

Global Insights

BRAVE NEW WORLD

AI and its Downstream Implications



EXECUTIVE SUMMARY

- The advent of Artificial Intelligence may represent a watershed in human history, with the potential to transform daily lives to an extent that may be difficult to appreciate fully at this moment in time. But as unprecedented as the technological shock from Generative AI may prove to be, the capital market response to it already follows familiar patterns.
- Rather than simply separate reality from hype, successful investors must be able to map that reality onto company fundamentals. This rewards second-and-third order thinking, as the most salient feature of the technological revolution – escalating revenue growth at companies at the epicenter of the technological quake – may ultimately prove to be a small fraction of the total economic value it delivers.
- As with the advent of electrification – a turning point to which the development of AI systems has been compared – the main risk for investors today may be viewing the AI revolution too narrowly. The productivity gains from investment in software development and life sciences, content generation, and CRM systems already suggest that the assets best positioned to benefit from AI may have not yet landed on the broader market’s radar.

It is difficult to overstate the transformation potential of Artificial Intelligence (AI). We may soon live in a world where computer systems can generate new scientific knowledge and perform virtually any human task. As unprecedented as the technological shock may prove to be, the capital market response to it already follows familiar patterns.

When a foundational technology enters the public's consciousness, investors naturally focus on the technology itself and companies thought to be operating at its frontier. Generative AI has been no exception. Asset prices quickly reach levels difficult to rationalize using conventional financial metrics; "value" comes to be associated with subjective impressions of the technology's potential, barriers to entry, and ultimate scalability.

Debates regarding the valuation of nascent technology often degrade on two axes. Enthusiasts, typically from the tech sector itself, recast investor skepticism as ignorance;

an unwillingness to deploy aggressively into the space reveals a lack of technical understanding. Detractors, for their part, often dismiss novel valuation methods and optimistic "total addressable market" forecasts (Figure I) as tell-tale signs of a hype campaign designed to separate credulous investors from their capital. Portfolios can be derided as uninformed or naïve, depending on perspective.

Such discussions elide a crucial point. While dismissing AI's transformational potential could prove to be a very expensive mistake, returns ultimately depend on how new technology gets adopted and monetized. And this process can occur over long horizons and manifest on income statements some distance away from the initial shock. As with the advent of electrification – a turning point to which the development of AI systems has been compared – the main risk for investors today may be viewing the AI revolution too narrowly and failing to perceive all of the downstream opportunities (and risks) it creates.

Figure I.
AI Market Size Expectations (\$Billions)

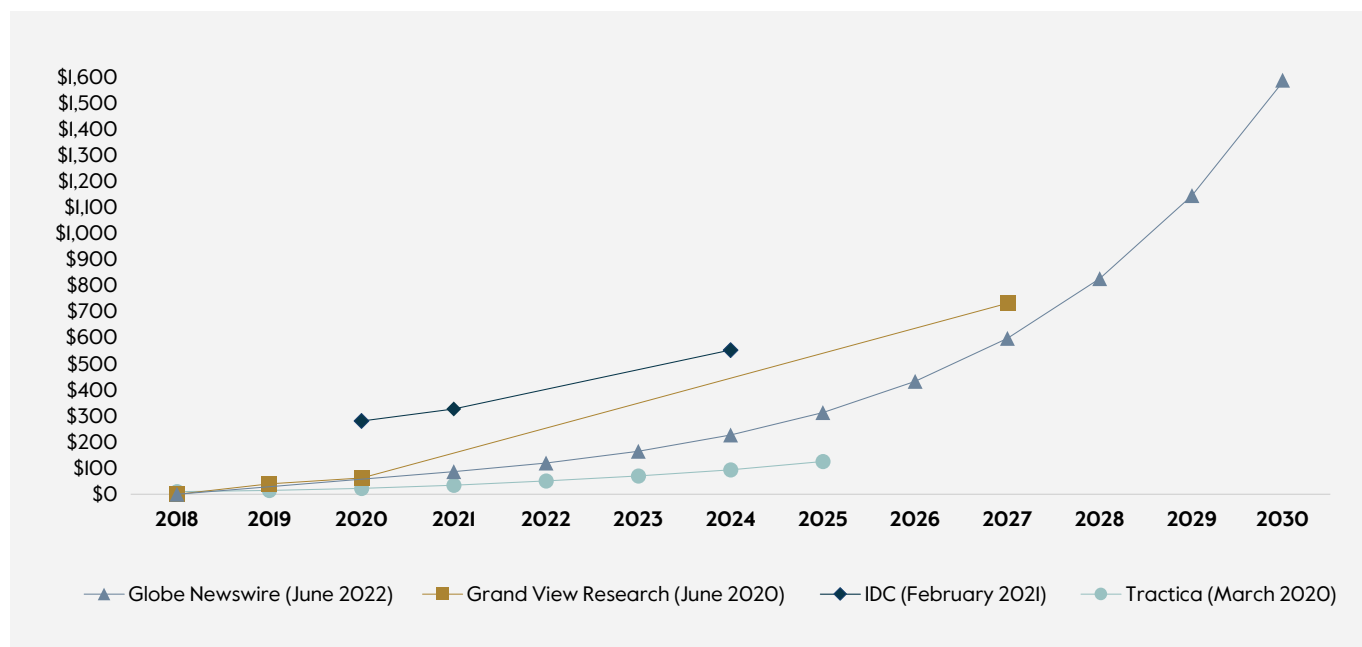


Figure I. Source: IDC, Tractica, Grand View Research, Statista, GlobeNewswire, Jefferies Equity Research.

GROUNDBREAKING CAPABILITIES & ADOPTION RATES

Investor interest in “artificial intelligence” has spiked over the past year thanks to the release of Generative AI tools capable of producing content and analyses of unprecedented sophistication and breadth in response to natural language prompts. Most notable has been OpenAI’s release of ChatGPT, which reached 100 million users in just two months, a small fraction of the time it took Facebook and other social media platforms to achieve similar scale (Figure 2). These models can reason probabilistically, have been trained on virtually the entire internet corpus, and can be directed to process that information through conventional text that one might otherwise put into an email (not arcane code).

Generative AI already represents an historic technological leap, at least as meaningful as internet-based search engines’ displacement of reference libraries. But whereas that revolution liberated information from the physical constraints of the analog world, AI liberates information flows from human intermediation. Machine Learning algorithms demonstrated

software’s capacity to identify patterns in data and anticipate sequences faster and more precisely than humans. Generative AI represents the next step in this evolution, with software now able to synthesize data and curate responses beyond those directly intended by the programmer (Figure 3, p. 5). And there is still ample opportunity to reinvent the language tools that help engineers develop new generations of software even more efficiently.¹

One notable subset of Generative AI is large language models (LLMs). Impressive as this class of deep-learning algorithm is, it represents but one step on a longer road to “Artificial General Intelligence” – autonomous computer systems that can learn to perform virtually any task of scientific or economic value. While many AI researchers would argue that we’re on the cusp of this world-historical turning point, others contend that AGI may be decades away if it’s ever achieved at all. Much of the disagreement centers on arcane Cartesian questions of self-awareness and mysteries surrounding the biochemistry of human consciousness and cognition.² The more practical and economically relevant the definition, the closer to AGI we may be.

