Brave New World

Innovation and the opportunities for investors

J.P.Morgan
ASSET MANAGEMENT

The world around us is changing rapidly, surfacing new opportunities as well as new challenges.

Current events present extremely heightened geopolitical pressures, with Russia waging war on Ukraine and imposing a tragic humanitarian crisis. The toll is devastating and our thoughts and support are with all of those who are impacted, and those calling for a peaceful resolution.

While geopolitical events generally have deep-rooted consequences across many fronts, their impact on market volatility is usually short-lived—although this bout of volatility is a powerful reminder of the importance of diversification.

Looking further ahead, there are a number of topics that will likely have more lasting implications for investors, including opportunities to drive long-term value.

With countless new investment prospects emerging, how do investors uncover those opportunities and distinguish what will be truly enduring innovation from a passing fad or trend? It's a critical question being asked, at a time of increased volatility and downbeat assessments around some technology companies that powered recent gains—and as the easiest monetary policy in a century is unwinding.

I'm pleased to introduce the second publication of our Strategic Investment Advisory Group—**Brave New World:** ***Innovation and the opportunities for investors.*** Our seasoned CIOs, portfolio managers and strategists spanning every asset class, led by Michael Cembalest, Chairman of Market and Investment Strategy, are anything but downbeat. With input from our global equity investment teams, the group analyzes a wide range of innovations and related investment opportunities.

It's clear that innovation looks very different today than just a few years ago. However, the outsized return projections still hold, even if over a longer time horizon, for investors who can uncover companies at the right time in the cycle and on the right side of change. Early indicators, including rising patent activity and new business applications, signal dynamic growth ahead. The group explores prospective areas of value creation—including genetics in medicine, the metaverse, cybersecurity and the industries enabling artificial intelligence—as well as potential value traps and pitfalls.

Coming at an inflection point, with increased uncertainty, rising interest rates and markets unlikely to simply reward growth investors, the group's latest work highlights how important rigorous research and active stock selection will be in the years ahead.

We hope you will find our insights valuable.

George Gatch
CEO
J.P. Morgan Asset Management

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A note from our Chair, Michael Cembalest

In our latest analysis, we look at innovation: its historical returns to investors, and at four sectors whose innovations we believe will stand the test of time. We conclude with history on innovation's victims, and how long investors have to adjust to changing trends.

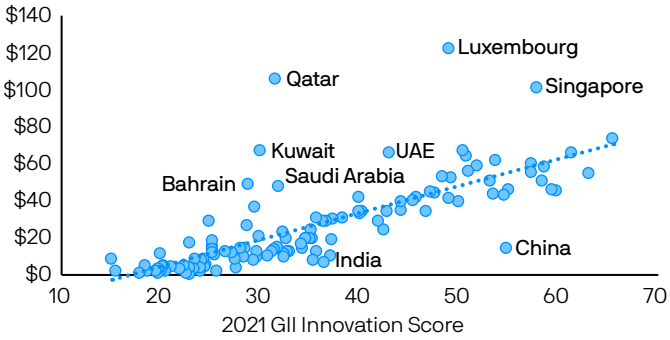
Over the long run, innovation drives growth. As you can see in the first chart, there's a very close connection between per capita GDP and "innovation," with the latter reflecting each country's research institutions, infrastructure, technological readiness and R&D. The positive outliers are oil and gas nations and well-run microstates, and the laggards have very large populations. But for investors, there's a market timing component to innovation as well. The second chart shows how one widely cited innovation basket has collapsed and has now converged with an "old economy" basket of agricultural farm equipment, business support services (uniforms, mops and cleaning supplies) and industrial REITs. In other words: Innovation is great, but don't overpay for it.

Innovation requires ample liquidity to thrive. The Fed is beginning to unwind the most expansionary monetary policy on record in response to rising inflation. We believe that the Fed will move deliberately, a topic we discussed in our SIAG paper last fall.[1] For example, even if there are 6–8 Fed hikes in 2022, policy rates would still be substantially negative in real terms. To the extent that the Fed is able to avoid a hard landing by overtightening, the recent pace of innovation should continue. However, a harder landing would temporarily create tighter liquidity conditions that could constrain the pace of innovation and its returns for investors.

All things considered, the ongoing current rout in NASDAQ and other growth stocks is a good time for this piece (at the time we went to press, the average NASDAQ stock was down ~45% from its peak). Many equity market sell-offs create opportunity; in the same way that many investors were indiscriminate in pricing growth on the way up, they also often indiscriminately devalue it on the way down. It's time to take another close look at innovation now that the price for it has changed.

Innovation drives per capita GDP

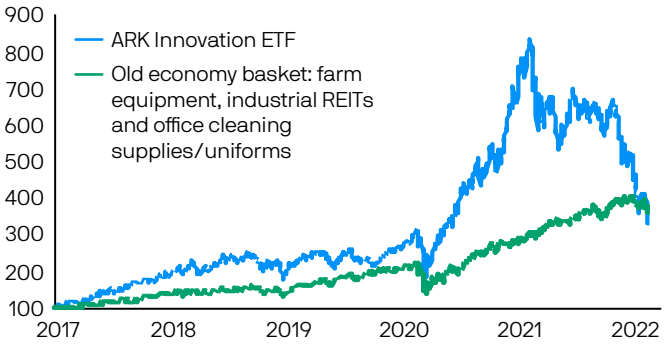
2021 per capita GDP, thousands



Source: WIPO, Conference Board, J.P. Morgan Asset Management. 2021.

The tortoise and the hare

Index (100 = Dec 2016)



Source: Bloomberg, J.P. Morgan Asset Management. February 23, 2022.

[1] *"Getting real about rates: The post-war era of substantially positive real interest rates may be gone for good ,"* J.P. Morgan Strategic Investment Advisory Group, October 2021.

Author

Michael Cembalest
Chairman of Market and Investment Strategy

Executive Summary

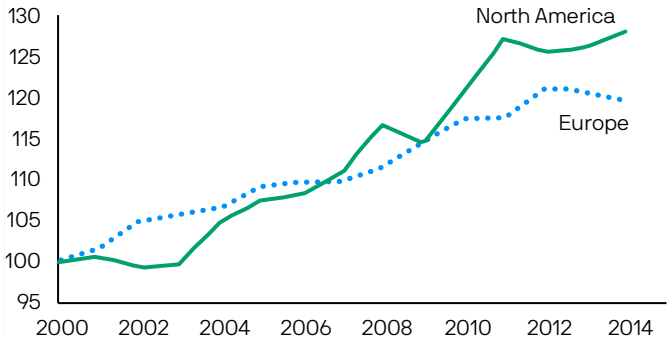
An investor's perspective on innovation

Many discussions about the dynamism of Western economies are downbeat. Measures of industry concentration are rising, measures of new firm birth rates are falling, and standard estimates of productivity growth look low.

However, for investors the picture is not as bleak. First, productivity growth of large publicly traded firms is much higher than overall economy-wide estimates, as illustrated in the second chart below. This appears to be a function of low cost, winner-take-all companies succeeding in a large global market. Another contributor: Deflation and productivity growth have been understated in tech and telecommunications sectors. From 2008-2017, an alternative measure of inflation for consumer digital access services (data, voice and video to households over internet, mobile cellular networks and cable television) fell by 19% per year, compared with a 1% annual rise in the official data. The impact on "true" inflation was material; reductions in estimated inflation result in a corresponding boost to real GDP growth.

Market concentration in manufacturing and services

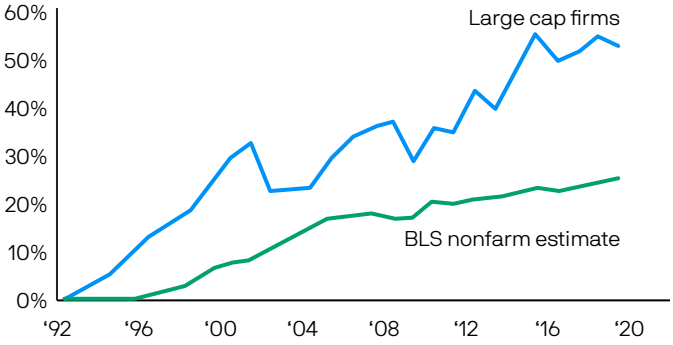
Index (100 = 2000)



Source: OECD. January 2019.

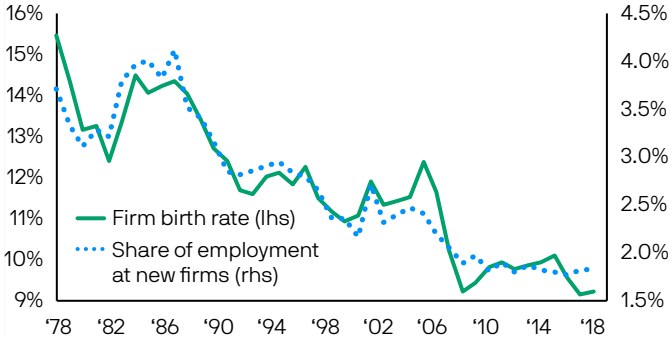
Productivity growth

%, growth since 1992



Source: Barclays Research, BLS. November 18, 2021.

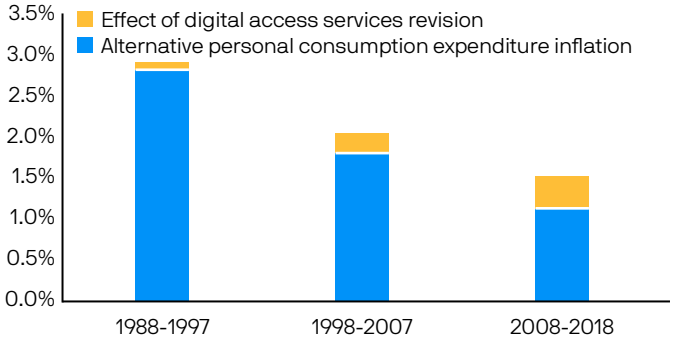
Firm birth rate and share of employment in new firms



Source: Census Bureau, J.P. Morgan Asset Management. 2019.

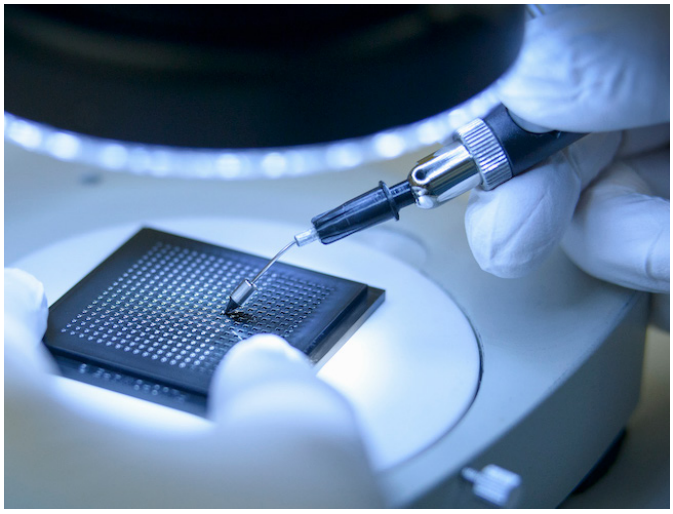
Official and alternative inflation

Average annual percent change, personal consumption expenditure inflation



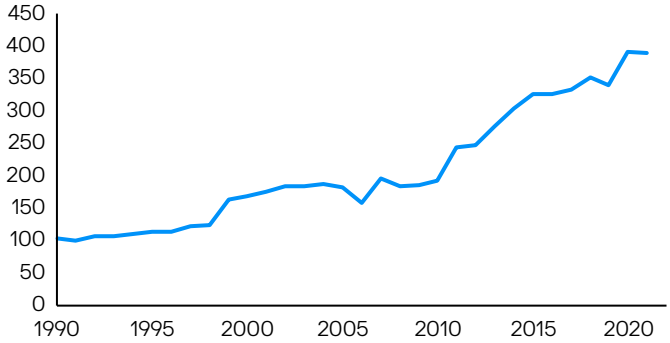
Source: Byrne and Corrado. 2020.

