULD GENERATIVE AI CREATE IN THE FUTURE?

1. **Generative Artists:** Generative AI could enable artists to create entirely new forms of art by generating unique and original pieces using AI algorithms.

2. **Virtual Fashion Designers:** Generative AI could be used to design and create custom clothing designs for individual customers based on their preferences and body type.

3. **AI-Powered Music Composers:** Music composers could use generative AI to create new and unique pieces of music that are personalised to the listener's preferences.

4. **Storytelling AI Content Creators:** Generative AI could be used to create new and engaging stories, articles, and other forms of content for various media outlets.

5. **Chatbot Developers:** Chatbots could use generative AI to create more human-like conversations that can help customers solve problems or obtain information in a more efficient and personalised way.

6. **Virtual Set Designers:** Generative AI could be used to create virtual sets for movies, TV shows, and other media that are customised to the specific needs of the production.

7. **Autonomous Creative Director:** Generative AI could be used to develop creative concepts, design ideas and content strategies, providing personalised recommendations for individual users and media companies.

These are just a few examples of the potential new jobs that generative AI could create in the future. As the technology continues to advance, it is likely that many more exciting job opportunities will emerge.

Source: ChatGPT, DBS

Quantifying the economic impact of AI

Numerically, McKinsey estimates that AI could potentially deliver additional economic output of around USD13t (c.16% of global output) between 2018-2030. Such gains may be back-end loaded, given that AI adoption is likely to follow an S-curve pattern in view of the aforementioned virtuous cycle that is the network effect. Apart from the creation of new jobs, this new growth also spans:

AUGMENTATION

Enhancing present human tasks with AI tools

PRODUCT INNOVATION

Expanding product portfolios, distribution channels, or new business models

SUBSTITUTION

Replacing labour with capital for productivity gains

GLOBAL DATA FLOWS

Facilitating cross-border commerce, supply chain efficiency, and expansion of data analytics, which reduces information asymmetry

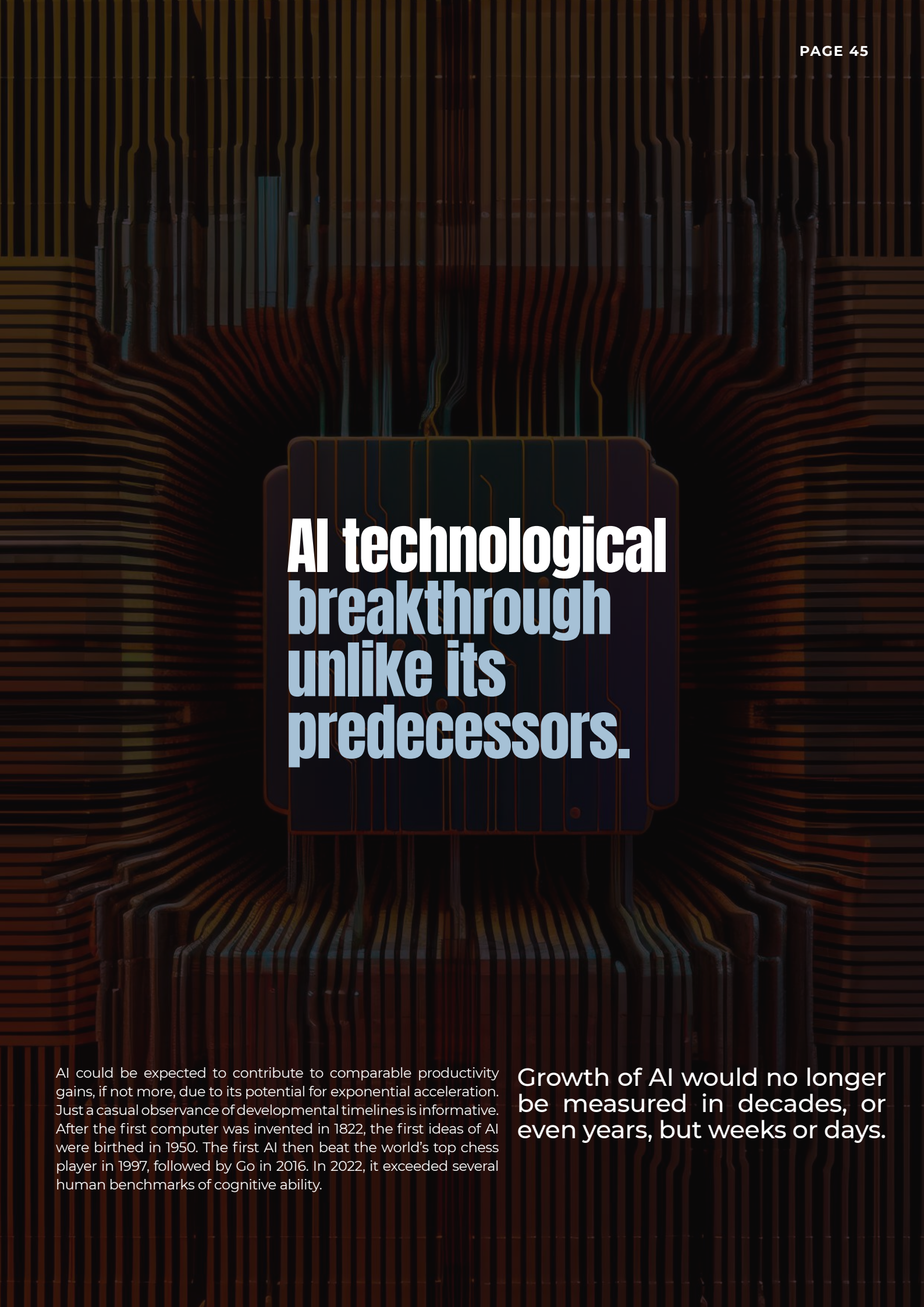
WEALTH CREATION

Through wage gains and profits within the AI value chain

AI STILL GROWTH POSITIVE

Economic impact of AI by 2023 (% of Global output)

Source: McKinsey Global Institute, DBS



AI technological breakthrough unlike its predecessors.

AI could be expected to contribute to comparable productivity gains, if not more, due to its potential for exponential acceleration. Just a casual observance of developmental timelines is informative. After the first computer was invented in 1822, the first ideas of AI were birthed in 1950. The first AI then beat the world's top chess player in 1997, followed by Go in 2016. In 2022, it exceeded several human benchmarks of cognitive ability.

Growth of AI would no longer be measured in decades, or even years, but weeks or days.