Figure 2. Time to 100 Million Users

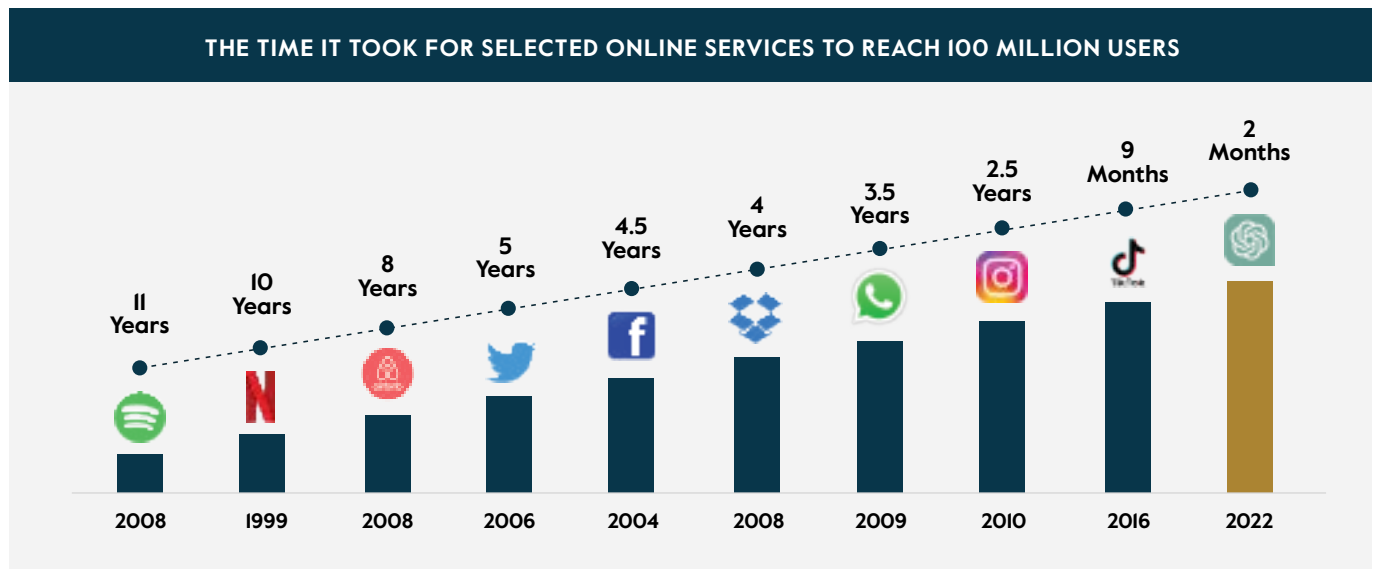
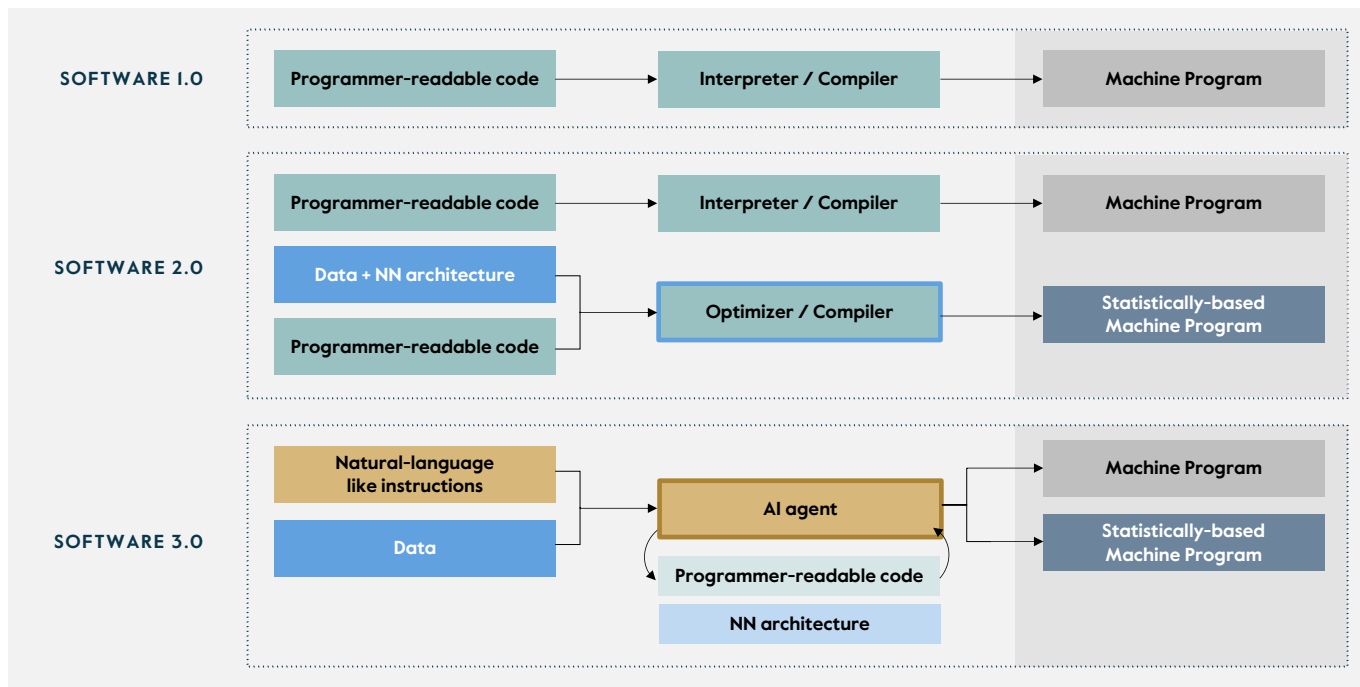


Figure 2. Source: Visual Capitalist, February 2023.
 1. “Developer Tools 2.0,” Sequoia Capital, March 2023.
 2. C.f. Landgrebe, J. and B. Smith. Why Machines Will Never Rule the World. Routledge, 2022.

Figure 3.
Next Step in Evolution of Software



IMMEDIATE APPLICATIONS

All major technology and software vendors are currently embedding Generative AI into their stack. Desktop applications (email, word-processing, etc.), e-commerce, internet search, social media, and content consumption will all integrate AI functionality. Such efforts remain in a beta stage with limited visibility into monetization. But the user experience is likely to improve immeasurably across each of these dimensions, with significant scope for labor productivity gains from accelerated information gathering and idea and text generation (Figure 4, p. 6).