Another measure of dynamism that shows more life: steady patent activity and rising median patent values. More recently, there has been a jump in patent applications due to COVID, particularly in products and services related to electricity distribution, broadcasting, wireless networks, data science and storage, food, household appliances and entertainment. More positive short-term post-COVID indicators: a rise in weekly business applications, particularly for nonstore (virtual) retail. While it's hard to directly assess the economic benefit of patents, we can infer value from their durability. In the US, ~84% of patents granted are still active 5 years later; the comparable figure in China is just 10%.



US annual patent grants

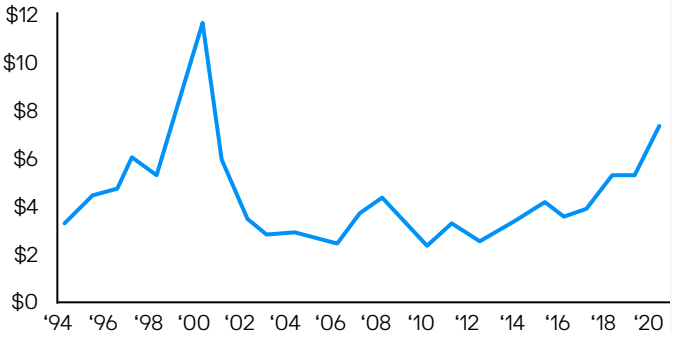
Thousands



Source: US Patent & Trademark Office. 2020.

Median value of US patents

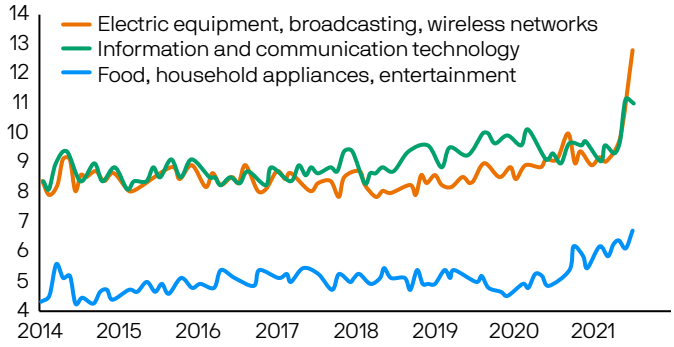
1982 USD, millions



Source: Barclays, Kogan et al. 2020.

US patent applications

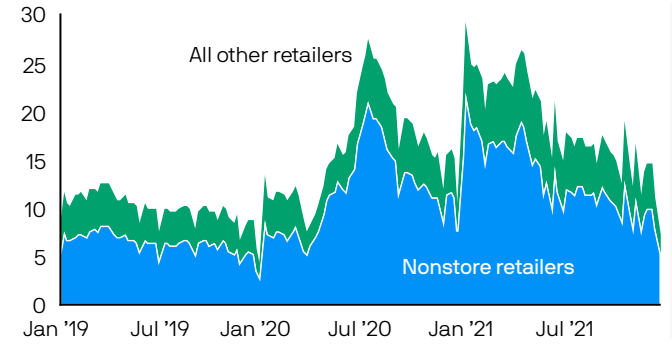
Thousands, 3-month moving average



Source: GS. November 19, 2021.

Business applications: nonstore retailers vs all other retailers

Thousands of weekly applications

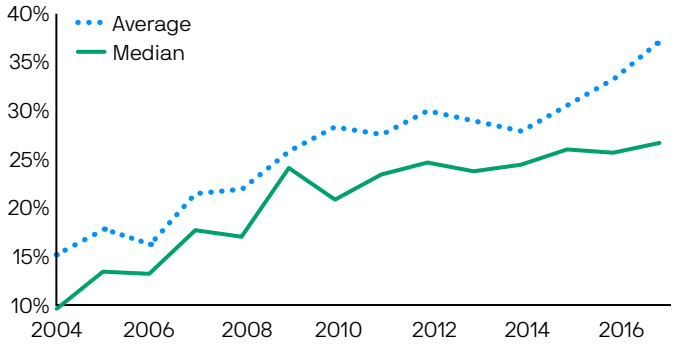


Source: Census, J.P. Morgan Asset Management. December 31, 2021.

Before getting into innovation by sector, we illustrate below the ultimate barometer of returns to innovation: venture capital.[2] Whether you look at internal rates of return (IRRs), multiples on invested capital (MOICs) or "direct alpha" (venture returns vs an S&P 500 benchmark), venture capital returns have been attractive for investors. In the fourth chart, we show venture capital returns relative to the S&P 500 using the PME (public market equivalent) ratio. For example, a ratio of 1.00 indicates that venture returns are equal to the S&P 500. Since 2010, even fourth quartile venture funds have been able to perform almost in line with the S&P 500.

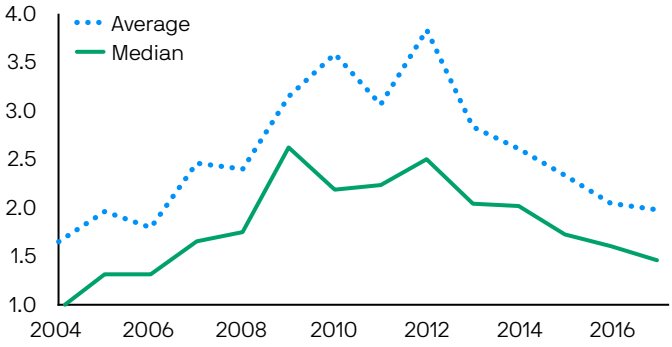
US venture capital IRRs by vintage year

%



Source: Steve Kaplan (Chicago Booth) and Burgiss. 2020.

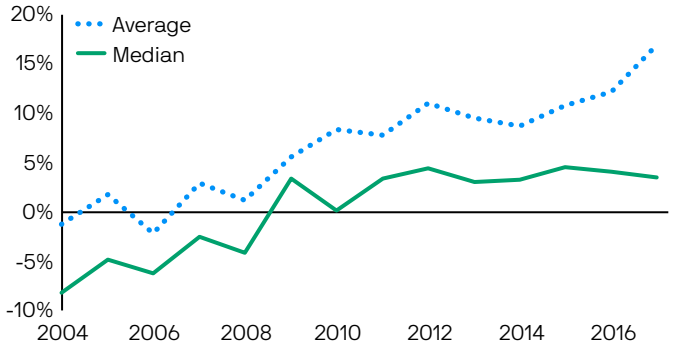
US venture capital MOICs by vintage year



Source: Steve Kaplan (Chicago Booth) and Burgiss. 2020.

US venture capital direct alphas by vintage year

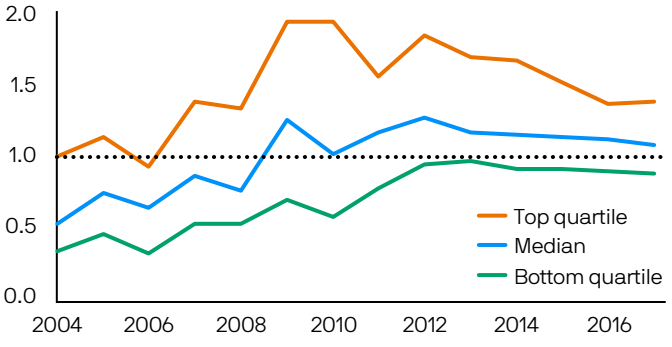
%, annualized vs S&P 500



Source: Steve Kaplan (Chicago Booth) and Burgiss. 2020.

US venture capital PME quartile by vintage year

PME ratio vs S&P 500



Source: Steve Kaplan (Chicago Booth) and Burgiss. 2020.

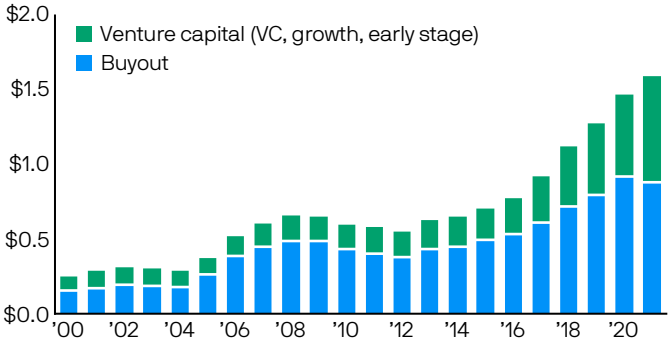
[2] The charts above are part of a broader private equity and venture study we published last year. See *"Food Fight: An update on private equity performance vs public equity markets,"* Eye on the Market, June 2021.

As of the end of 2021, there was a lot of dry powder to fund innovation in venture and private equity. As a result, even if monetary conditions were to tighten substantially, there's a reserve to fund future innovation in the years ahead.

Here's a measure of the returns on innovation applied to public equity. The average equal-weighted return on new companies generally outperforms an equal-weighted investment in the market. **In other words, there's a steady drumbeat of innovation that benefits investors that embrace change, even after accounting for the longer periods of time that many remain private, during which their gains accrue to pre-IPO investors.**

Global dry powder by category

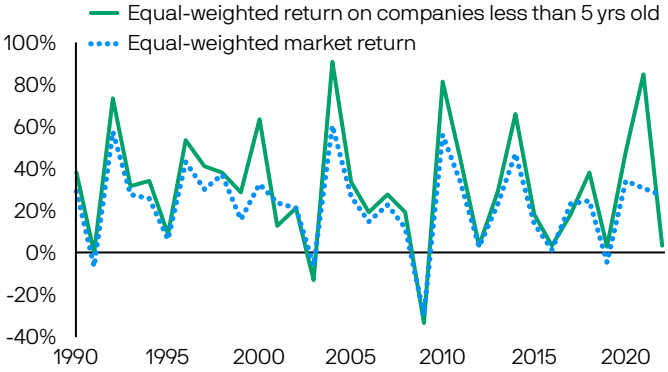
USD, trillions



Source: Preqin. 2021.

Annual returns on new companies vs the overall market

Average annual equal-weighted return



Source: FactSet. 2021. Universe: top half of CRSP all cap stocks.

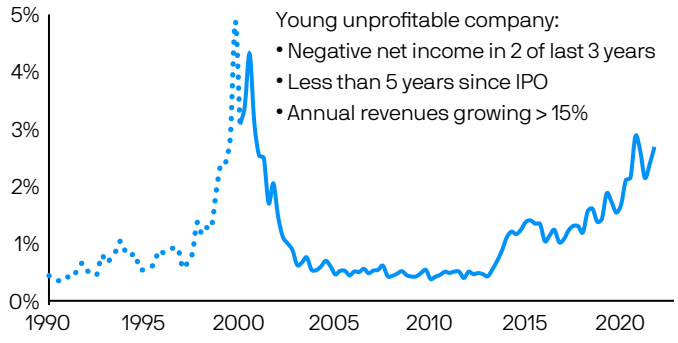
Returns on innovation and market cycles.

By the end of 2021, equity markets had the highest share of young unprofitable companies since the late 1990s. As shown in the last chart, a decade of negative real interest rates starting in 2010 led to higher and higher equity valuations relative to sales. As of Labor Day last year, markets were still pricing in just *one Fed hike* in 2022 despite tightening labor, goods and commodity supply conditions. Many investors were apparently expecting a continuation of the easiest monetary policy conditions since the 1800s. But now that the Fed is set to respond, valuation multiples are declining from very high levels. The Russian invasion of Ukraine has accelerated this repricing: many momentum-driven crowded sectors (SPACs, IPOs, renewable energy and Fintech) have been selling off, the average NASDAQ stock is down 45% from its peak and the outperformance of low margin companies was completely unwound by the end of February.

As a result, while returns on innovation have been high, it's important to distinguish between true innovation and novelty, and to accept high levels of volatility in the price for both. In the sections that follow, we outline four areas of true innovation that we believe will emerge as sustainable, profitable industries that portfolios of all kinds should be exposed to. We then address some macroeconomic drivers of innovation and conclude with a discussion of innovation's victims and how long investors have to adjust to change before asset prices do.