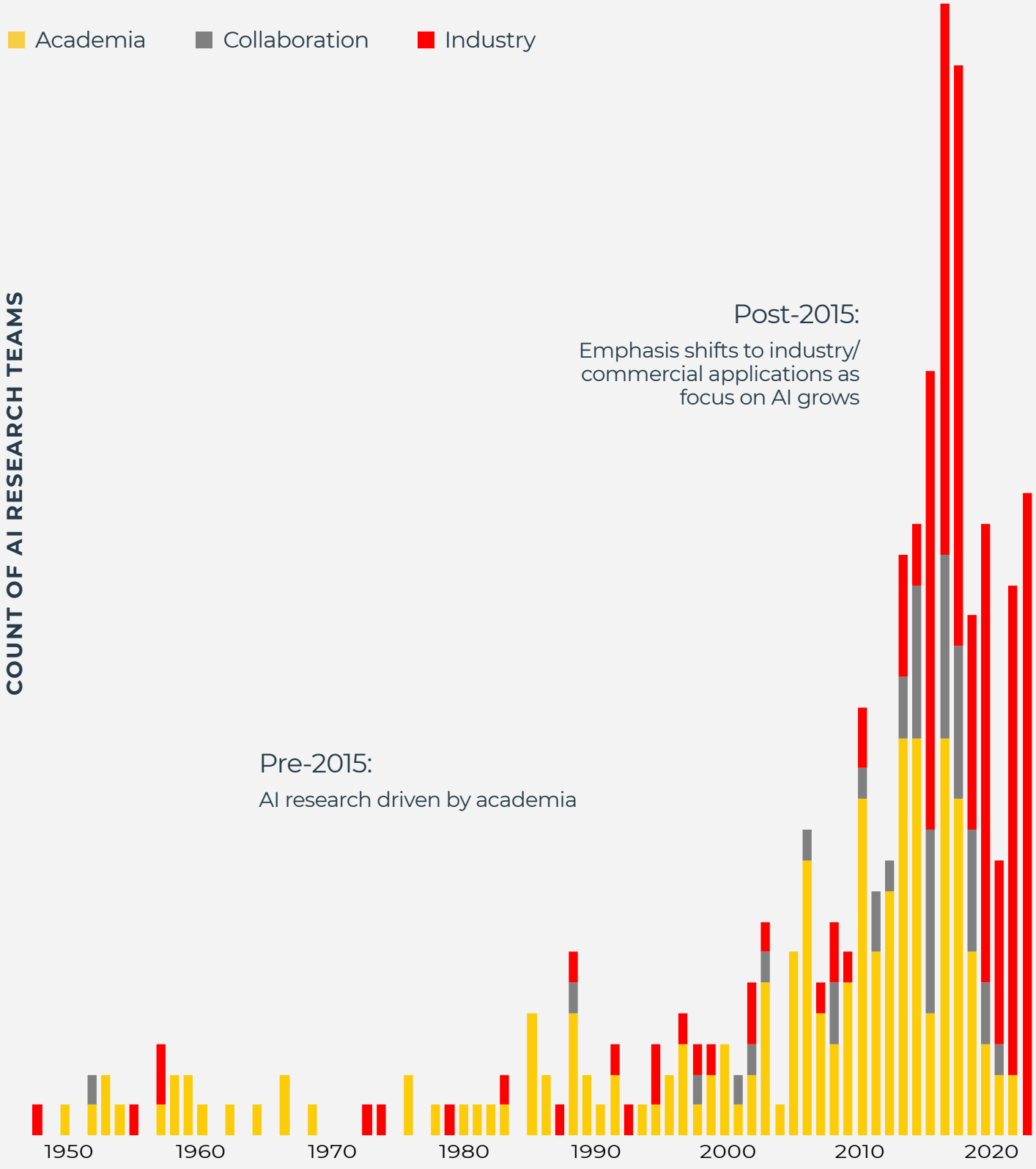
Industries affected & Business applications

AI'S USE IN INDUSTRY

Although AI already boasts an extensive scope of foreseeable uses cases and more, we are only seeing the tip of the iceberg. It is no wonder that this area is a bright spark attracting rising levels of interest, especially from businesses. While AI development was initially driven by academia, company/industry-affiliated research teams now head the charge in AI development, as businesses clamour to stay ahead of the curve and seize opportunities to grow their businesses and revenue.

Source: iStock

Affiliation of research teams building AI systems



Source: Sevilla et al, OurWorldInData, DBS

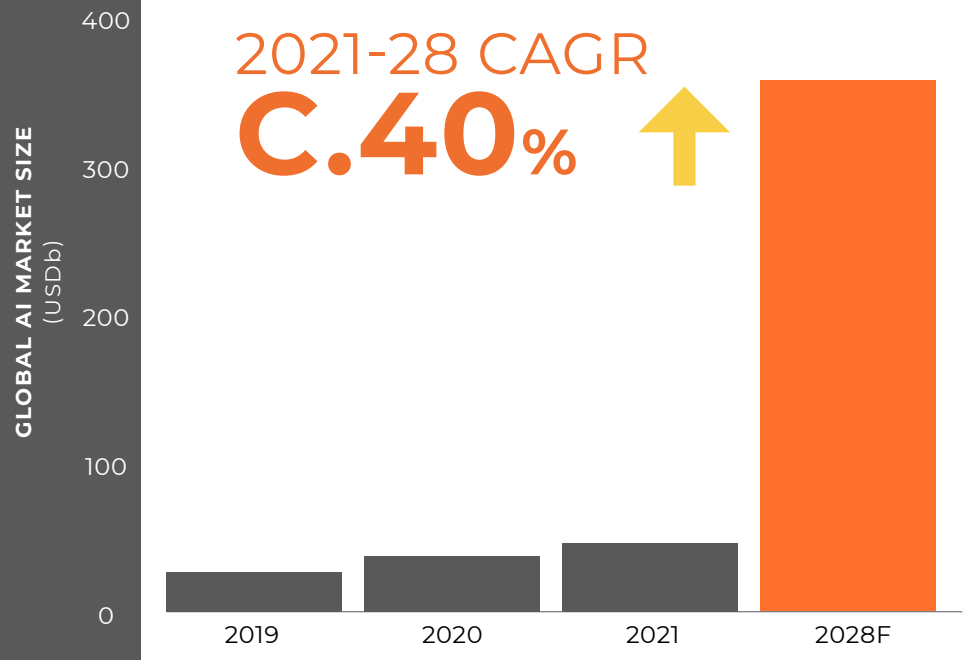
"Nobody is ahead of anybody else by more than two to six months"

Yann LeCun, Meta's Chief AI Scientist (2023)

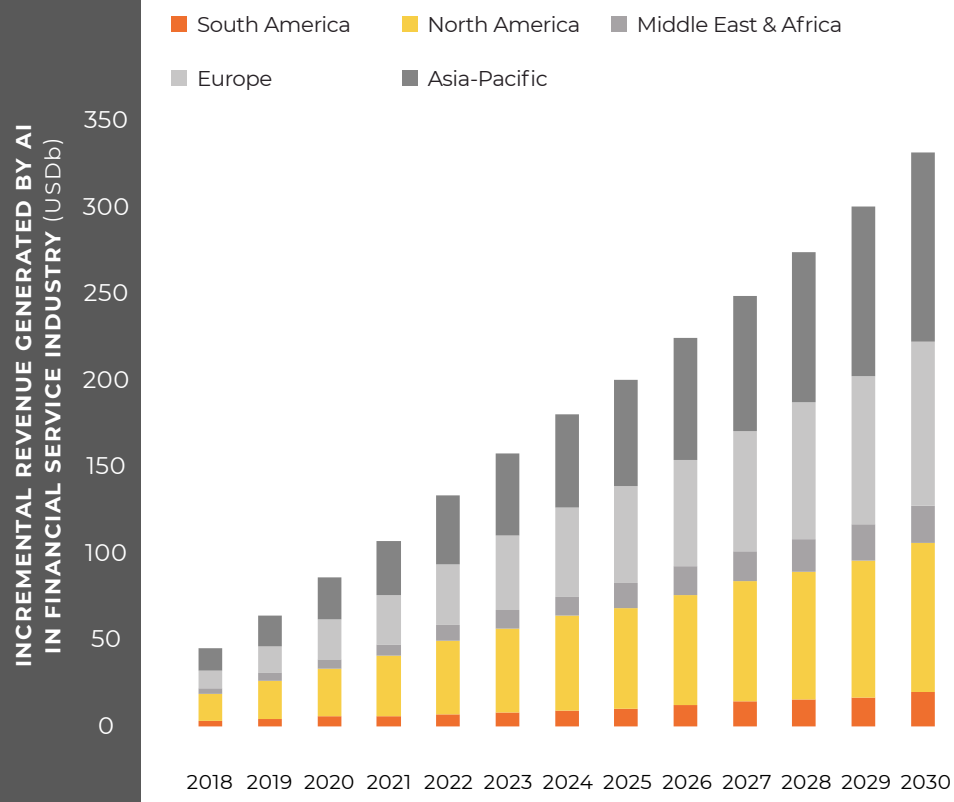
Exponential growth ahead.