More consequential may be the evolution of business models and corporate strategy. Management teams could increasingly rely on AI to formulate marketing strategies and pricing decisions and diligence potential acquisition targets. Digital marketing is likely to become even more

precisely tailored, both in terms of the content of advertising campaigns and the targeting of audiences most likely to act on them. AI will revolutionize customer relations management (CRM) across industries, generating upselling proposals in real time based on text from the conversation cross-referenced with internal customer data, external market trends, and other relevant information. Chatbots may soon account for the bulk of consumer-facing interactions in travel, finance, and e-commerce and eventually guide customers' entire shopping experience.

The applications for media and education are obvious. Generative AI applications can produce new music, fictional narratives, poetry, visual artwork, and digital imagery. The recent Screen Actors Guild (SAG) and Writers Guild of America (WGA) strikes have been fomented, in part, by concerns about AI's displacement potential. AI-generated content raises novel copyright issues since existing works are accessed to produce

Figure 4.
AI Use Cases

| CONTENT GENERATION | SOFTWARE DEVELOPMENT | IMAGE GENERATION | NEW PRODUCT DEVELOPMENT | SALES & MARKETING | Q&A INTERFACES |
|---|---|---|--|--|--|
| <ul style="list-style-type: none"> • Content • SEO • Primary research • Synthesis • Alert generation • Support ticketing systems • Language translation • Create website drafts | <ul style="list-style-type: none"> • Automatic code generation • CoPilots • Regenerative code • Test script generation • Bug fixes | <ul style="list-style-type: none"> • Custom generated photos • Image touch up • Banner creation • Medical imaging • Product detail page image generation • "Try it on" AR | <ul style="list-style-type: none"> • Interactive data products • Conversational interface & querying • Whitelabeled 1st party trained models • UX design • Translation from design to code | <ul style="list-style-type: none"> • Content creation • Lead generation • Sales forecasting • Personalized ads • Org specific sales collateral • Customer support • Conversion rate optimization • A/B testing | <ul style="list-style-type: none"> • R&D idea generation • Identity verification • Order taking • Advanced Chatbots • Disaster planning & recovery • Strategy development • Competitor research |

"substantially similar" outputs.³ Technologically, the horse is out of the barn; the question is whether owners of existing copyrights will be the only ones legally sanctioned to employ AI to assist in the formulation, production, and marketing of cinematic, televisual, and audio works.

ChatGPT easily passed the Uniform Bar Examination taken by U.S. law school graduates and would earn a respectable 3.4 grade point average (on a 4-point scale) if enrolled as a freshman at Harvard College.⁴ Generative AI's prowess writing essays and taking tests raise thorny issues about the future of educational integrity, but also open the door to a new generation of digital tutors, autodidacts, and more flexible educational arrangements.

Huge productivity gains are already evident in software development, where Generative AI has halved the time necessary to write and test new code (Figure 5, p. 7). LLMs can predict the next lines of code based on the code already written and generate new code in response to tailored prompts from software engineers who are skilled in natural language describing software structures. As LLMs become familiar with the functionality and structure of programming languages, prompts can become less precise, allowing neophytes to code like seasoned professionals.⁵

While guidance from experienced engineers is fundamental to enable LLMs to write code, LLMs create significant efficiencies by filling in coding gaps in simplified prompts. Eventual gains from such automation may be especially pronounced among video game makers operating at the intersection of AI-generated content and software.

Companies will increasingly rely on Generative AI to clean existing data and produce prototype designs and accelerate product development. Life sciences companies, for instance, already use AI to generate sequences of amino acids and DNA nucleotides to shorten the drug design phase from months to weeks. Existing development programs require researchers to sort through millions of potential chemical reactions to synthesize a target molecule. AI models trained on existing chemical reactions data have already yielded a 15% reduction in development costs.⁶ We should expect to see comparable productivity gains wherever R&D depends on time-consuming, iterative processes based on complex interactions between variables or inputs.

Manufacturers can not only use Generative AI to design new products, but also optimize supply chains and automate shipping and production processes. The automotive industry has been especially aggressive in its adoption of AI and antecedent algorithmic technologies to these ends.

Figure 4. Source: Carlyle Analysis, 2023.

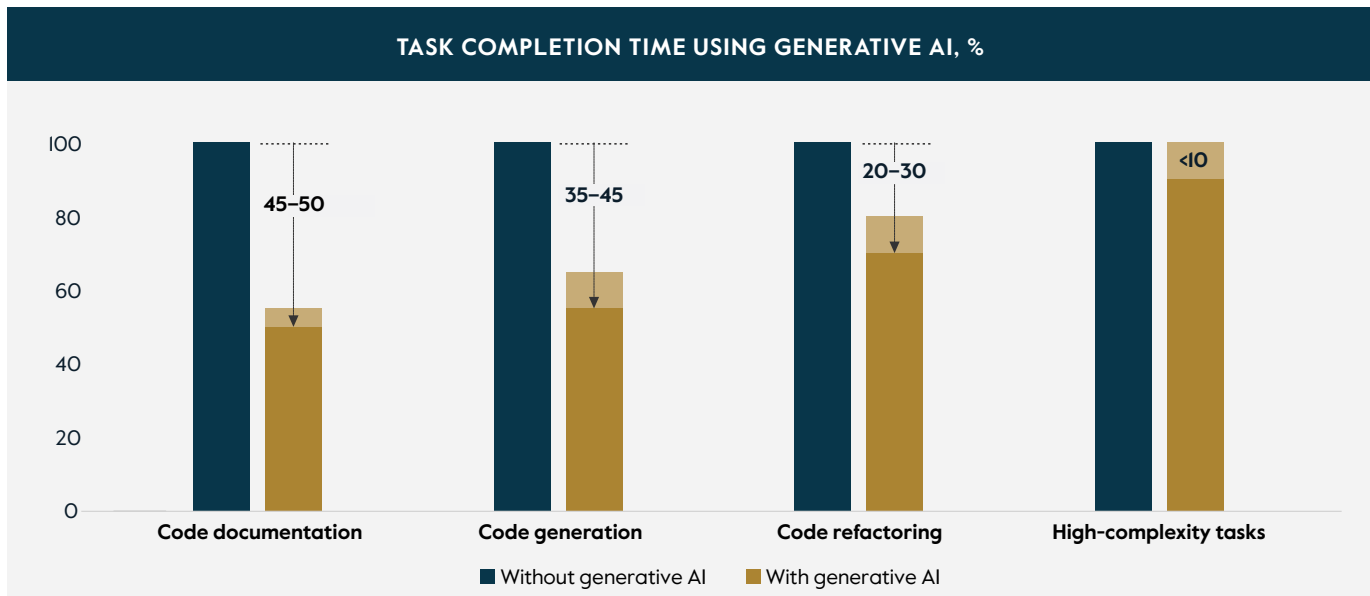
3. ABA Journal, March 2023. "ChatGPT goes to Harvard." Substack, July 2023.

4. "Beyond The Hype: How Generative AIs Transforming Software Development," Towards Data Science, May 2023.