Market cap of young unprofitable companies

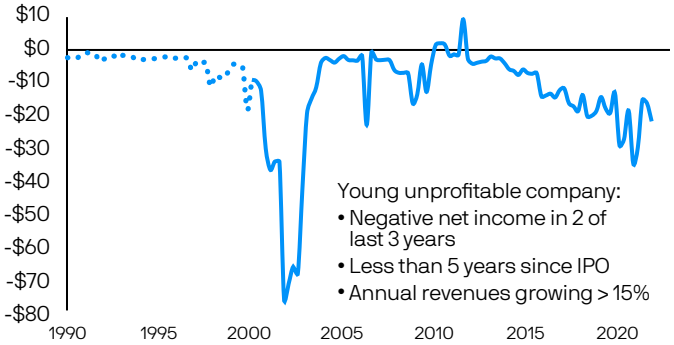
% of total market cap



Source: FactSet, J.P. Morgan Asset Management. Q4 2021.

Net income of young unprofitable companies

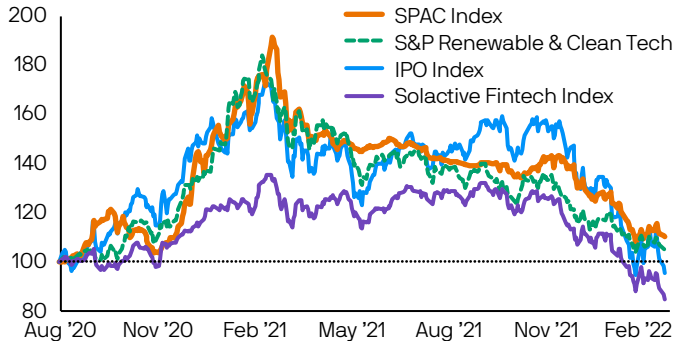
USD, billions



Source: FactSet, J.P. Morgan Asset Management. Q4 2021.

Signs of weakness

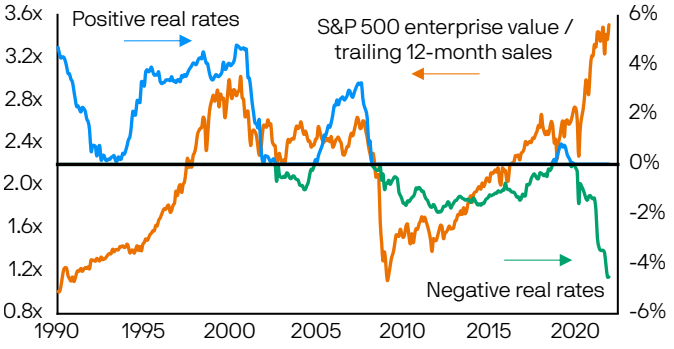
Total return index (Aug 2020 = 100)



Source: Bloomberg. February 23, 2022.

Equity multiples vs real interest rates

Ratio **Real Fed funds rate**



Source: Bloomberg, J.P. Morgan Asset Management. December 2021.

Author

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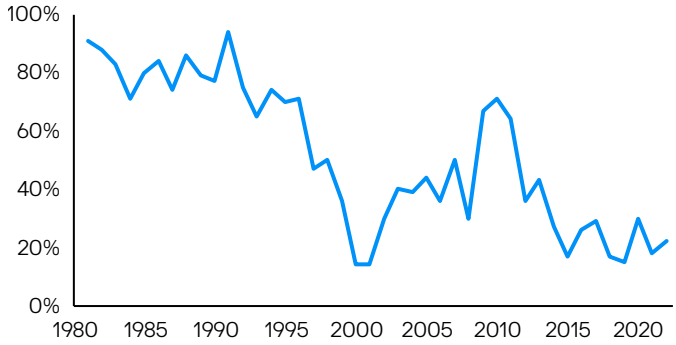
A note on our four innovation sections

Our investors have been focusing on innovation for decades; the lessons learned in previous cycles are crucial to success. We believe that stock selection will become increasingly important after a unique period over the last four years when the market has rewarded growth investors to an unprecedented degree. The unwinding of the most expansionary monetary policy on record may amplify the importance of stock selection relative to simple market cap-weighted portfolios.

Innovation requires investors to identify large secular shifts that create a large gap between winners and losers. Once we recognize these paradigm shifts, identifying emerging potential winners and getting the investment timing right are key. While we're excited about the pace of innovation, we also see signs of market exuberance in areas such as technology that have some parallels to the dot-com bubble (for example, the rise in young unprofitable companies shown on page 10). Another parallel: Just 22% of tech IPOs were profitable in 2021, only modestly higher than the 14% of tech IPOs that were profitable in the years 1999 and 2000.

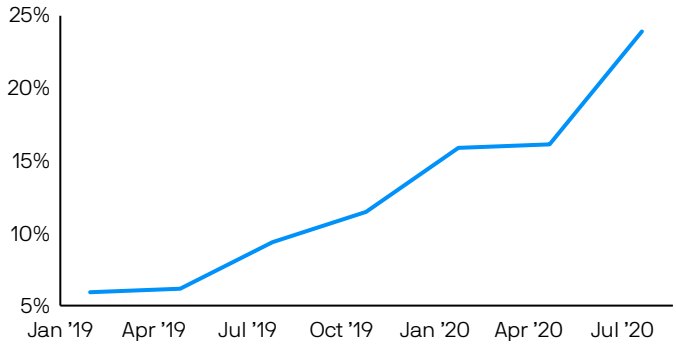
Profitable tech IPOs: back to late 1990s levels

% of tech IPOs with profits at issuance



Source: Jay Ritter, University of Florida. 2021

Snowflake market share among Fortune 100 organizations using AWS, Google Cloud Platform & Microsoft Azure



Source: Enterprise Technology Research. July 2020.

Long-term investors need to focus on areas of innovation that are still early. In the pages that follow, our equity investors review the dramatic changes afoot in genetic medicine, the Metaverse, factory automation, financial technology and cybersecurity. **There are common secular drivers at the core of each** that lower barriers to entry and allow companies to build businesses at scale without having to spend large amounts of capital on proprietary hardware and software:

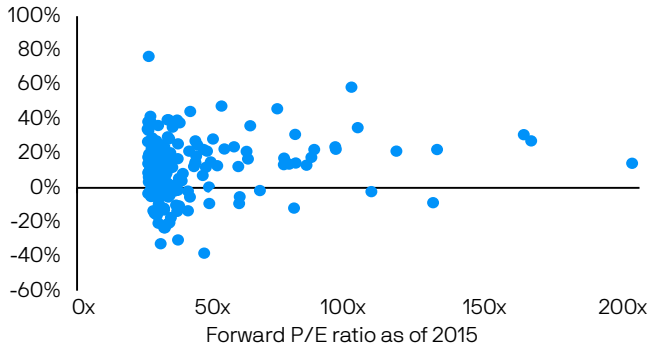
- Democratization of software access driven by open-source technology
- Improvement in cost and power of computing and storage
- Public cloud increasing access to computing and storage
- Proliferation of data and the application of artificial intelligence
- Advancements in communication systems, including 5G
- COVID pandemic driving digital acceleration

The rapid growth of a cloud data warehouse company like Snowflake is an example of just how innovative companies can rapidly access tools and software in the public cloud, allowing them a faster runway for success.

While valuations are critical investor metrics, traditional approaches have been ineffective for some high growth companies. The next two charts show price to earnings and enterprise value to sales in 2014 as predictors of subsequent 5-year returns for high growth companies in the S&P 1500; they didn't help investors much at all.

S&P 1500 ex-real estate (starting P/E ratio > 25x)

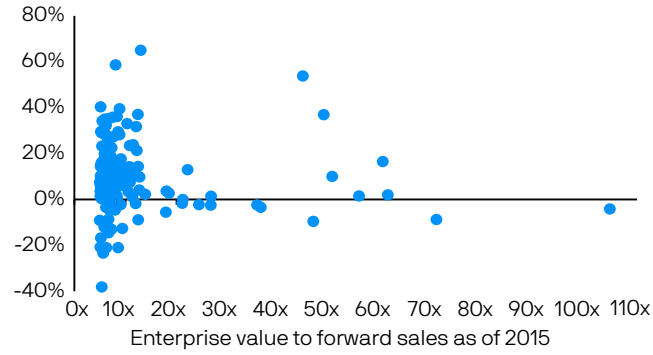
Subsequent 5-year annualized return (2015-2020)



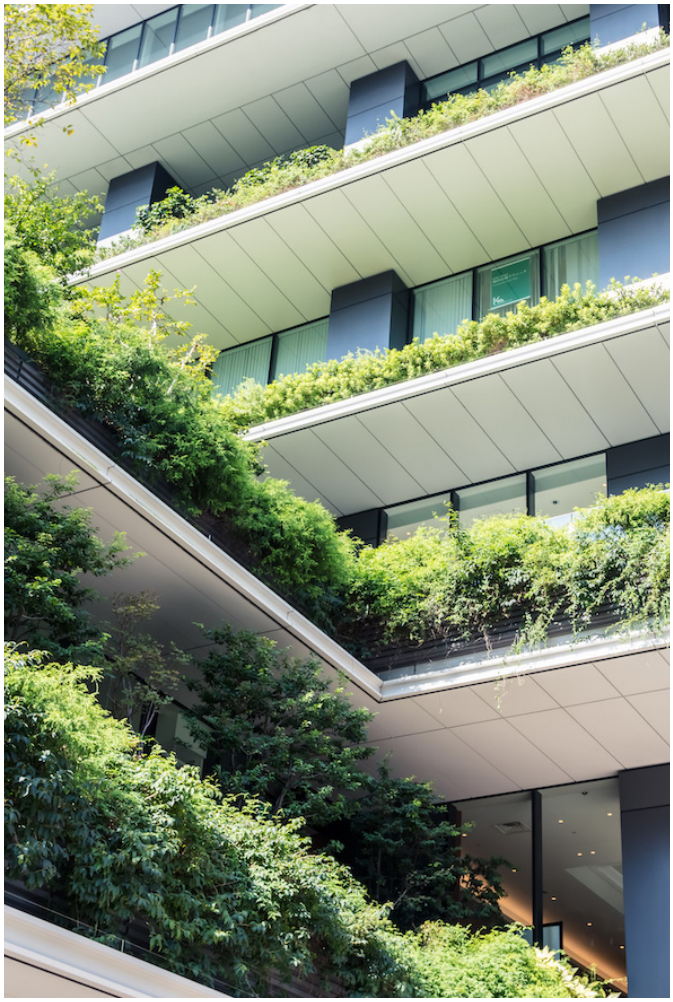
Source: Datastream, J.P. Morgan Asset Management. 2020.

S&P 1500 ex-real estate (starting EV/sales ratio > 5x)

Subsequent 5-year annualized return (2015-2020)



Source: Datastream, J.P. Morgan Asset Management. 2020.



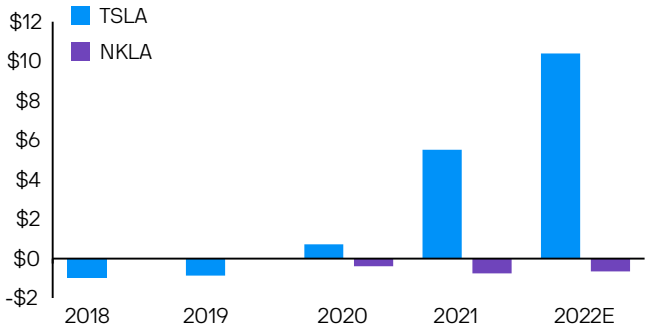
Investing in innovative companies requires deep domain expertise and assessments of future earnings and free cash flow. Investors often underestimate growth when there are seismic shifts in industries. Our proprietary views are designed to help us identify winners and losers. **The bottom line: When investing in innovation, valuations are secondary to being able to anticipate which business models will thrive and which won't.**

Tesla and Nikola are prime examples. In 2019, there was no shortage of commentary on Tesla being expensive at a P/E of 100x. However, critics missed that Tesla was at the cusp of establishing first-mover advantage in the electric vehicle industry with technology and cost that were difficult to replicate. EV adoption was in its infancy, and many analysts underestimated the company's long-term revenue and earnings potential. In fact, Tesla's net income rose from -$862 million in 2019 to an estimated $21 billion in 2025. The stock now trades at a more reasonable valuation on more visible long-term earnings and free cash flow estimates.