AI's revenue potential is projected to grow rapidly over the next decade. Back in 2021, Fortune Business Insights had already estimated that the Global AI market size would grow at a CAGR of 40% to reach USD360.4b by 2028. Considering these projections were made even before the meteoric rise of ChatGPT and the recent quantum leaps in AI technology, they would most likely be considered conservative by today's standards. All this to say, the total addressable market for AI is more than likely to grow at breakneck speed moving forward.

TOTAL ADDRESSABLE MARKET FOR AI SET TO BALLOON



AI TO BRING TOP LINE GROWTH TO FINANCIAL SERVICES INDUSTRY



Source: Fortune Business Insights, Statista, DBS

Example: AI giving banks more bang for their buck. As testament to AI's potential for exponential growth, we already seeing businesses leveraging AI capabilities to drive better productivity and decision making. Take the banking and financial services industry for example. The use of AI in banking is not new; we have seen rising adoption of chatbots to answer frequently asked customer questions in the past five years. As generative AI models grow increasingly competent, the scope of customer queries and transactions that can be outsourced to AI will expand. Consequently, this will allow banks to deal with drastically larger transaction volumes with smaller staff strength, which will in turn lower their cost-to-income ratios and increase profitability.

But more than just increasing productivity, AI is also benefitting banks in other ways; managing credit risk of small and medium-sized enterprises among others. Notably, business value-add contributed by AI has been steadily increasing since 2018 and this figure is projected to reach USD300b by 2030, of which APAC alone will command the largest piece of the pie, with approximately 1/3 of the share.

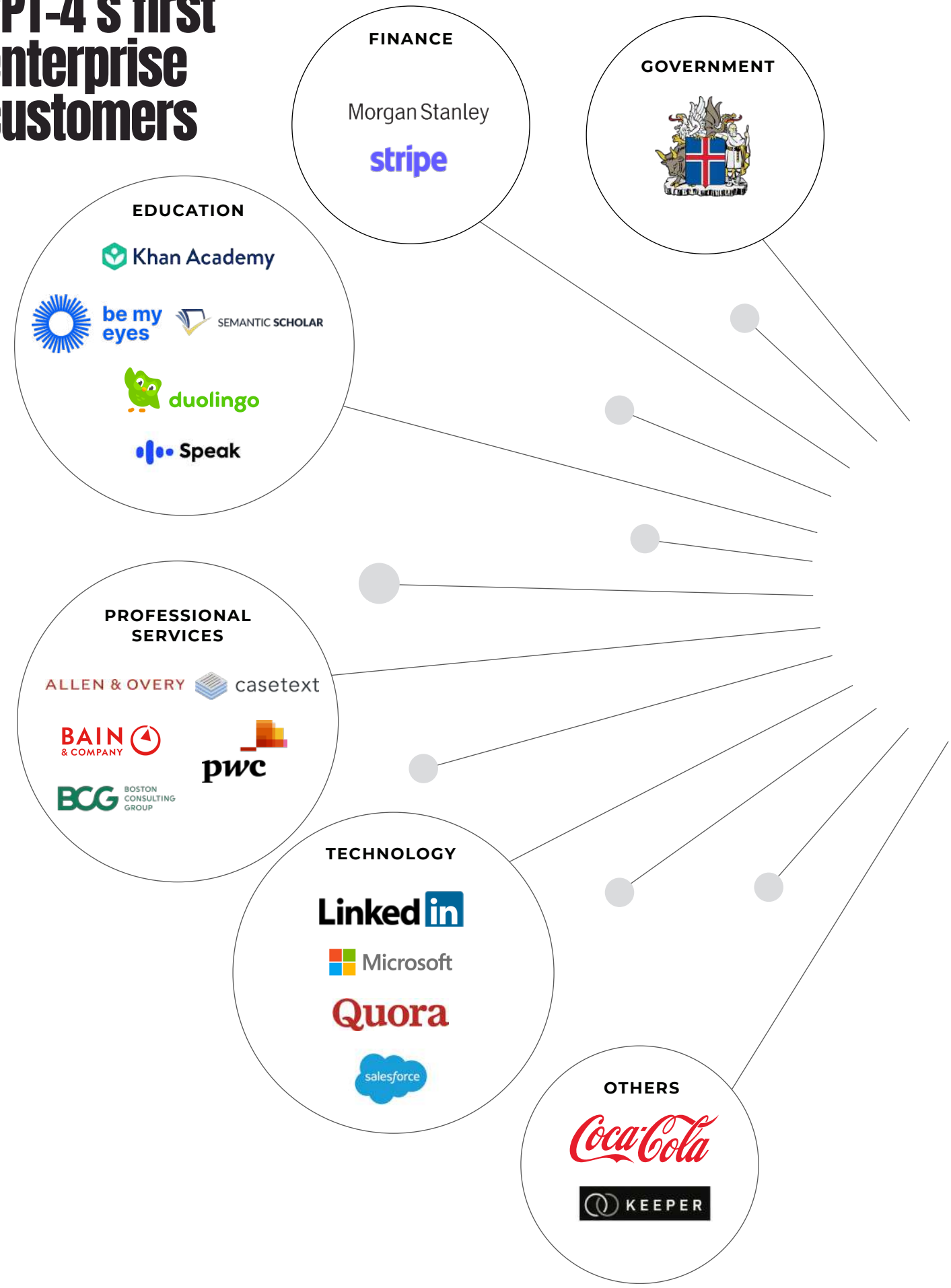
AI disrupting across industries. Beyond financial services, other industries also stand to benefit from AI's core strengths, including idea-generation, search, and data analysis. This is apparent from GPT-4's list of its first enterprise customers, which, despite being launched barely one month ago (at the time of writing), already boasts notable names across industries such as tech, finance, education, professional services, and even governments. Although the dynamism of AI's advancement makes it unclear to predict exactly how it will transform industries, or what it could create, what is evident is that technology's newfound ability to autonomously produce novel content and emulate human action is creating an exciting explosion of creativity, ideation, and productivity.