5. G2Retro as a two-step graph generative models for retrosynthesis prediction, Communications Chemistry, May 2023.

6. G2Retro as a two-step graph generative models for retrosynthesis prediction, Communications Chemistry, May 2023.

Figure 5.
Accelerated Software Development



RISKS & JOB LOSS

The Janus face of new technology is obsolescence. It is estimated that Generative AI applications could eventually automate 60% to 70% of employee workloads,⁷ and this naturally arouses fear of job loss. It is important to note that this estimate refers to employee tasks not the employees themselves. For most occupations, we subscribe to the view that AI won't take your job; someone using AI will. This will result in dynamic adjustments in labor demand across occupations and activities rather than job loss (Figure 6, p. 8). Workload automation should increase throughput volumes, naturally increasing productivity levels (output per hour of work); and by freeing managers' finite time and attention and speeding more junior employees' progression up the learning curve, AI also could facilitate a sustained increase in productivity growth rates as human capital gets deployed more creatively (Figure 7, p. 9).

Obsolescence may be of greater concern for businesses and business models, as competition increasingly depends

on the speed with which companies adopt AI capabilities to cut costs and increase scalability. Competitive pressure this great naturally opens the door to charlatanry. Companies will market themselves opportunistically and, occasionally, deceptively. Mentions of "AI" on corporate earnings calls has risen exponentially (Figure 8, p. 9), and the more "AI" is invoked by competitors, the more susceptible laggard management teams become to imprudent budgeting and fairy-tale solutions.

We must also be mindful of the "hallucination problem" with LLMs, or their tendency to generate factually incorrect text that may seem semantically or syntactically plausible based on the corpus of data on which it has been trained. These statistical models predict the next word based on massive volumes of data and past context. They are built for fluency rather than reason, which means human verification of their outputs will still be required in many cases, and their use in mission critical applications like aeronautics or defense could lay very far in the future.

Figure 5. Source: McKinsey, 2023.
7. "Economic Potential of Generative AI," McKinsey & Co. June 2023.

Figure 6.
Dynamic Adjustment in Labor Demand

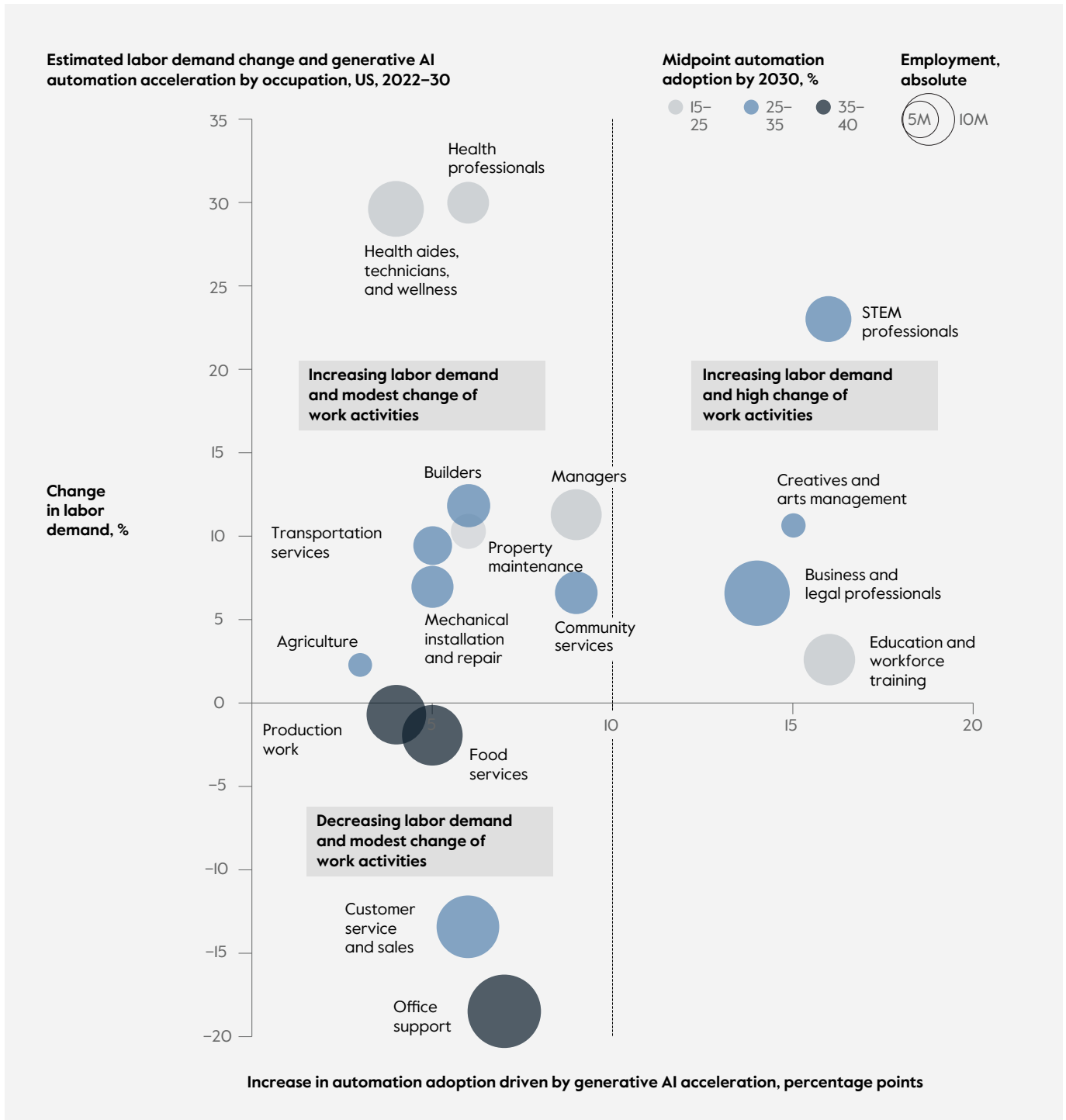


Figure 6. Source: <https://www.mckinsey.com/mgi/our-research/generative-ai-and-the-future-of-work-in-america>.