Alternatively, Nikola, an electric and hydrogen trucking company, went public via SPAC in 2020, and its market cap peaked at over $24 billion early in 2020. Nikola also had a high near-term valuation and lack of profitability, but its financial performance has been extremely disappointing, as its lack of technology and competitive moat resulted in a lack of demand for its electric trucks. Nikola's forecasted 2022 net loss has grown, with no visibility into future success.

Net earnings: Tesla vs Nikola

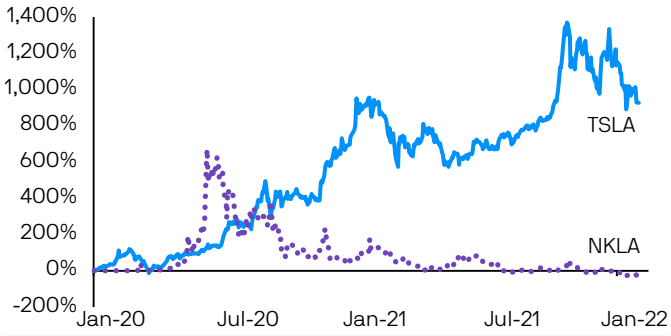
USD, billions



Source: Bloomberg, J.P. Morgan Asset Management. February 2022.

Cumulative total return: Tesla (TSLA) vs Nikola (NKLA)

%



Source: Bloomberg, J.P. Morgan Asset Management. February 2022.

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Innovation #1

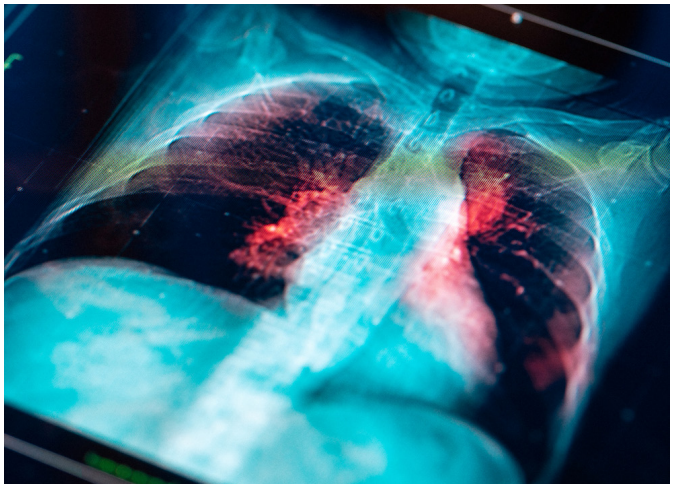
Genetics in Medicine

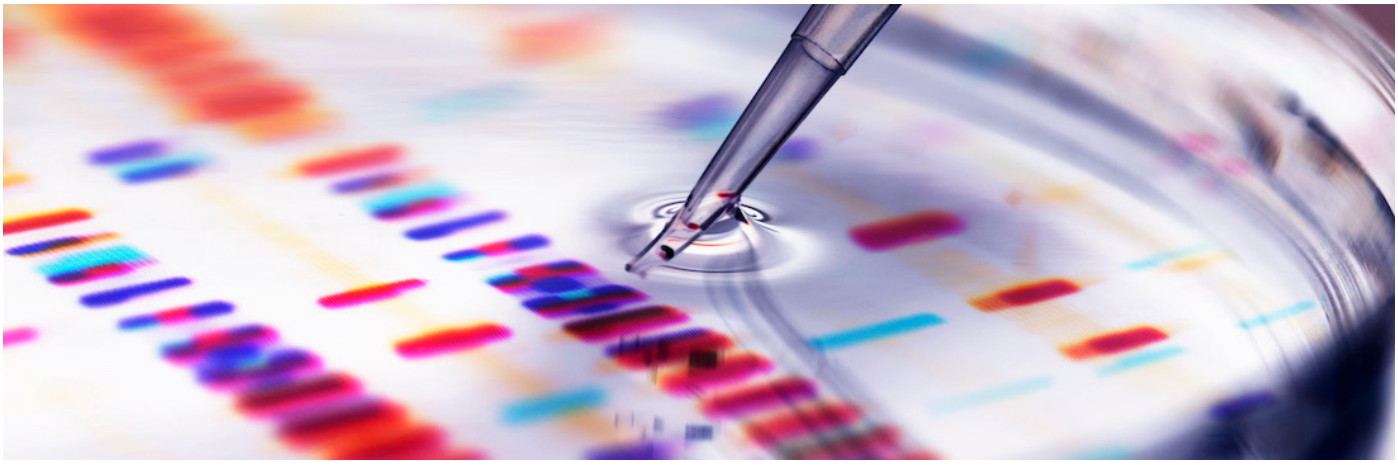
The Genome Project, which started in 1990 and was completed in 2003 concluded with the mapping of the entire human genome (a spectacular 20,300 human genes). This changed the way that we diagnose, treat, monitor and prevent genetic illnesses such as cancers and genetic mutations, and set the stage for how we will manage disease in the future. The development of tools such as Zinc Finger (ZFNs), TALENs and CRISPR, which act as precision scissors to cut and manipulate DNA, has launched a new era in therapeutic development.

Although we are still far from understanding all the intricacies of disease, significant progress has been made toward treating cancers and genetic disorders that are embedded in our own cells' DNA. We anticipate that in the next 20 years there will be continued advances in precision medicine, AI-assisted drug development, and precision/targeted diagnostics and treatment, all based on the identification of gene-level changes in the body.

Oncology and the example of lung cancer.

Treatment for lung cancer has progressed significantly since 1990, when life expectancy was low and patients would often die several months after diagnosis. Reliance on toxic nontargeted treatment such as radiation and chemotherapy, which affect cancerous and noncancerous cells, has declined in favor of more precise approaches that target specific markers on cancer cells. This has led to longer life expectancy for lung cancer patients, although most still do not survive beyond two to three years. Within the next 10 years, we expect future treatments to include the ability to target an individual's unique cancer mutations, leading to a shift toward chronic treatment and longer survival rates, measured in decades rather than years. Targeted oncology biotech companies, such as Blueprint Medicines, are set to further improve genetic cancer targeting in EGFR (Epidermal Growth Factor Receptor) cancers.



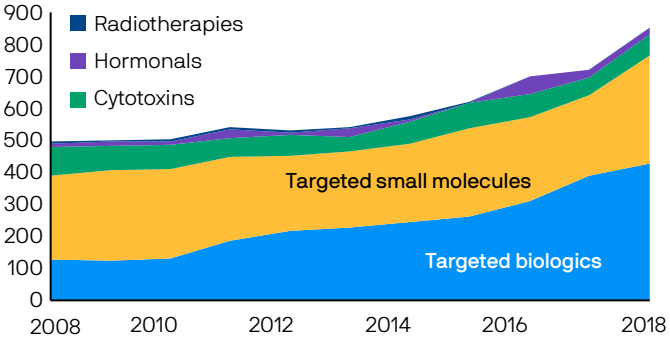


Where are we headed from here, and who will lead?

The industry is headed in the direction of targeted therapy, as illustrated by the increasing number of targeted drugs approved by the Food and Drug Administration (FDA). In 2019, the FDA approved 48 novel drugs, of which 39 were targeted drugs. Although there are some clear obstacles, such as cost and accessibility, gene therapy treatments such as CAR T are moving forward, with five FDA approvals to date. The first chart below shows the late-stage oncology pipeline and how targeted biologics and targeted small molecules have risen sharply over the last decade relative to other treatments and therapies. The second chart shows the increase in oncology trials where patient pre-selection and stratification are based on specific genetic biomarkers in those individuals. Bottom line: Genetic data is increasingly affecting the way we treat cancer, with biotech companies focused on hard-to-drug, genetic targets (including Revolution Medicines, Relay Therapeutics and Blueprint Medicines) poised to lead in this space.

Increased targeted oncology therapies

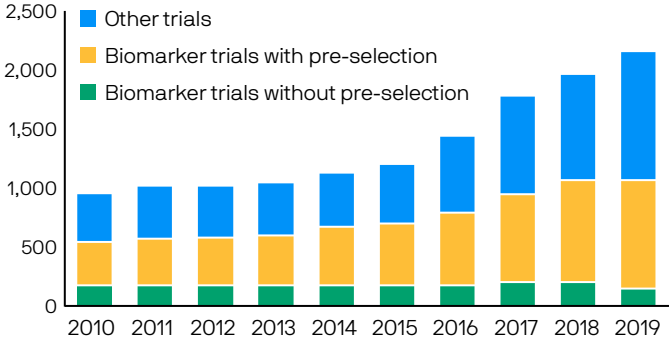
Number of molecules, oncology late-stage trials



Source: IQVIA Institute. May 2020.

Oncology trials by biomarker use

Number of oncology trials



Source: IQVIA Institute. August 2020.

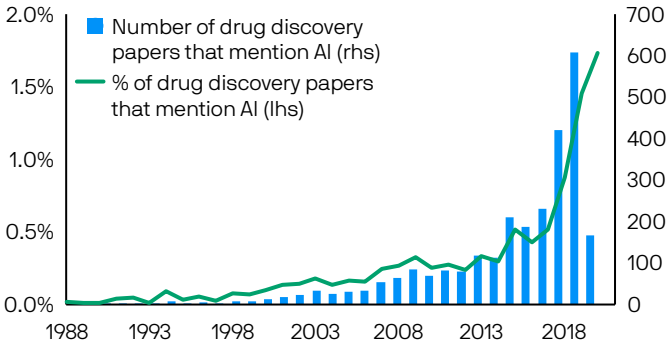
There are several key areas developing rapidly that will use our expanding understanding of the human genome to increase quality of life.

Diagnostic moves toward less invasive techniques using liquid biopsy. Diagnostics for genetic disorders and cancer have benefited from our current knowledge of the genome and have allowed doctors to take tissue or blood samples from cancer patients and rapidly look for specific mutations or changes that are driving an individual's disease. Therapies can then be developed to focus on specific mutations. Within five years, we will see leaders in this space being able to diagnose early-stage cancers and provide a full array of markers to treat an individual's cancer. Liquid biopsy, which allows for detection of free-floating cancer cells or DNA fragments of cancer cells in blood rather than from physical tumor samples, is a clear area for focused investment. Liquid biopsies will allow for easier screening for earlier disease detection, monitoring and therapeutic drug selection. Leaders in diagnostics today include Natera, Exact Sciences, Personalis, Guardant Health and Twist Bioscience.

AI-assisted drug development as a means to increase drug development efficiency. The high cost of drug development is driving AI-assisted research, with the potential to provide a higher "hit rate," thereby reducing cost. McKinsey estimates there is a 45%–75% increase in EBITDA from investing in AI drug development. It is costly to build out these specialized AI teams, so some companies are outsourcing this type of development to specialists. However, disruptions can come from leading innovators, such as Twist Bioscience and Relay Therapeutics, and non-traditional players such as Google's DeepMind, whose AlphaFold project outperformed around 100 other teams to predict 3D protein-structure folding, which is an essential part of drug development. Within five years, we expect a significant shift toward AI-driven research that can lower the costs and speed-to-launch of target therapies. The following charts illustrate the AI mentions in drug discovery papers and the size of the AI drug discovery market, with projections to 2027.