Select applications of AI in various industries

INDUSTRY	RELEVANT STRENGTHS OF AI	USE OF AI
LEGAL	Interpretation of text in a fixed format	• Answering complex questions using vast amounts of legal documentation
	Interpretation of repetitive technical phrases	• Drafting of contracts • Reviewing documents, identifying clauses of interest
TRANSPORT & LOGISTICS	Reliance on location services	• Converting of satellite images to map views • Enabling exploration of new locations
SEMICONDUCTOR CHIP DESIGN	Use of reinforcement learning	• Optimising component placement in semiconductor chip design, to reduce the time taken to develop products
PHARMACEUTICALS/ BIOMEDICAL SCIENCE	Generation of synthetic data based on real data	• Accelerating drug discovery through better understanding of diseases and discovery of chemical structures • Generating synthetic data for healthcare/medical research and analysis, to protect privacy of real patients
PRODUCT DESIGN	Generation of new images based on existing designs and text prompts	• Generating ideas, designing product models • Customising visuals to match text/ audio based on content
SALES & MARKETING/ CUSTOMER CARE	Generation of text, image, music by referencing an internal database	• Crafting personalised marketing and sales content • Developing virtual sales assistants
BANKING & INSURANCE	Generation of text responses by referencing an internal database	• Supporting front office staff to synthesise responses to customer queries using a company's internal database
OPERATIONS	Generation of text responses by referencing an internal database	• Generating task lists based on verbal prompts, for efficient execution of a given activity
IT/CYBERSECURITY	Ability to take text instructions and/or use different programming language	• Writing, documenting, checking, and simplifying code • Translating between programming languages • Reviewing large amounts of code for defects/inefficiencies • Generating synthetic data to test cybersecurity software

Source: Gartner, McKinsey, DBS

GPT-4's first enterprise customers



Source: Alan Thomson, DBS

Investment expressions

In search of the next big thing. Investors are always on the lookout for the next iPhone or the next Tesla, hoping to catch the cusp of the next wave of innovation that would astronomically propel returns. However, the key difficulty isn't discerning the winners emerging from disruptive technology; rather, they are the (a) scarcity of investable avenues that can truly capture the upside of the new technology given that such companies might still be privately owned (or not even incorporated yet), or (b) the complexity of knowing how much of this upside is already priced into existing opportunities. Nonetheless, we believe there are four major current themes that would emerge as long-term beneficiaries of the AI revolution.

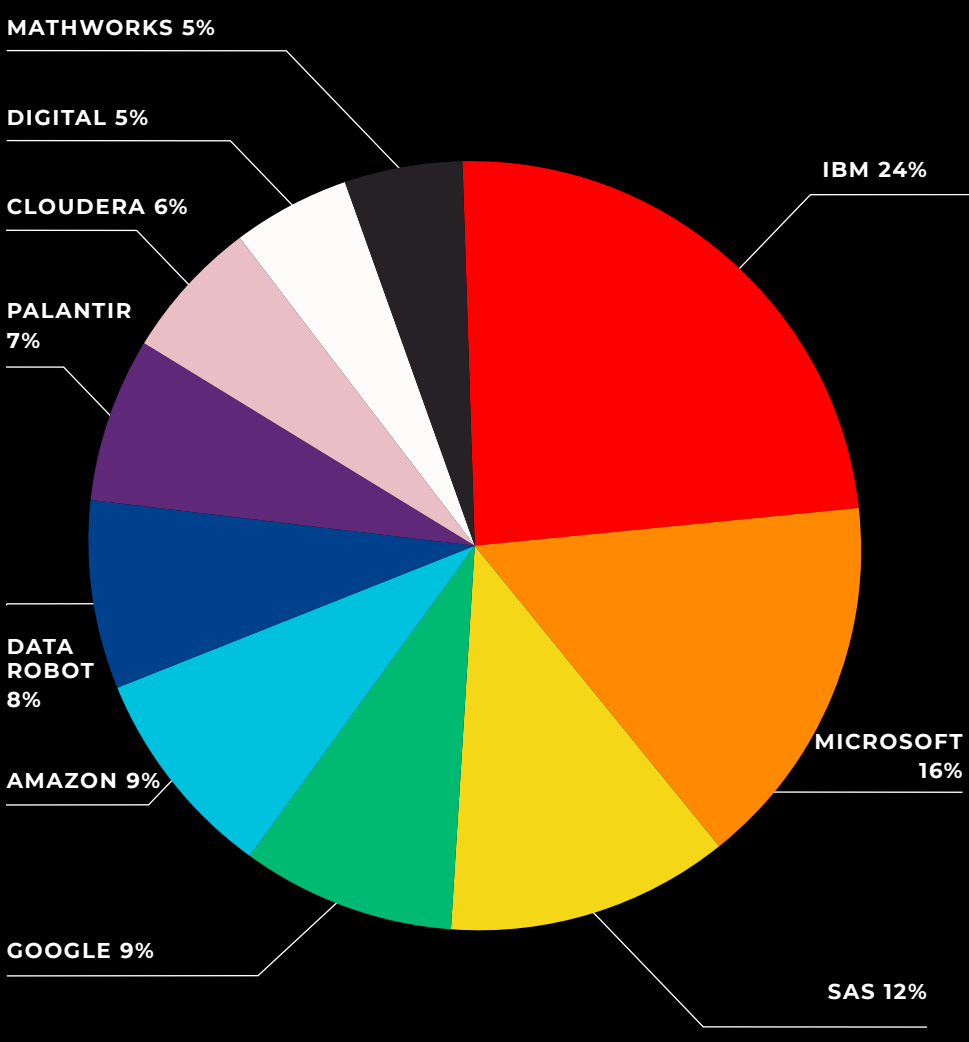
It is no surprise that Big Tech companies are spending big, and feature prominently in the recent years of AI-related acquisitions.

1. BIG TECH

The strong get stronger. It's no secret that Big Tech companies (FAAMG - Facebook, Apple, Amazon, Microsoft, and Google) have emerged as structural winners under the irreversible secular trends of technological disruption and digitalisation. With (a) billions of dollars in cash reserves, (b) ready access to tech-talent, and (c) a huge repository of user data to train AI models, structural tailwinds could only flow more forcefully under the AI revolution.

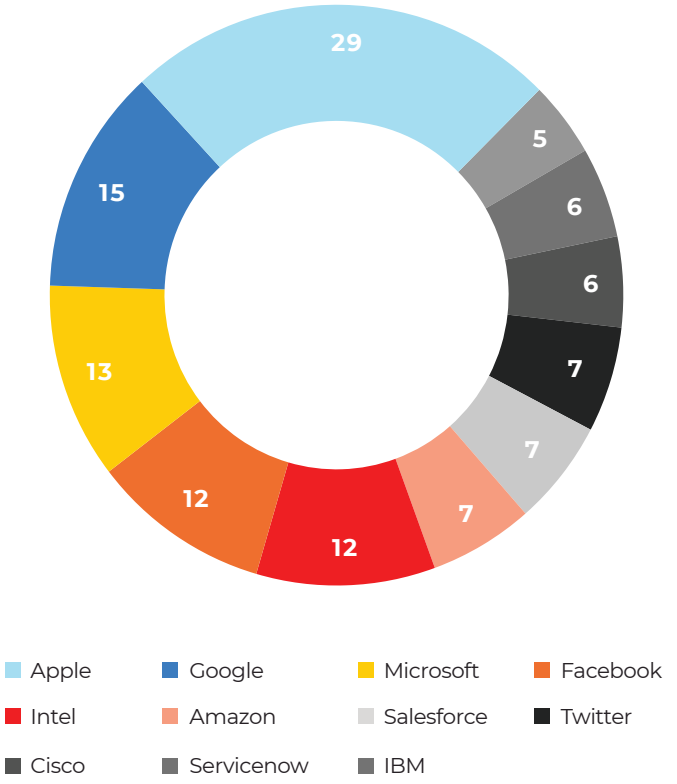
Big Tech, Big wallets. Moreover, such training of AI models requires extensive computing power and high running costs, costs that only the most profitable companies have the bandwidth to incur. For example, a single training run for GPT-3 reportedly costs Open AI c.USD12m. Such expenditure is undeniably imperative in the tech industry, having experienced how network effects have led to a "winners-take-all" dynamic.