Figure 7.
Economy-Wide Positive Productivity Shock

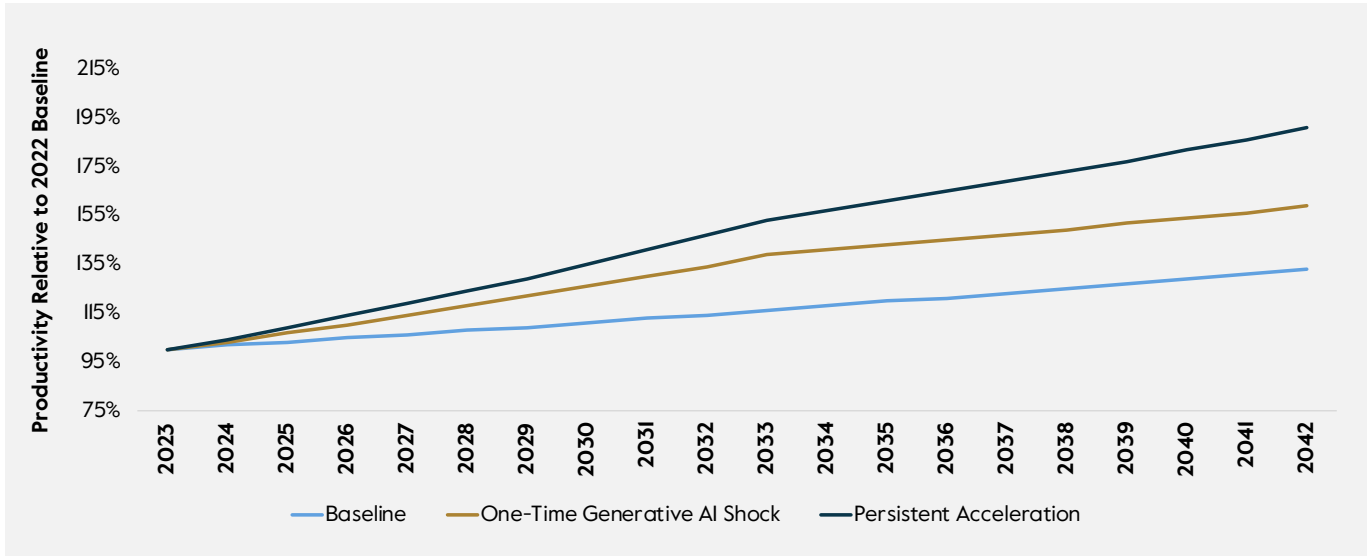


Figure 8.
Mentions of AI on Company Earnings Calls

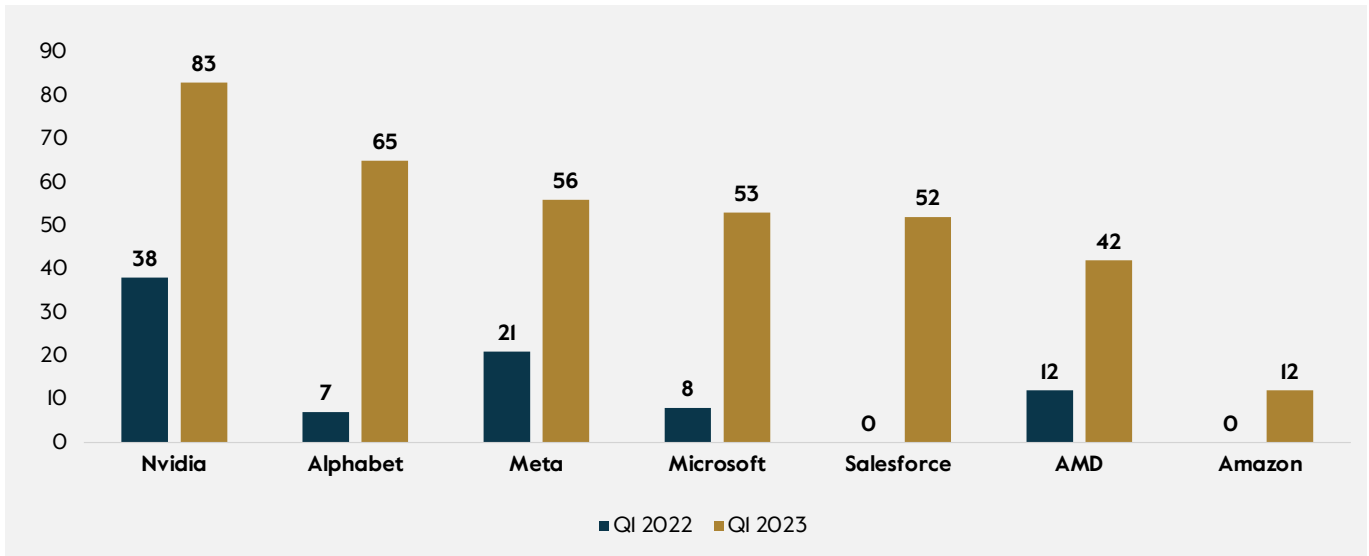


Figure 7. Source: Carlyle Analysis, Brookings Institution, 2023.

Figure 8. Note: Includes mentions of "AI" in analyst/journalist questions. Source: Company data, Statista, Goldman Sachs Global Investment Research.

BARRIERS TO ENTRY

At this stage, most of the market discourse has focused on those companies directly responsible for the development of LLMs. And, given the enormous costs involved, this has been and is likely to continue to be dominated by massive, cash-rich incumbents. Developing a state-of-the-art Generative AI model requires massive computational resources, specialized hardware like Graphics Processing Units (GPUs) and Tensor Processing Units (TPUs), and vast datasets that must be collected, stored, and curated. A single training run for a model comparable to ChatGPT requires millions of dollars.⁸ Rather than compete with better funded and more sophisticated incumbents, enterprises seeking to integrate AI into their products and services are more likely to partner with them. This has led to a boom in the market values of industry-leading hardware, software, and data cloud platforms (Figure 9) – including a \$700 billion increase in

Nvidia’s market capitalization since ChatGPT’s release – and creates significant headwinds for new entrants and small companies across much of the value chain.

This has not stopped capital from flowing to newer and younger companies, however. Over the past year, virtually any asset with known “AI upside” has become very richly valued, especially on a relative basis (Figure 10, p. 11). While all industries have been affected by the decline in venture and growth capital over the past year, AI companies have captured a larger share of that funding, especially those focused on novel approaches to AGI. In the U.S., AI’s share of funding rounds reached 23% in Q2-2023, more than tripling over the past 10 years and now the highest among all industry verticals (Figure 11, p. 11). In terms of invested capital, AI’s share has increased even more over the past year thanks, in large part, to Microsoft’s \$10 billion investment in OpenAI and Stripe’s \$6.3 billion Series I round.⁹