Artificial intelligence in drug discovery papers

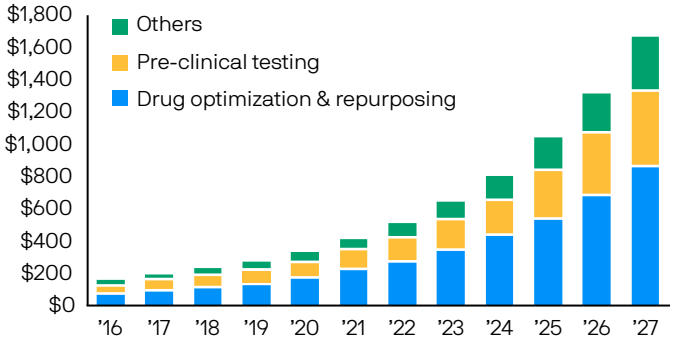
% of drug discovery papers



Source: BenchSci. April 2020. 2020 bar represents YTD through April 2020.

US artifical intelligence drug discovery market size

USD, millions, with projections to 2027



Source: Grand View Research. September 2020.

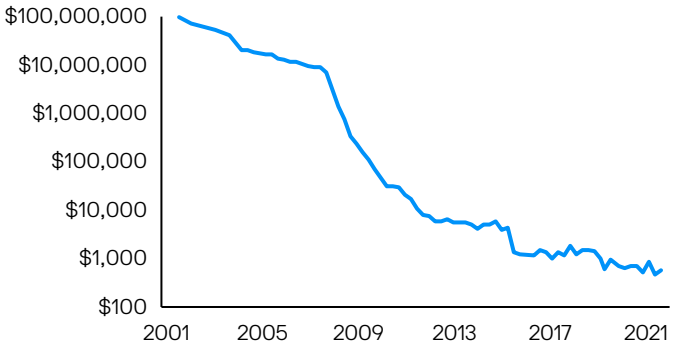
Outsourcing of biologics research and manufacturing accelerates development timelines and decreases costs. In recent years, investment in outsourced research and manufacturing capacity for gene therapies, cell therapies and other target therapies has accelerated. Companies such as Thermo Fisher Scientific and Catalent have done this organically and through acquisition, and demand is surging for both development and commercial grade capacity. These efforts are global: We have also seen activity in Europe and China to grow out capacity and prepare for the burgeoning pipeline of genetic-based therapies that promise to impact clinical outcomes. Companies such as Lonza, WuXi AppTec and WuXi Biologics are poised to benefit from these trends.

Precision treatment promises to improve patient efficacy and safety. Precision medicine allows for the development of therapies that target specific genetic drivers of inborn or acquired (e.g., cancer) disease. There are multiple therapeutic approaches on the horizon, from better-designed, gene-targeted therapeutics such as bispecific (double-targeted) antibodies, RNA modalities (RNAi: small copies of our DNA blueprint that can start or stop protein production in a cell) and immunotherapy (harnessing the body's immune system to fight disease). Within five years, we expect to see an increase in the quantity and quality of precision therapies using various precision modalities, addressing a broader array of unmet clinical needs. Biotech companies that stand to benefit from this trend include Alnylam Pharmaceuticals, Arrowhead Pharmaceuticals and Regeneron Pharmaceuticals.

Gene therapy began in 1990, when a child underwent the first treatment for a mutation in a specific enzyme. Since then, the cost of DNA sequencing has plummeted and the race has been on to prove that first-generation gene editing technologies (e.g., TALENs, CRISPR) can be used to modify cellular behavior to treat disease predictably and safely. The space is evolving quickly, and next-generation gene editing technologies (e.g., base editing, prime editing) promise to be more targeted and less disruptive to normal cellular machinery, and hence highly effective with lesser risk. Most gene therapy treatments are currently in pre-clinical trials or early Phase I trials. In the next five to 10 years, we expect treatments to address and potentially cure a broader host of inborn genetic diseases (e.g., genetic lipid disorders), ushering in an exciting new era in drug development and clinical medicine. Such treatments may not become widely available for at least 10 years until longer-term trial data are available and increased competition blunts their expected initial high price tags.

Human genome sequencing cost

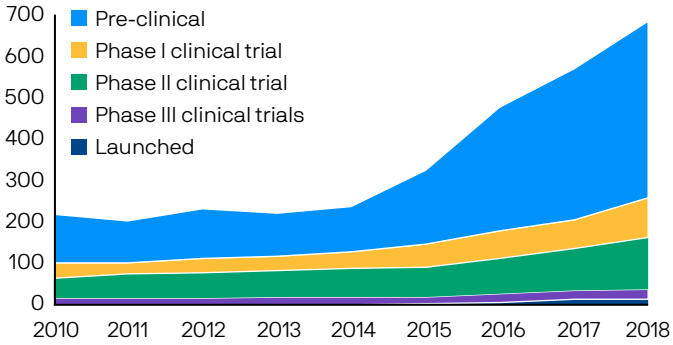
USD, log scale



Source: National Human Genome Research Institute. August 2021.

Global gene therapy clinical development

Number of therapies by phase

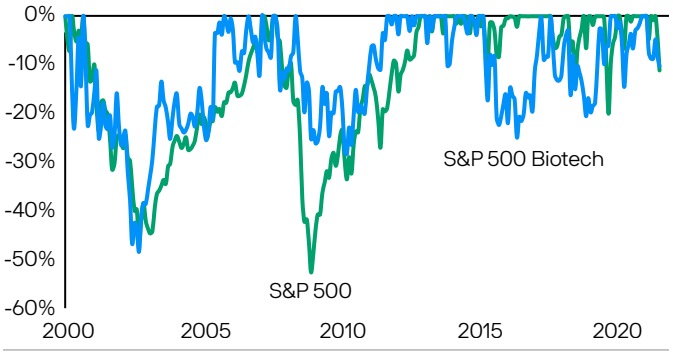


Source: L.E.K. Consulting. 2019.

From an investment perspective, it is important to keep in mind that innovation and investor returns do not always move in a straight line. While investing in cutting-edge innovation in health care can lead to very strong returns, it is important to remember that therapeutic treatment development is a highly technical and inherently risky business, given the high degree of scientific and clinical failure, as well as the impact of rigorous regulatory approval processes, changes in reimbursement, intense competition and limitations on any product's patent life. As always, investing in innovation is best achieved in the context of a broadly diversified portfolio.

S&P 500 vs biotech drawdowns

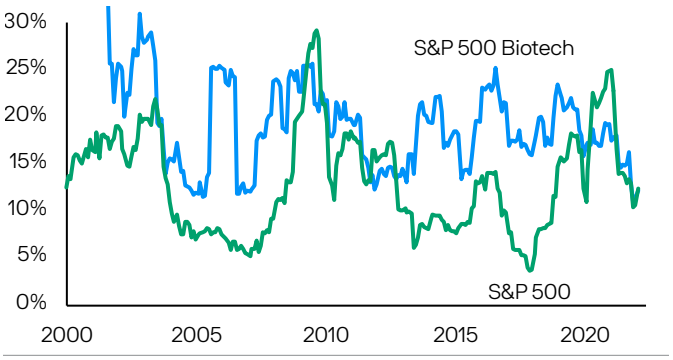
% decline from prior peak



Source: Bloomberg, J.P. Morgan Asset Management. February 23, 2022.

Biotech volatility vs S&P 500

Rolling 12-month volatility, annualized



Source: Bloomberg. January 2022.

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Innovation #2

The Metaverse

The Metaverse, a term used to describe shared 3D virtual spaces in a virtual universe, is believed to be the next paradigm shift in social networks as well as in work collaboration. In the Metaverse, users interact together by playing, communicating, connecting, making friends, learning, collaborating or simply socializing, all in 3D environments.

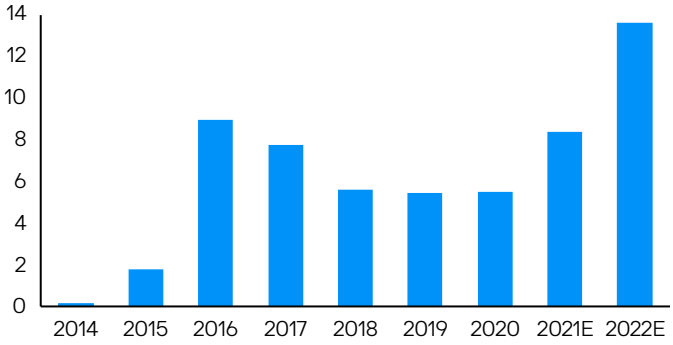
Some refer to the Metaverse as the next iteration of the internet, or Web 3.0, which also explains some of the hype we're seeing that is reminiscent of the late 1990s. Web 3.0 is viewed as the next level of tech evolution that would make the internet smarter, decentralized and more secure, powered by distributed ledger technology, blockchain and decentralized finance.

The idea of the Metaverse has captured the imagination for decades. Futurists have been writing about it since author Neal Stephenson coined the term in the early 1990s. Interest in the Metaverse spiked with the 2021 listing of Roblox, one of the world's largest social communities and online multiplayer game platforms, where players interact as communities in the Metaverse they create themselves. Roblox's user growth was amplified during COVID lockdowns as children from all corners of the globe sought the closest thing to much-needed real-life interaction with peers.

Then, in the fall of 2021, Facebook announced its name change to Meta and its plans to reposition its business and become a true Metaverse company. Facebook had been working on the Metaverse for years via its virtual reality Oculus headsets. However, it wasn't until 2021, after 5+ years of development, that Oculus and its mobile companion app could claim meaningful success with ~10 million downloads, up 10x from 1.2 million downloads when it was launched in 2018. Current estimates peg the virtual reality headset market at 8 million-10 million units in 2021, with Meta capturing over 70% of the market.

Virtual reality headset shipments

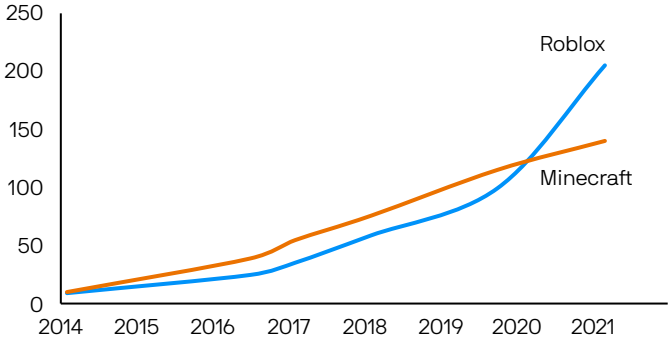
Millions of units



Source: International Data Corporation, Morgan Stanley Research. 2020.

Roblox vs Minecraft users

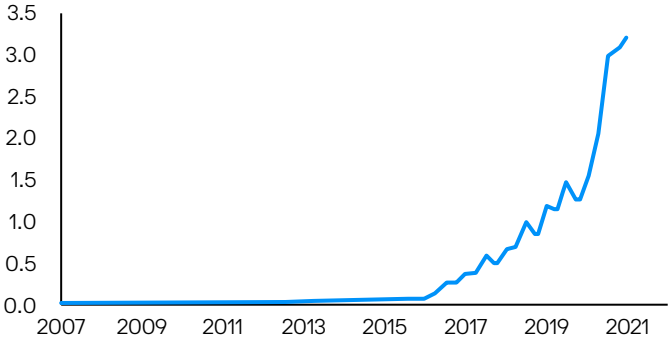
Millions of monthly active users



Source: Matthew Ball (June 29, 2021), Roblox. 2020.

Roblox hours of gameplay

Billion hours of monthly playtime



Source: Matthew Ball (June 29, 2021), Roblox. 2020.

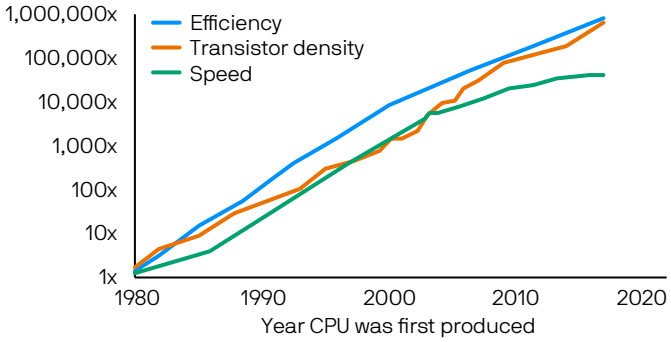
While we have been living in the Metaverse since the age of networked PCs, a combination of lower cost hardware and faster processing speeds has changed the paradigm.