TOP-6 FIRMS COMMANDED C.75% MARKET SHARE WITHIN AI SOFTWARE LEADERS



Source: Statista, DBS

SELECT AI-RELATED ACQUISITIONS FROM
2010 TO 2021



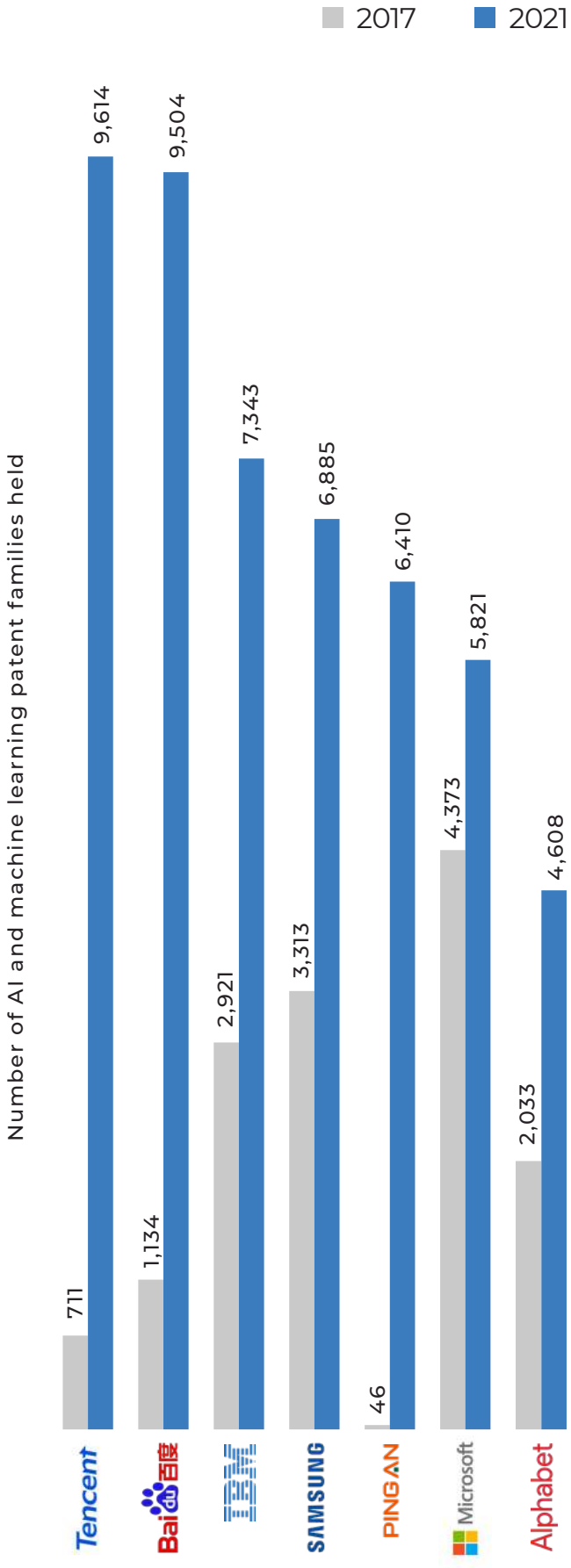
Source: cb insights, DBS

2. INTEGRATED CIRCUIT – CHIP DESIGNERS + SEMICONDUCTOR FOUNDRIES

Semiconductors are the foundational bricks of the digital world. AI models typically require advanced chipsets, both in training and in production. For instance, ChatGPT is able to generate responses in split seconds due to Microsoft Azure datacentres that are powered by tens of thousands of Nvidia GPUs. Market research agency TrendForce estimates that the GPT model needed about 20,000 GPUs to process training data in 2020, and moving forward, running ChatGPT is expected to require at least 30,000 GPUs.

Further development and uptake of AI across industries would only increase demand for GPUs, microprocessors, power management ICs etc, especially as commercial development takes over which requires the speed and sophistication of AI models to grow.

COMPANIES OWNING THE MOST AI/MACHINE LEARNING PATENTS



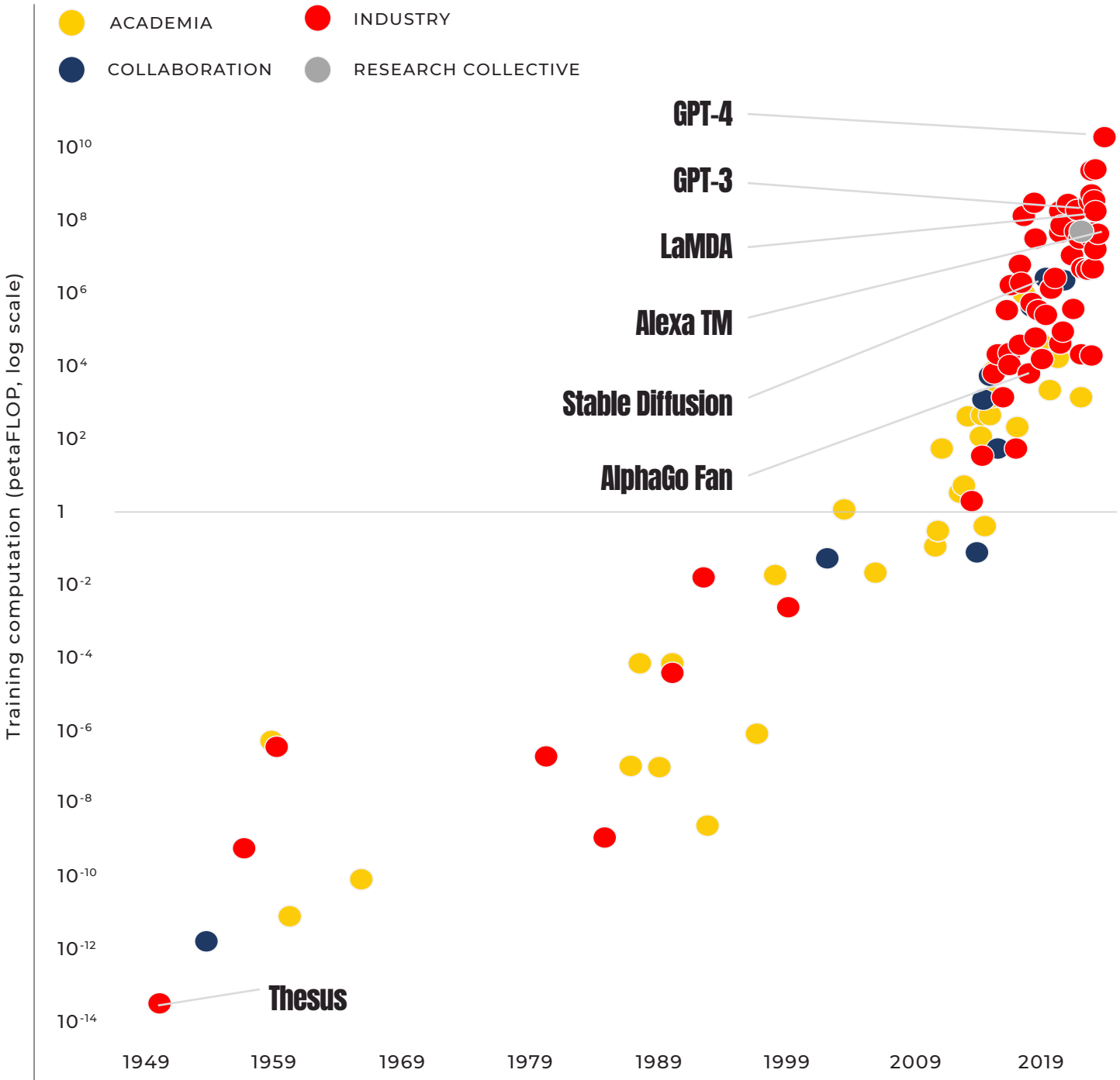
Source: Statista, LexisNexis, PatentSight, DBS