Figure 9.
MegaCap AI Companies’ Share of Total Returns

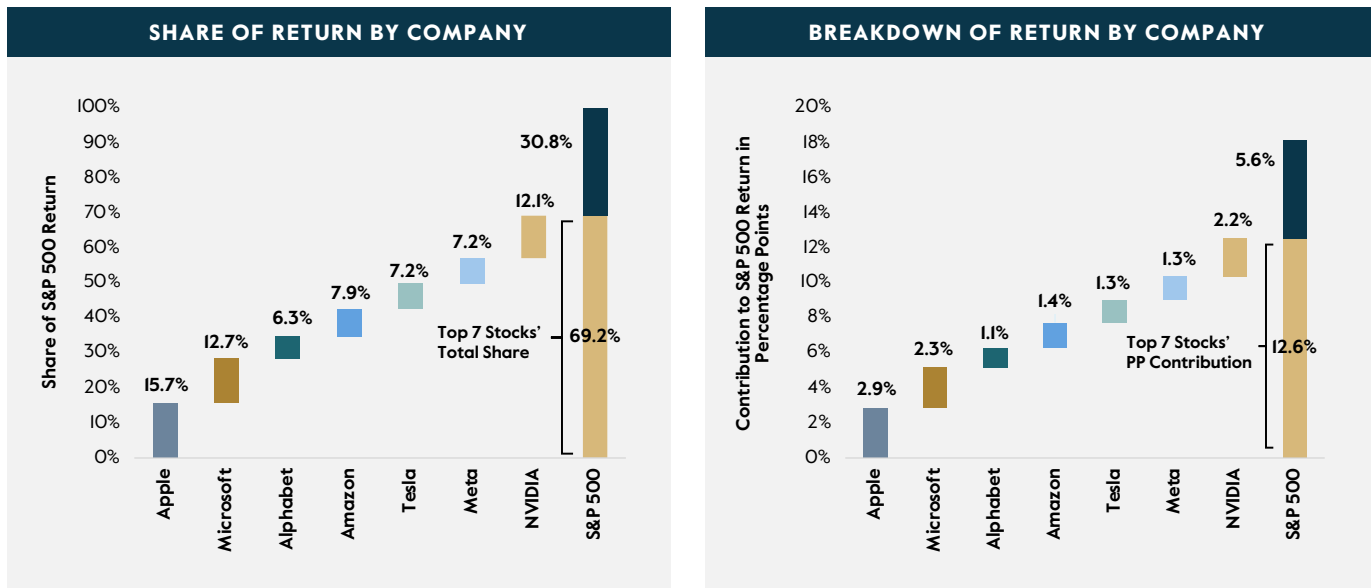


Figure 9. Source: Carlyle Analysis of Bloomberg Data, July 21, 2023.
 8. “Can You Build Large Language Models Like ChatGPT At Half Cost?” UniteAI, May 2023.
 9. Global Private Markets Quarterly Q2-2023, Carlyle Global Investment Solutions, July 2023.