In our view, the dream of improved experiences many imagine for the Metaverse will simply be further iterations on existing hardware and software capabilities, and will not require further major breakthroughs. The following charts illustrate the improvements in CPU processing speed and efficiency, storage costs and bandwidth speeds.

It is within some of these core building blocks where we are most excited to invest: companies that contribute to a highly connected, graphically intense, real-time AI workload. As we look into the future, we expect companies involved with gaming, e-commerce, and professional and social networking to continue to adapt. For example, we envision a social networking app or e-commerce site will still operate in its current mode, but in order to provide a real-time immersive experience in the Metaverse, it will need to provide an on-ramp (for when the connection moves from the smartphone to AR/VR) and will continue to operate in a dual mode that will allow for the real-time synchronization of the physical and virtual worlds.

CPU improvement rates

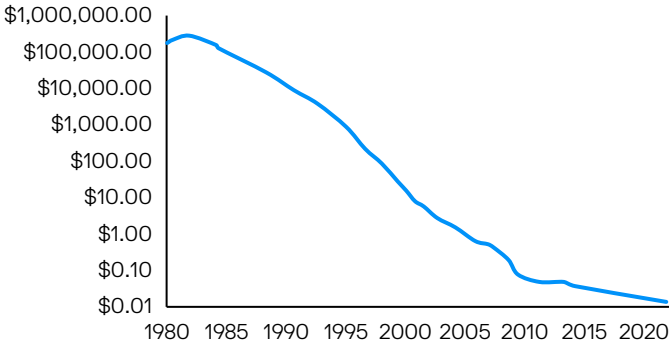
Improvement, multiple of 1979 value (log scale)



Source: Georgetown Center for Security and Emerging Technology. April 2020.

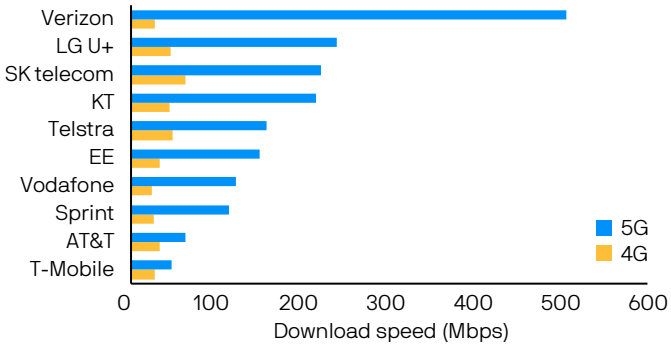
Cost of information storage

USD, hard drive cost per gigabyte (log scale)



Source: AI Impacts, DiskPrices, J.P. Morgan Asset Management. 2021.

5G vs 4G: average download speed



Source: Opensignal. April 2020.

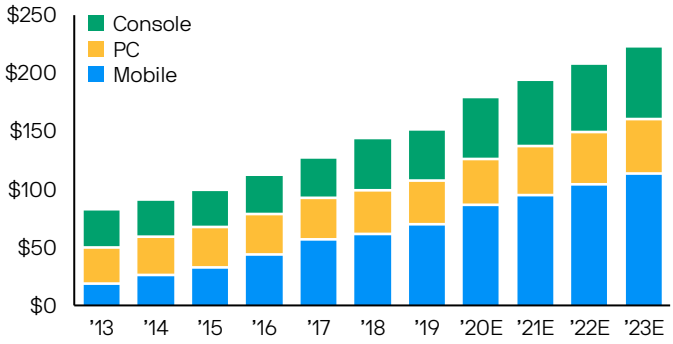
It's no surprise that gaming is spearheading the Metaverse market. Even so, other use cases will continue to emerge. The big question: Is the Metaverse investible, and if so, how? Some argue that the Metaverse is here now, as evidenced by the gaming expansion that's underway, as illustrated below, growing Metaverse concert attendance,[3] marketing campaigns, activity around non-fungible tokens and digital real estate.[4] We think these use cases are merely the tip of the iceberg and that the Metaverse's exponential growth phase, and the more meaningful investment opportunities, still lie in the future.

Interestingly, Microsoft's acquisition of Activision is geared toward augmenting its Metaverse strategy, which we believe encompasses not only gaming (given its large presence with Xbox and gaming subscription services, where Activision fits in) but also expands many enterprise use cases. Microsoft has ambitions to build a collaboration platform that leverages AR/VR and incorporate its productivity suite. We also think it is likely that Microsoft leverages its gaming and Metaverse know-how into industrial use cases as well.

Stock selection in Metaverse companies will be one of the most important decisions made in portfolios, given the potential for both outsize gains and spectacular losses, since some of these experiences may not be durable or economically viable. **In fact, we wouldn't be surprised if revenue from the Metaverse only started to take shape by the end of this decade.** We think the current stage is the bottom of the S-curve hype cycle: That's the point we have observed in the past when large frictions were removed from enabling technologies. For example, the mobile app economy and e-commerce didn't take off until innovation made cloud computing cost-effective and versatile, allowing app marketplaces to safely handle hundreds of billions of e-commerce transactions daily.

Global games revenue

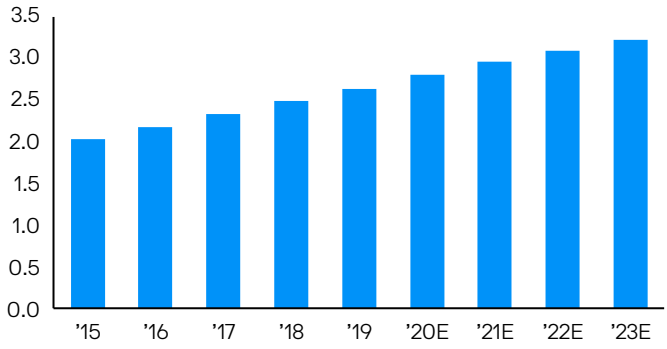
USD, billions



Source: Newzoo, GS. December 2021.

Global games players

Billions



Source: Newzoo, GS. December 2021.

The collection of all these technologies and ecosystems will need to come together in order to achieve the full vision and potential of the Metaverse.

[3] One example: Ariana Grande and Travis Scott both held live concerts via Fortnite that attracted over a million viewers on a single occasion, many multiples of the number of people attending in-person concerts.

[4] Digital real estate is virtual property being developed and invested in within the Metaverse. The long-term vision is that consumers will be able to buy and sell both digital goods in this 3D community.

The Metaverse: a proposed blueprint for relevant enabling technologies and ecosystem

Technologies	
Artificial intelligence	Automatic digital twin, computer agent, autonomy of avatar
Blockchain	Data storage, data interoperability, data sharing
Computer vision	Localization & mapping, body & gaze tracking, scene understanding, image processing
Network	5G/6G, QoS/congestion control, QoE, network slicing, network aware applications
Edge computing	Edge cloud, distributed/federated learning, fairness and privacy preserved user presence
User interactivity	Mobile input techniques, mobile headsets, user feedback cues, haptic devices, telepresence
Extended reality	Projection and hologram, augmented reality, mixed reality, virtual reality
IoT & robotics	IoT, connected vehicles, human-robot interaction

Ecosystems	
Avatar	Appearance and design, user perceptions, human-avatar interaction, avatars-in-the-wild
Content creation	Authoring, multi-user collaboration, creator culture, censorship
Virtual economy	Metaverse commerce, virtual objects trading, oligopoly, economic governance, ownership
Social acceptability	Privacy threats, user diversity, fairness, user addiction, cyberbullying, devices, cultural diversity
Security & privacy	Deep-fakes, alternate representations, ethical design, protection of digital twins, biometric data
Trust & accountabillity	Fairness and bias, power and control, opacity and transparency, auditing, governance

Source: *"All One Needs to Know about Metaverse,"* Lee et al. (Korea Advanced Institute of Science and Technology). October 2021.

What progress needs to happen to enable the full vision of the Metaverse?

We see many areas where significant improvements have been made, while others remain works in progress.

Augmented reality. The consumer interface will be the gateway to the Metaverse, just like PCs and smartphones were, and therefore progress in this area is of significant import. Augmented and virtual reality are the most commonly discussed hardware systems, and we think the Oculus experience is the best current platform on the market. We think the progression of Oculus hardware in both capability and pricing is underappreciated: $300 now provides access to a fully formed hardware and software gaming experience that has cut its tether to the PC, and which now enables wireless hand controllers, audio, haptic feedback and front-facing cameras to provide mixed reality experiences. We expect continued progress in shrinking many of these core pieces of technology to make them more mobile.

Artificial intelligence. Progress in AI will be crucial to enabling various technologies related to natural language processing, communication, computer vision, processing and acting on large amounts of data, e-commerce and gaming. Furthermore, we believe that as this gap between humans and AI closes, the Metaverse will be the place where many of these milestones are reached. Today, Tesla's 8 cameras capture the world around it and learn how humans interact with the road, pedestrians and other vehicles. Similarly, data collected between interactions in AR/VR experiences will drive a rich conversational/interactive dataset that will further train and improve the systems themselves.

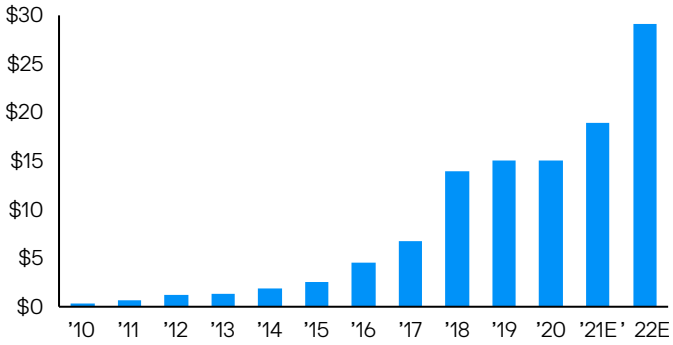
Software tools that allow the creation of real-time 3D graphics have been difficult to produce at mass scale. We see AI as enabling automated creation of 3D graphics in which any person can become a 3D artist/creator, just as anyone today can become a content creator on Instagram/TikTok/YouTube. This is one of the reasons Unity (a widely used software creation tool for 2D gaming) bought Weta, the 3D studio behind the Lord of the Rings franchise. Unity plans to democratize content creation by enabling drag-and-drop and automatic creation of avatars and scenes using 3D visual techniques that every person, not just game developers and coders, can deploy. Another example: NVIDIA has put forth a development platform (Maxine) that leverages AI to intuitively build virtual Metaverses for collaboration.

Improvements in computing power have been critical to enabling Web 2.0 to act as a central repository of commerce and data for consumers, enterprises and government. Thanks to the growing computational power enabled in the cloud and on consumer devices, Web 2.0 has become the most vibrant, secure and trustworthy medium, where billions of entities consume trillions of dollars of goods and services. Apple's smartphone now holds the computing power of several mainframes that existed two decades ago. While Moore's Law is not dead, it's becoming more challenging to drive major boosts in performance by relying solely on shrinking transistors. Semiconductor processor companies are developing new modular architectures to incorporate more system bandwidth, memory and alternative compute cores.

Communication speed will also need to be massively enhanced. We believe 5G is a key enabler of expanding reach into highly graphically intense experiences, not just in virtual world experiences but also in increasing demand for uploading real-time physical experiences around us. The network to support larger populations in virtual experiences also raises the need for more data center construction. It's no surprise that Meta stepped up its capex meaningfully to around $30 billion for FY 2022, driven by investments in data centers, servers, network infrastructure, AI and machine learning capabilities.