EXAMPLES OF GENERATIVE AI APPLICATIONS BY TYPE AND COMPANY

	OpenAI	stability.ai	DeepMind	Meta	NVIDIA.
Images	Dall-E2	Stable Diffusion	Imagen Image	Make-a-scene	eDiff-I
Language	ChatGPT	StableLM	PaLM	LlaMa	MT-NLG
Code	ChatGPT/ CoPilot		Pitchfork	Aroma	
Audio	JukeBox	Dance Diffusion	MusicLM	Audio Gen	
Bio-chemistry	BioGPT/ MoLer	Libre Fold	Alpha Fold2	ESMFold/ Galactica	MegaMol Bart

Source: iStock, Company websites, DBS

COMPUTING POWER USED TO TRAIN AI SYSTEMS



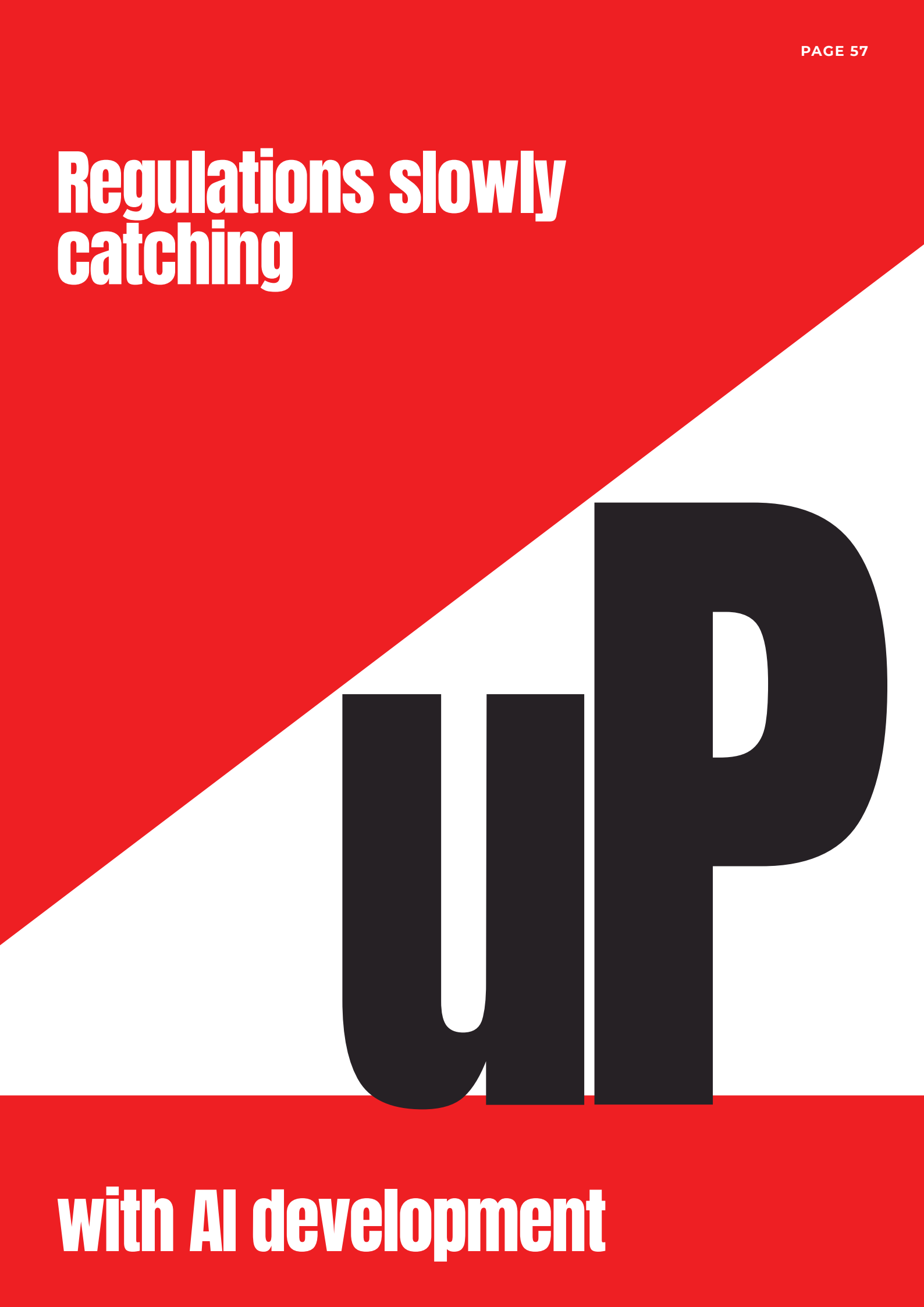
3. CLOUD PLATFORMS

Model data needs a home. Once AI models have been sufficiently trained and deemed fit for commercial purposes, they are likely to be deployed on cloud platforms for ease of access by a general user base through an API. A proliferation of models for language, image, video, music, etc. would naturally give rise to demand for cloud companies to host them, while also requiring ever-expanding bandwidth to accommodate the rise in AI adoption.

A "Cambrian explosion" of AI-generated content. Given that Generative AI is particularly adept at generating large amounts of content, businesses that produce voluminous amounts of material (news websites, e-commerce platforms, online videos) would also likely require ever-increasing hosting space from cloud providers.

Source: Sevilla et al., OurWorldInData, DBS

Regulations slowly catching



with AI development

4. CYBERSECURITY

“What all of us have to do is to make sure we are using AI in a way that is for the benefit of humanity, not to the detriment of humanity.”

Tim Cook, Apple CEO

The dark side of AI. The world had benefitted greatly in the Age of Information – democratising access to data and permeating knowledge to millions across the world. But that has now given way to the Age of Misinformation, empowered by AI. Generative AI is especially gifted in “Deepfakes” – synthetic media that assimilates the likeness of a person in realistic fashion – which can be used to spread misinformation at scale. We believe that this warrants a greater need for cybersecurity across all platforms, especially to prevent the misappropriation of identity for theft or more malicious purposes.

For example, an experiment conducted by Singapore’s GovTech found that phishing emails composed and customised using generative AI had significantly higher clickthrough rates compared to human-generated emails, highlighting potential use by cyber criminals. Moreover, Binance executive Patrick Hillmann reported that scammers had created an AI hologram version of him to trick people into meetings. Such developments underline that real threats from malicious misuse of generative AI already exist today.

Slumdog Millionaire: Images generated using MidJourney






Source: Artist Gokul Pillai created a series of portraits of billionaires - including former US president Donald Trump, and business magnates Mark Zuckerberg, Jeff Bezos, Bill Gates, Elon Musk, and Warren Buffett.