Figure 10.
Rise in AI Attention & Valuations

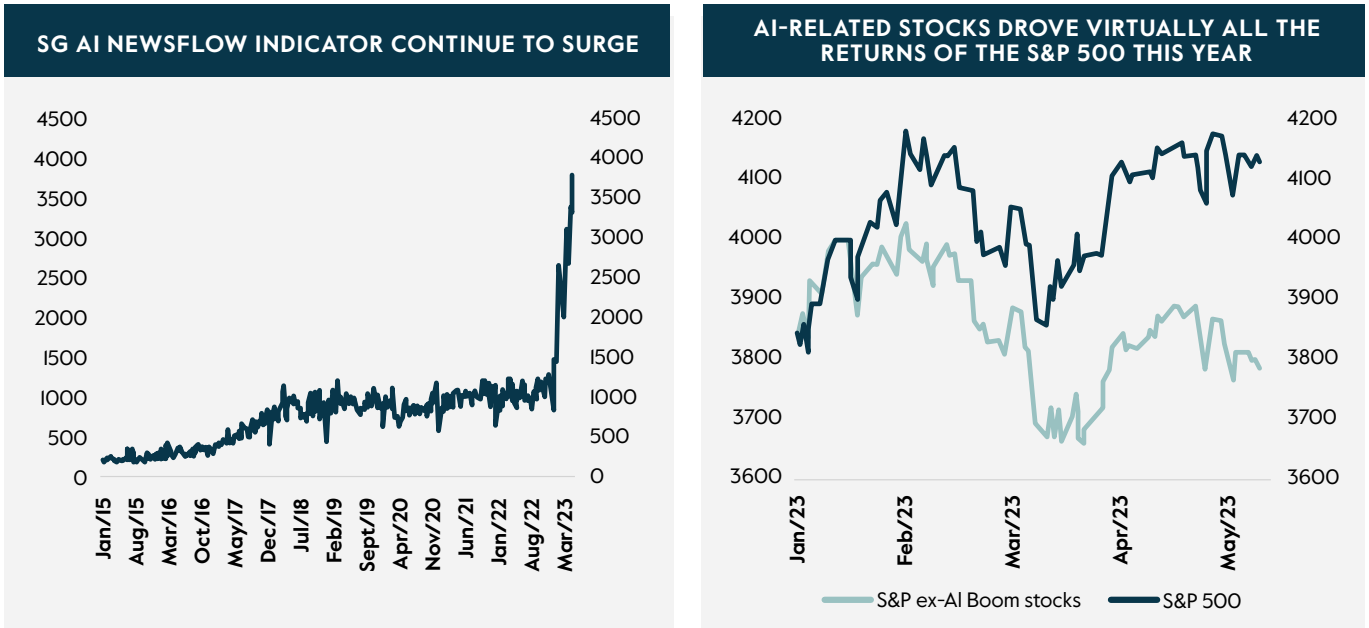


Figure 11.
AI's Increasing Share of VC Funding

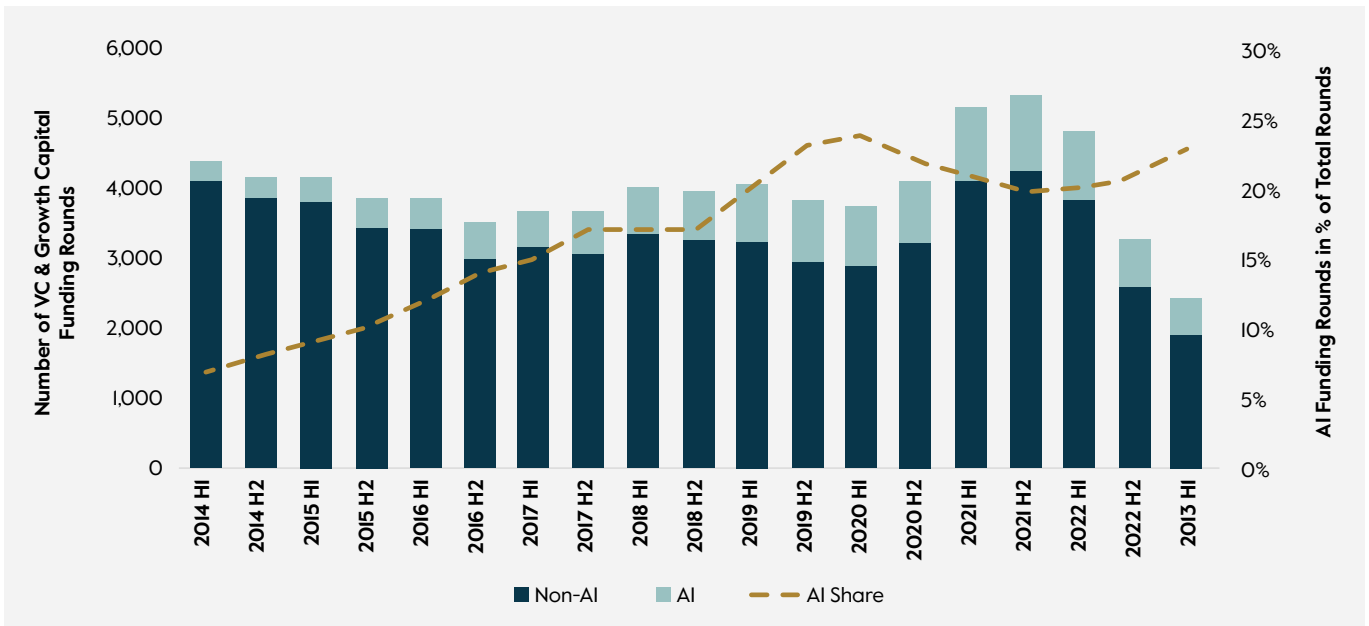


Figure 10. "SG AI Newsflow Indicator Continue to Surge" Source: Factiva, SG Cross Asset Research/Equity Strategy. Data as of 08/05/2023.
 "AI-Related Stocks Drove Virtually All the Returns of the S&P 500 This Year" Source: Datastream, SG Cross Asset/Research/Equity Strategy. Data as of 11/05/2023.
 Figure 11. Source: Carlyle Global Investment Solutions, Global Private Markets Quarterly, Q3-2023.

LESSONS FROM ELECTRIFICATION

One wonders if by focusing narrowly on the assets closest to the epicenter of this technological quake, investors may be repeating the mistakes of the past. Generative AI has been analogized to the advent of electricity, and this comparison may be apt for reasons that extend well beyond its technological significance. Though discovered in the 1880s, electric current only began to transform society in the 1920s when mass electrification was made possible by high-pressure steam power plants and centralized generation, distribution, and system management. In just a few years, electric companies' revenues grew by more than 3.4x (~35% CAGR) during a period of consumer price deflation. The valuations assigned to those fundamentals doubled during this time (Figure 12, p. 13), as investors aggressively bid up the market values of companies operating at the frontier of this technological revolution.

As it turned out, far more economic value was being created by the companies buying that power. Electrification allowed manufacturers to use a large number of complex machines simultaneously, which made mass production processes possible and sharply reduced the cost of producing consumer durables like refrigerators, washing machines, and radios (Figure 13, p. 13). And since these products had to be plugged in to operate, mass electrification not only drove down manufacturers' production costs, but also stimulated demand for their products.

In the ten years from the start of the sustained boom in electricity generation, durable goods manufacturers generated a 200% total return, on average, in the depths of the Great Depression (!), which was more than 2x the average total return to electric companies over the same period (Figure 14, p. 14). No sane person could contend that mass electrification was mere "hype," as eventual market demand for electricity met or exceeded the most optimistic forecasts. But the displacement of kerosene-fired illumination was but the tip of the iceberg, as the vast majority of the economic value accrued to the

downstream users of the new technology rather than the companies responsible for its introduction.

The same dynamics are likely at play today with Generative AI. Specialized semiconductor sales may indeed go through the roof, just as demand for the most advanced boilers rose exponentially during the period of mass electrification. A step-function increase in the volume of data generated, stored, and analyzed by companies will almost surely benefit cloud platforms just as a comparable jump in the regional transmission of electric current benefited electric utilities. Future growth in the utility sector will require significant investment in Generative AI to support power grid development. And companies at the forefront of the design of advanced AI systems today will likely be as influential to economic development as those responsible for developing the latest iteration of high-pressure steam turbines then. But the bulk of the economic value may, once again, be created by the companies most adept at capitalizing on these trends by slashing production costs and developing the new products and services made possible by these new technologies. This is likely to be especially true in software, pharmaceuticals, and other sectors where Generative AI can reduce the enormous sums spent developing intangible assets that can be infinitely reproduced at nearly zero marginal cost.

"But the bulk of the economic value may, once again, be created by the companies most adept at capitalizing on these trends by slashing production costs and developing the new products and services made possible by these new technologies."