Facebook annual capital spending

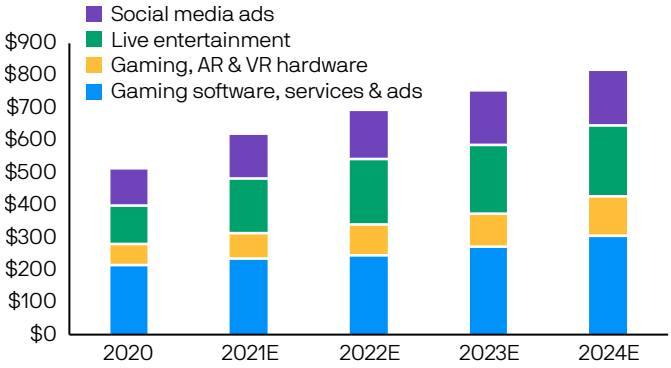
USD, billions



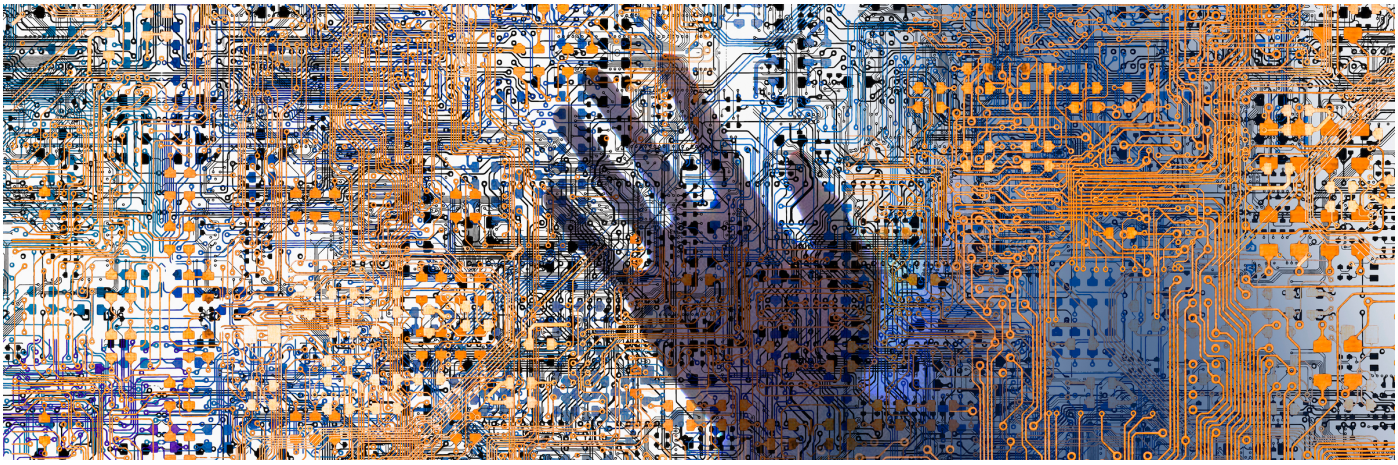
Source: Bloomberg, J.P. Morgan Asset Management. January 2022.

Metaverse revenue outlook

USD, billions



Source: Bloomberg Intelligence. December 1, 2021.



There are many areas where we still don't have full visibility into what will happen next.

In the PC era, Microsoft dominated the operating system, but that dominance didn't translate into the mobile world, partly since Microsoft used the same OS as in PCs in its smartphones, which weren't built from the ground up to support a new mobile OS and device. Apple, on the other hand, reimagined the mobile OS and smartphone device, and built the two in tandem to maximize the full potential of mobile computing. Apple then leveraged the full force of a developer community that Microsoft largely didn't attract. We think the quality of the gateway and the OS that manages it will be central to the success of whatever Metaverse platform emerges. Just like today, when we have a different gateway for professional and personal, we might have to have separate platforms for the social/gaming Metaverse vs content consumption and professional collaboration.

Similarly, there are many areas around security, privacy, finance, record keeping, intellectual property, copyright, government regulation, real estate and property ownership that have yet to be answered. All of these issues are beyond the scope of this paper yet represent important questions that will determine the readiness of the Metaverse to become a trusted environment for global commerce.

How are we investing in the Metaverse? We think the Metaverse will be a multi-decade investment opportunity where the S-curve will ebb and flow, with plenty of failures along the way. As of now, we see the most compelling opportunities within enabling technologies that will be critical in building the Metaverse. The list might sound familiar because the Metaverse will represent the next iteration of many foundational elements in place for years. For example, semiconductors will remain foundational to enabling the computing bandwidth required for Web 3.0. We believe the AI and graphical intensity of the Metaverse will present opportunities for many semiconductor companies, including equipment manufacturers such as Lam Research, ASML, Taiwan Semi, Advanced Micro Devices and NVIDIA. We believe enabling content creation software from Roblox and Unity could play a pivotal role.

How will the Metaverse evolve in China? China is highly engaged and interested in AI, Metaverse and electric vehicles/advanced driver assistance, but lags in many of the critical enabling components (i.e., CPU, GPU, compound semi, etc.) that enable them. Chinese government policy will continue to be supportive toward building self-sufficiency in critical enabling technologies, and as such, our view is that China will be a critical region in which the Metaverse is adopted and embraced.

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Innovation #3

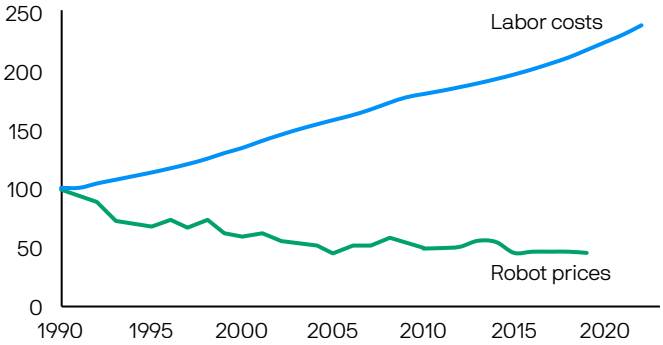
Automation/Artificial Intelligence

Multiple enabling factors are now converging to drive what we think will be an elongated phase of industrial automation and robotics adoption. Increasing computing power, falling computing costs and cloud computing are accelerating machine learning functionality. Advances in robotic dexterity and machine vision are catalyzing new applications and more productive uses.

Advances in communication technology (i.e., 5G, Wifi6) are enabling factories to become increasingly digitized and connected while helping them better leverage cloud-based functionality and storage. At the same time that automation's cost and functionality are improving, labor availability is increasingly constrained by aging populations and pandemic-related disruptions. As a result, C-suites are increasingly focused on capturing the value of enhanced digitization and automation.[5]

US robot prices vs labor compensation

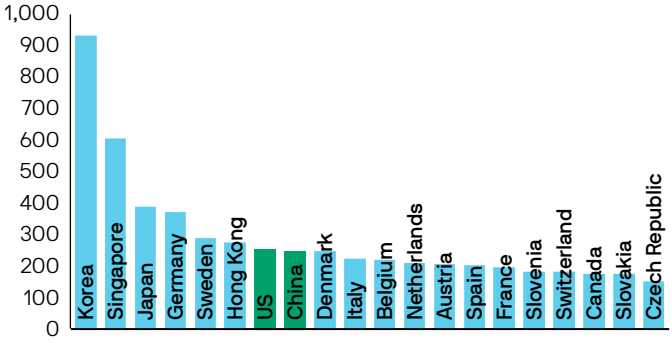
Index (100 = January 1990)



Source: CBO, EIU, McKinsey, International Federation of Robotics. 2021.

Manufacturing industry robot density by country

Robots installed per 10,000 employees



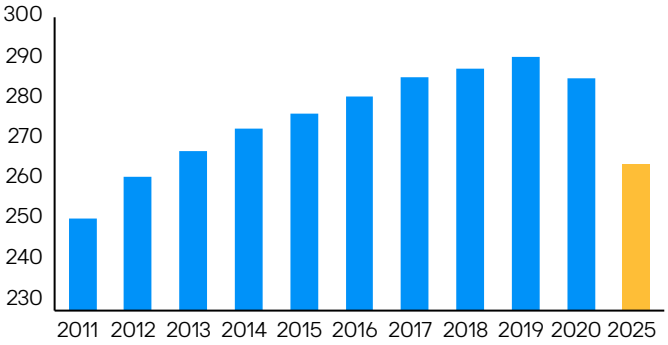
Source: International Federation of Robotics. 2020.

5 **Does artificial intelligence increase or decrease the need for workers?** According to a study from McKinsey, AI adoption coincided with fewer workers required in some companies and more in others. In other words, AI does not by default reduce labor demand and can coexist with increased output and employment. McKinsey concluded that more respondents overall (17%) reported job increases than decreases (13%).

The opportunity around industrial automation and robotics cuts across multiple sectors and regions, and is still early days. Market forecasts from Teradyne suggest that the penetration of collaborative robots and autonomous mobile robots is still only 1%-2% of all automatable tasks. China is the largest market for industrial robots and is so far leading the growth charge, and 2020 marked an inflection point for its migrant worker populations. Chinese manufacturers are also losing labor to the service industry as China's economy evolves. The Chinese government in its latest Five-Year Plan is providing financial incentives to double robot density and drive annual robotics industry revenue growth over 20%.

Migrant workers in China

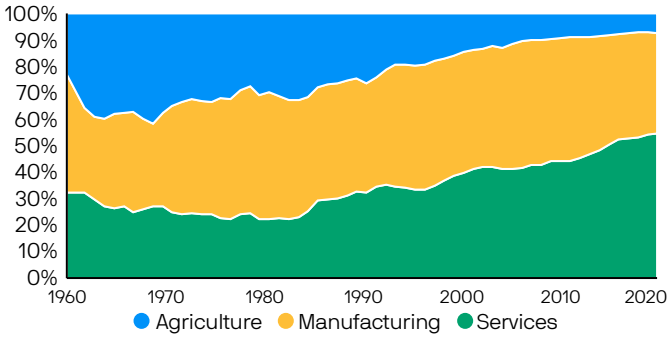
Millions of workers



Source: Bernstein. 2020. Yellow bars indicate estimates.

China GDP sector breakdown

% of GDP



Source: World Bank. 2020.

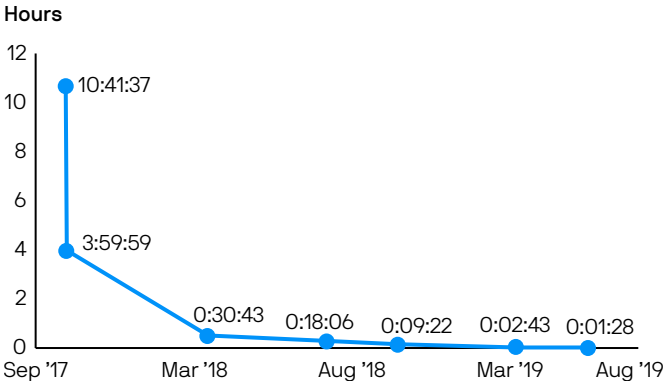
The main barrier to broader adoption of robotics has been the development of the software ecosystem and computer vision technologies.

Deploying robotics technology at large scale (at auto and industrial factories, for example) has been largely resolved, since there is a concentrated ecosystem of interwoven companies involved. However, inserting robotic technology into everyday tasks and making robotics more approachable to engineers of all backgrounds have been more challenging. Primary reasons: the scarcity and lack of maturity of integrated software components; the lack of a modern software operating system akin to Android/iOS that standardizes the market for engineers; and the early stages of computer vision technology.

Computer vision in particular has been challenging, since it requires the development of advanced AI techniques (training large AI models, using inference at large scale). Progress is underway: As illustrated in the first chart, image recognition times have declined by a factor of 20x in just two years, according to a Stanford University assessment of NVIDIA's artificial intelligence architecture (its costs also declined). As shown in the second chart, AI algorithms continue to improve with respect to image identification accuracy vs a human baseline (note that the latter is affected by spelling errors and response ambiguity).