EXAMPLES OF AI INDUSTRY PARTICIPANTS

AI Software & Platforms

- Google
  - Deepmind, TensorFlow
- Amazon
  - Bedrock
- IBM
  - Watson
- Microsoft
  - OpenAI
- Salesforce
  - Einstein
- H2O.ai

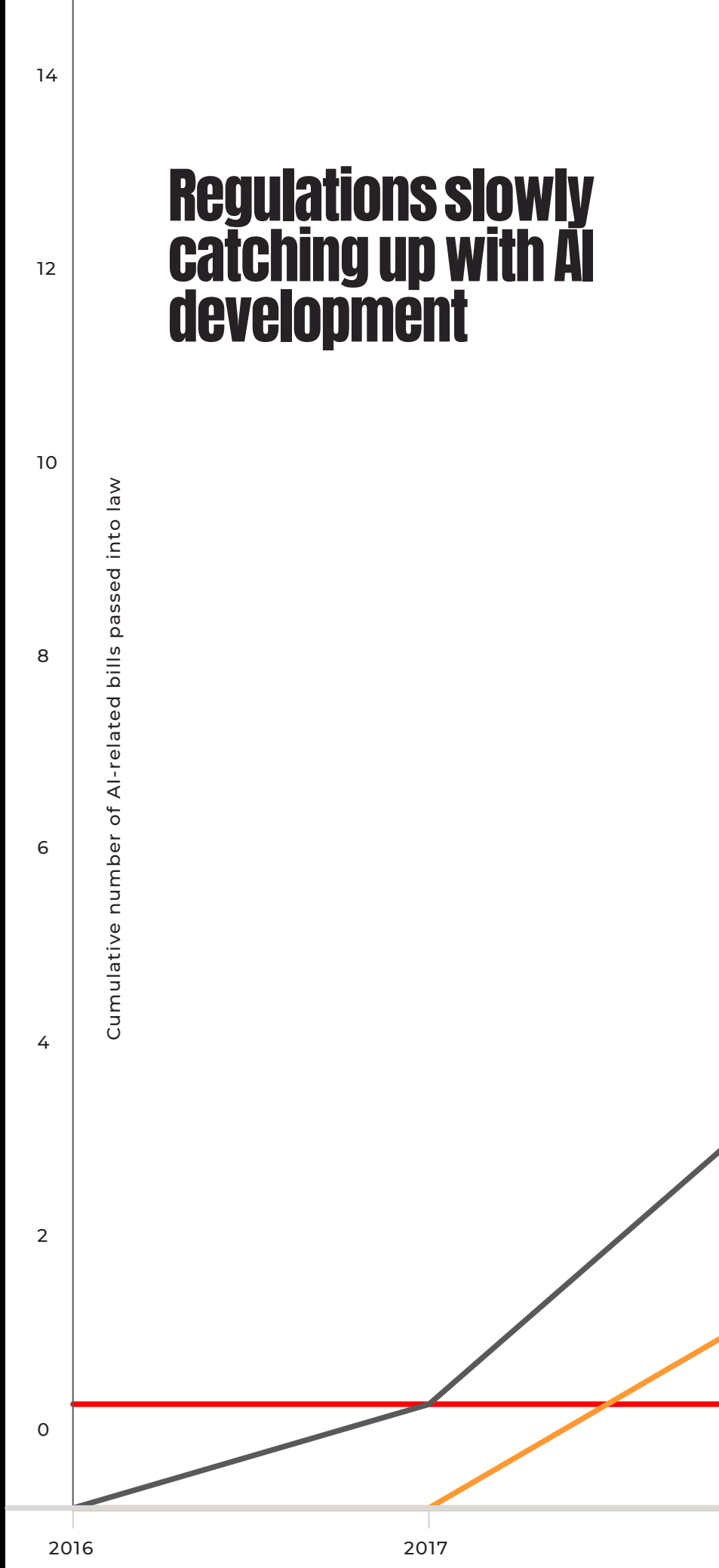
AI Chip Designers

- Nvidia
  - Volta, Xavier, H100
- IBM
  - AIU
- Xilinx
  - Versal, Everest
- AMD
  - Ryzen, Radeon
- Apple
  - ANE
- Alibaba
  - Hanguang 800
  - Xuantie
- Intel
  - Xeon, Nervana
- Broadcom
  - Jericho3-AI
- Baidu
  - Kunlun
- Qualcomm
  - Cloud AI 100
- NXP
  - NXP eIQ
- Dassault
- Amazon
  - AWS Inferentia
- ARM

Semiconductor Foundries

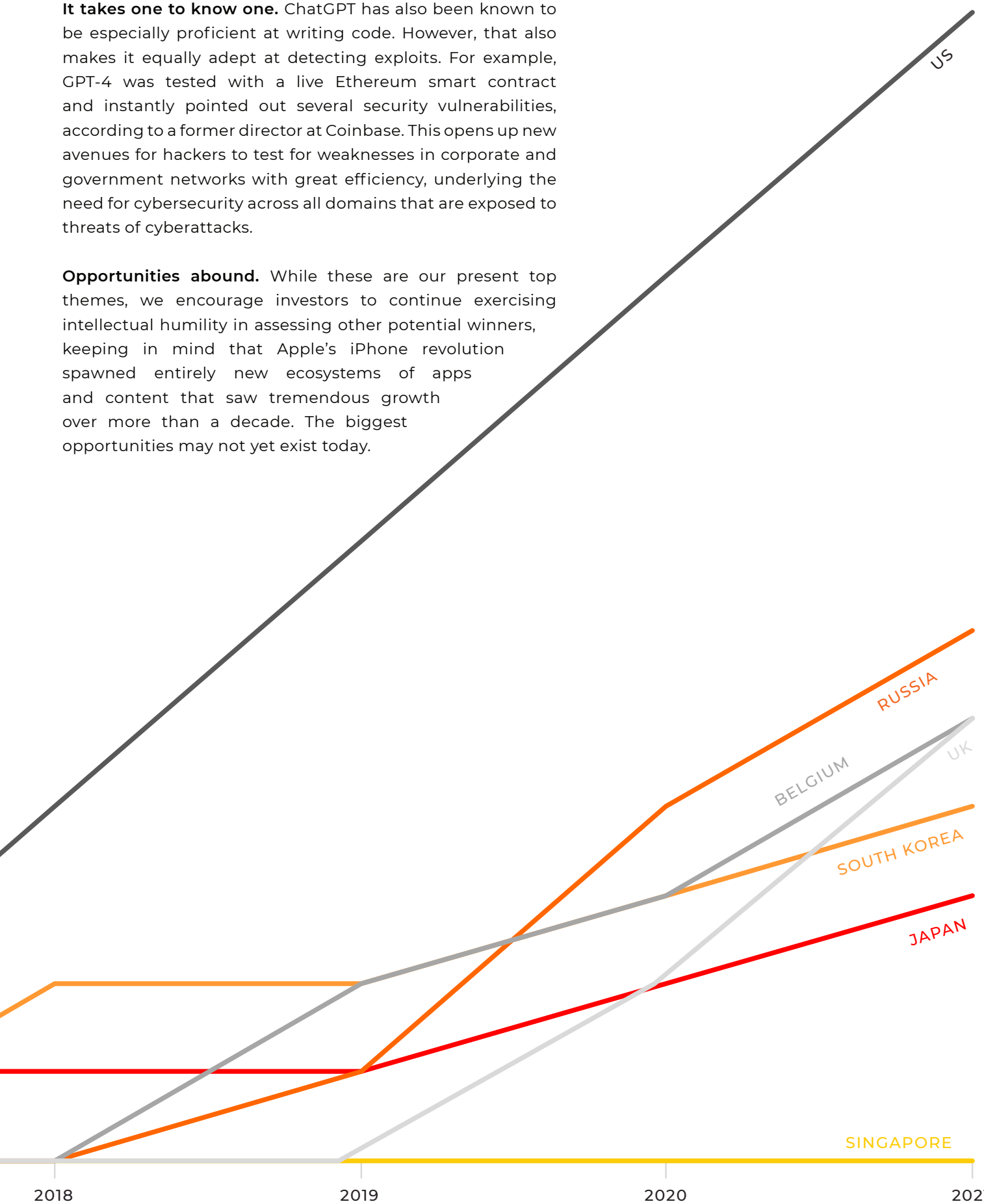
- TSMC
- Samsung
- SMIC
- Global Foundries
- HH Grace
- DB Hitek