Figure 12.
Rise in Valuation Ratios, 1925-29

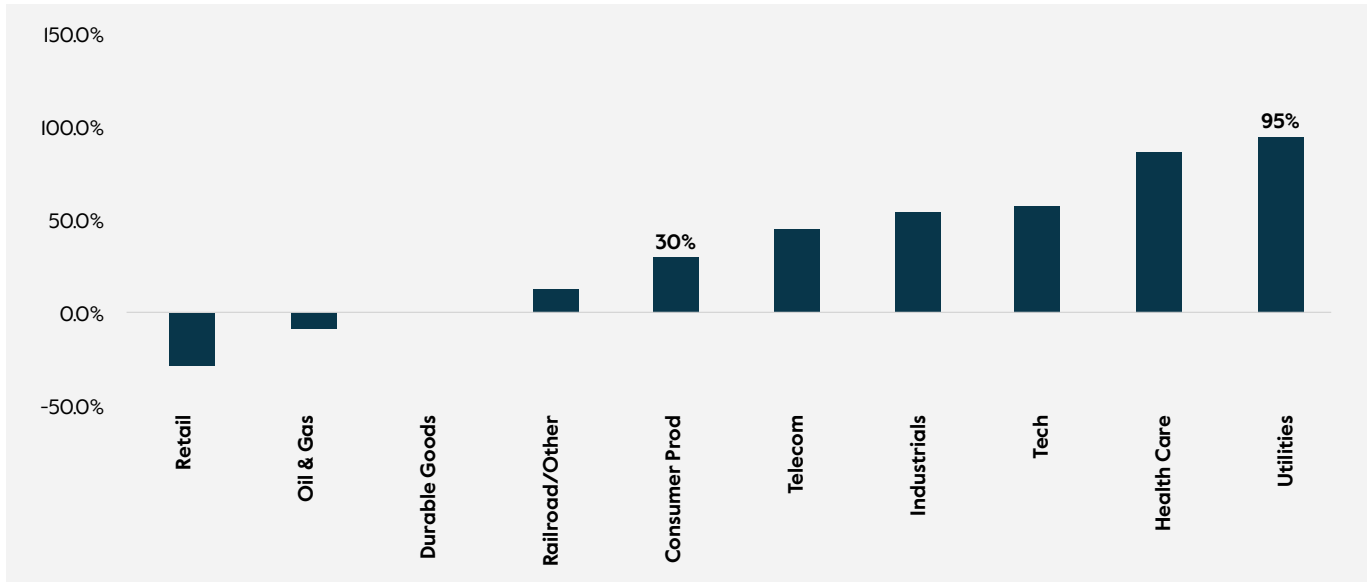


Figure 13.
Two-Year Decline in Production Costs by Item

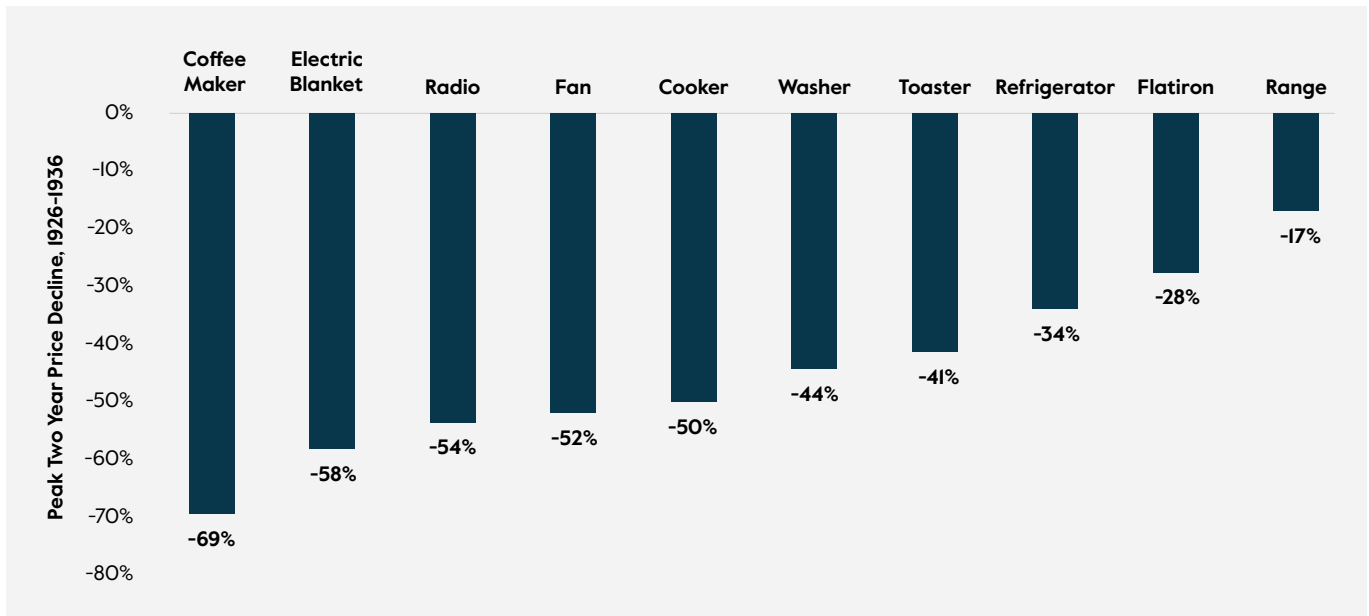
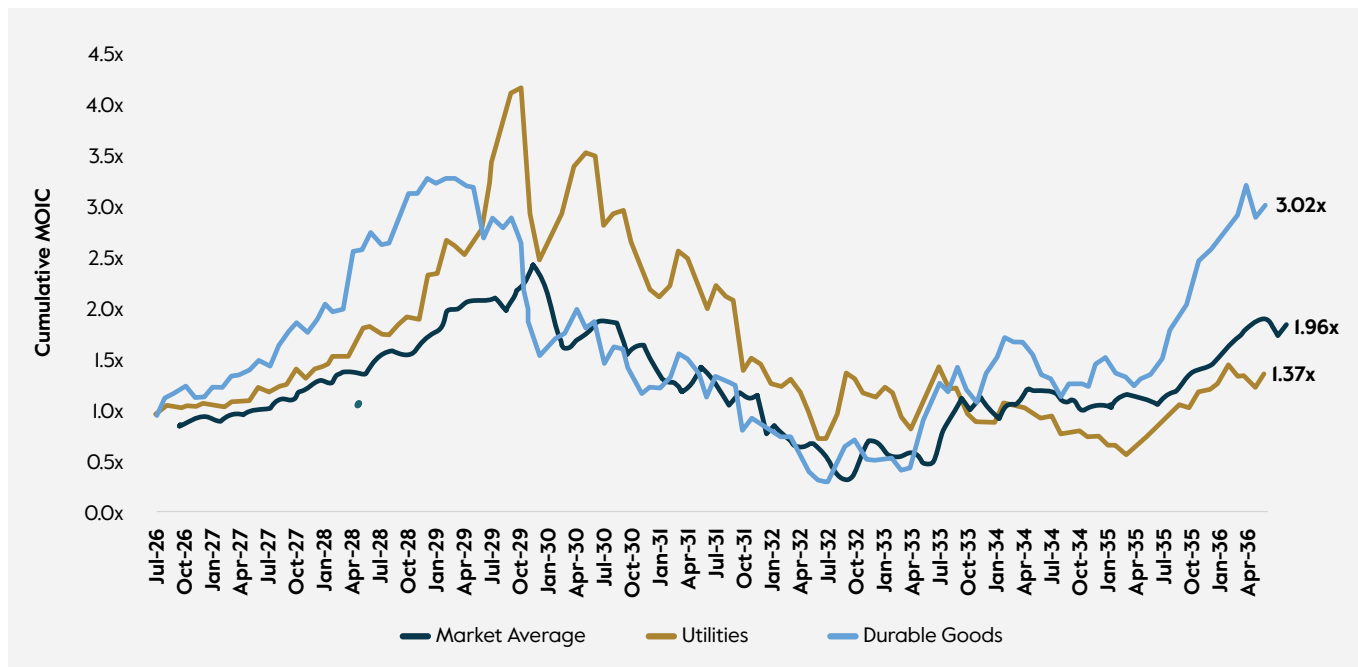


Figure 12. Source: Carlyle Analysis; CRSP Database, December 2021.

Figure 13. Source: Ronald C. Tobey, 1997, "Technology as Freedom: The New Deal and the Electrical Modernization of the American Home."

Figure 14.
Total Stock Market Returns by Sector



PLAYING THE LONG(ER) GAME

Rather than simply separating reality from hype, successful investors must be able to map that reality onto company fundamentals. This rewards second-and-third order thinking, as the most salient feature of the technological revolution – escalating revenue growth at companies at the epicenter of

the technological quake – may ultimately prove to be a small fraction of the total economic value it delivers. One company’s revenue is another’s investment. And the productivity gains from investment in software development and life sciences, content generation, and CRM systems already suggest that the assets best positioned to benefit from AI may have not yet landed on the broader market’s radar.

Figure 14. Source: Carlyle Analysis; CRSP Database, December 2021.

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Committee which was formed in 2022 to drive deeper collaboration across all the firm's Corporate Private Equity activities in the region.

Prior to joining Carlyle in 2001, Mr. Wand worked for approximately 10 years in investment banking, the last seven years of which were in the technology sector. As a Managing Director, he was responsible for the European software and Internet research team at Deutsche Bank in London. Prior to that, he worked as a European Software Analyst for Paribas in London and BHF-Bank in Frankfurt, Germany. During his banking career, Mr. Wand was the underwriting analyst for European technology innovators such as SAP, Autonomy, SurfControl, Utimaco and nCipher.