Regulations slowly catching up with AI development

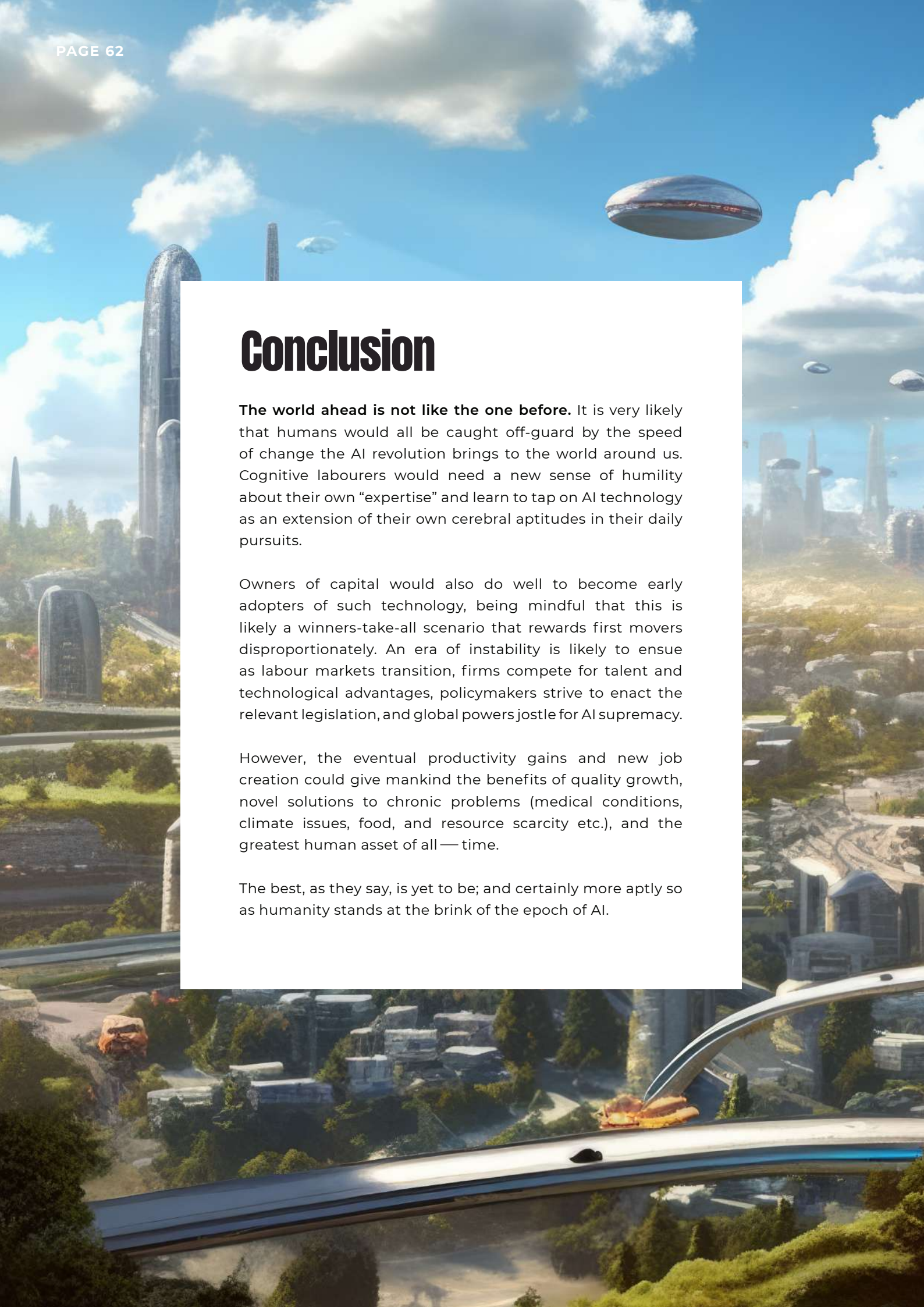


It takes one to know one. ChatGPT has also been known to be especially proficient at writing code. However, that also makes it equally adept at detecting exploits. For example, GPT-4 was tested with a live Ethereum smart contract and instantly pointed out several security vulnerabilities, according to a former director at Coinbase. This opens up new avenues for hackers to test for weaknesses in corporate and government networks with great efficiency, underlying the need for cybersecurity across all domains that are exposed to threats of cyberattacks.

Opportunities abound. While these are our present top themes, we encourage investors to continue exercising intellectual humility in assessing other potential winners, keeping in mind that Apple's iPhone revolution spawned entirely new ecosystems of apps and content that saw tremendous growth over more than a decade. The biggest opportunities may not yet exist today.



Source: AI Index Report (2022), OurWorldinData, DBS
Count of bills passed into law by national legislative bodies with the keywords "artificial intelligence" in the title or body of the bill.



Conclusion

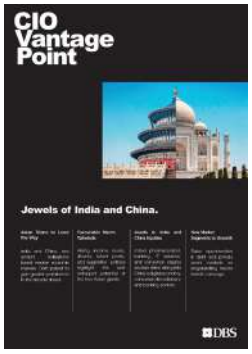
The world ahead is not like the one before. It is very likely that humans would all be caught off-guard by the speed of change the AI revolution brings to the world around us. Cognitive labourers would need a new sense of humility about their own “expertise” and learn to tap on AI technology as an extension of their own cerebral aptitudes in their daily pursuits.

Owners of capital would also do well to become early adopters of such technology, being mindful that this is likely a winners-take-all scenario that rewards first movers disproportionately. An era of instability is likely to ensue as labour markets transition, firms compete for talent and technological advantages, policymakers strive to enact the relevant legislation, and global powers jostle for AI supremacy.

However, the eventual productivity gains and new job creation could give mankind the benefits of quality growth, novel solutions to chronic problems (medical conditions, climate issues, food, and resource scarcity etc.), and the greatest human asset of all — time.

The best, as they say, is yet to be; and certainly more aptly so as humanity stands at the brink of the epoch of AI.

CIO COLLECTION



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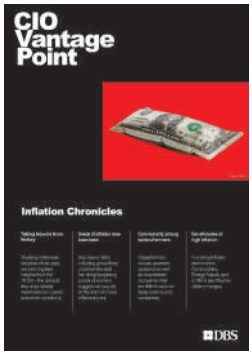

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