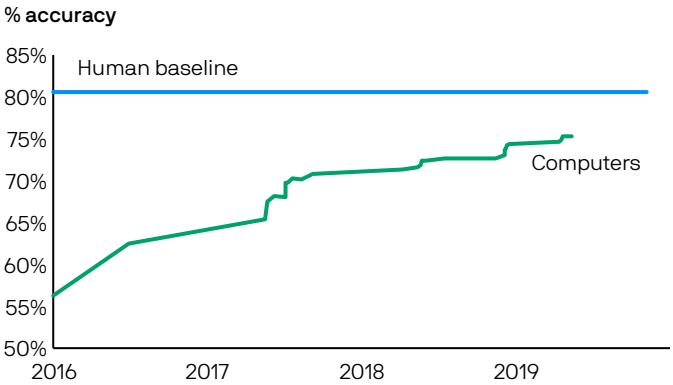
However, many years of work will be needed before AI can deliver computer vision that mirrors the speed, accuracy and effectiveness of the human eye. While AI recognition capable of distinguishing between certain human activities has improved markedly in the last few years, it is still in its infancy in being able to distinguish others (see third chart). That's one reason only a small fraction of commercial robotics deployments are equipped with AI/deep learning computer vision, a testament to its underlying complexity.

Time to train an AI model to classify images



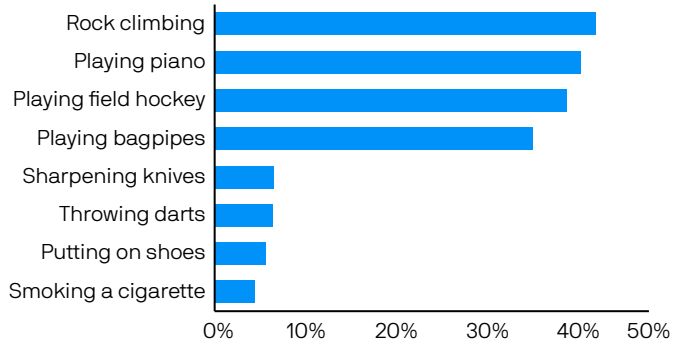
Source: Stanford Human-Centered Artificial Intelligence Institute. 2019.

Image identification accuracy vs human baseline



Source: Stanford Human-Centered Artificial Intelligence Institute. 2019.

AI recognition improvement measures since 2015



Source: Stanford Human-Centered Artificial Intelligence Institute. 2019.

We see potential for more meaningful progress ahead. We believe the success of robotics will be largely influenced by the development of cloud-enabled technology (software that runs robotics; cloud applications; simulation software, which is critical; as well as cloud infrastructure and broad software tools). On that note, all public cloud vendors (Amazon Web Services, Microsoft Azure and Google Cloud) are making tools available aimed at accelerating the pace of innovation.

Our research and investments span a wide spectrum of companies that are levered to an accelerated pace of industrial automation. Our focus is on separating the winners from the losers: Some industries and companies are inherently better structured than others to support long-term durable growth. We look to invest in companies whose products are technology-leading, high value-add and difficult to displace, and whose scale and organizational structure can maintain that differentiation.

We see the most compelling opportunities within the enablers. There's a wide spectrum of enablers across software and hardware:

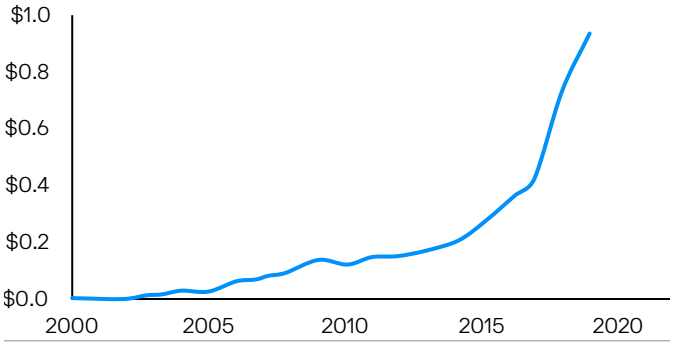
- Semiconductor companies that are critical enablers to robotics technology and underlying computer technology: Analog Devices, Texas Instruments, NVIDIA
- Semiconductor capital equipment and semiconductor software that enable tech providers: Lam Research, Teradyne, Synopsys, Cadence. Demand for AI-based chipsets is projected to quadruple revenues by 2025
- Cloud companies that will enable democratization of robotics (Amazon, Microsoft, Google)
- Key component companies to robotic companies, such as Nabtesco (manufacturer of precision reduction gears), with very high market share in high value-add products; Shenzhen Inovance (leading motion control and NEV powertrain maker in China); Delta Electronics (global leading consumer and enterprise power supply maker and NEV charging facility enabler); Han's Laser (China's largest laser equipment maker and Apple's primary laser equipment supplier); Advantech (global leading embedded system producer) and Keyence (leading provider of industrial vision and sensing)
- Industrial automation and control system companies such as Rockwell and Zhejiang Supcon, which have very sticky installed bases

We are wary of parts of the value chain where barriers to entry are lower and it is more challenging to enable durable differentiation. The assembly of robots is less of a value-add, with lower barriers to entry, and as a result robotic assemblers face increasingly elevated competition from new entrants, creating longer-term pricing and margin risks.

To conclude, here's a look at large revenue drivers of AI products and services (the US government) and at the increased corporate activity linked directly to AI:

US government contract spending on artificial intelligence

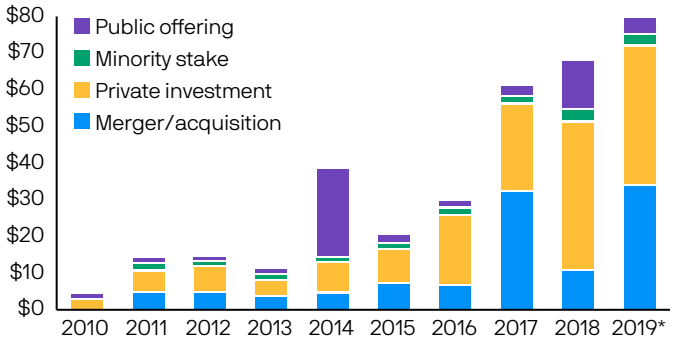
USD, billions



Source: Stanford Human-Centered Artificial Intelligence Institute. 2019.

Global artificial intelligence investment activity

USD, billions



Source: Stanford Human-Centered Artificial Intelligence Institute. 2019.
*indicates YTD investment through October 2019.

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Innovation #4

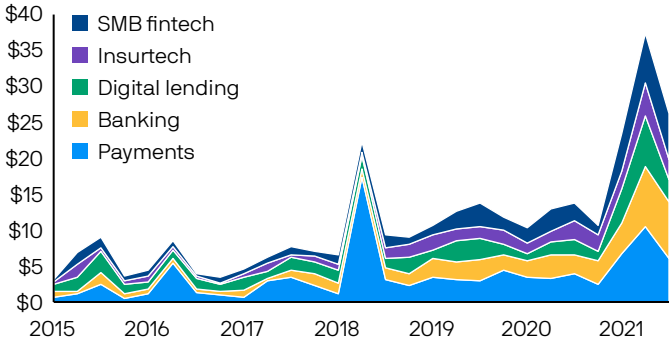
Fintech and Cybersecurity

A common characteristic of many companies that generate alpha is that they're on the right side of change. The convergence of cloud computing, machine learning and digitization of financial services has resulted in innovation and the formation of new business models in financial services.

As the landscape evolves, we believe that parts of the traditional bank business model are at risk if they do not embrace machine learning and digitization effectively. Alternatively, the big banks that adapt could really thrive. By creating new products that maximize value and convenience for consumers, fintech companies can bypass large incumbent moats. This has occurred in a sector that's been slow to leverage new technology and as banks have been weighted down by a large increase in regulatory complexity (see fourth chart), allowing fintech leaders to benefit from growing consumer adoption. One last point to make on fintech companies: They are often of interest to large banks that are increasing their own digital offerings to clients, as illustrated by the chart by the following page.

Fintech VC funding by sector

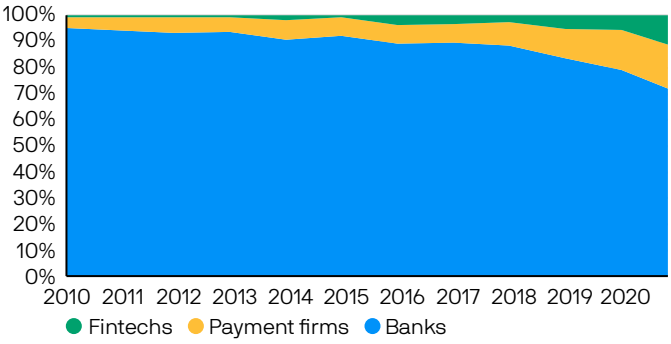
USD, billions



Source: CB Insights, J.P. Morgan Asset Management. Q3 2021.

Top 500 global banks, payment and fintech firms

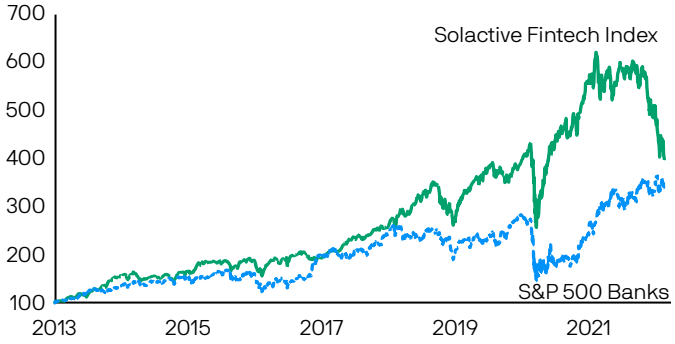
% of market cap



Source: The Economist. October 7, 2020.

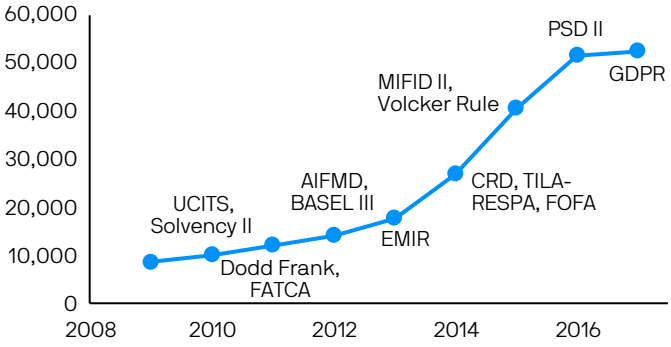
US fintech vs bank performance

Total return index (100 = Dec 2012)



Source: Bloomberg, J.P. Morgan Asset Management. February 22, 2022.

Global number of regulatory publications, changes and announcements per year



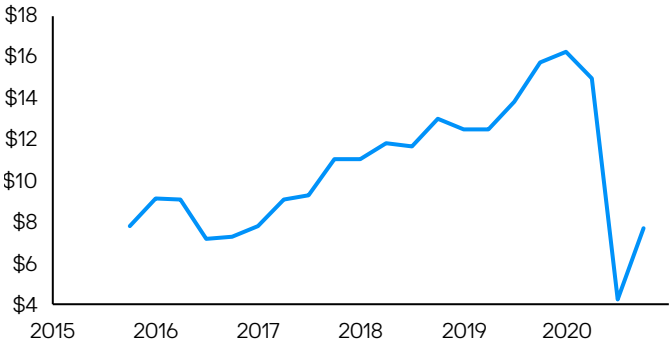
Source: Infopulse. 2021.

The availability of cost-effective cloud storage and computing has brought machine learning directly into product design. One recent example is "buy now pay later" (BNPL) loans, which allow platforms like Affirm to create two-sided payment networks that provide transparent and lower fee credit to consumers at the time of purchase while helping merchants sell to new audiences and drive customer loyalty. Other examples include emerging residential real estate iBuyers that leverage machine learning to forecast future home prices when buying homes directly from consumers, and AI-driven consumer lending companies that supplement legacy FICO scores[6] with more robust and granular customer-specific data. Despite being in very different markets, these business models all approach opportunities where profit margins are small relative to total dollar volumes, allowing for potential incremental improvements to significantly increase profits.

The chart below shows the impressive penetration of BNPL loans by generation, and the top chart at right shows quarterly originations for digital personal finance, small and medium enterprise (SME) and student loan lenders. While COVID interrupted the industry's growth, volumes began to pick up again in Q3 2020. As shown in the second chart at right, digital loan origination volumes are expected to continue to rise.

Personal, SME and student digital loan originations

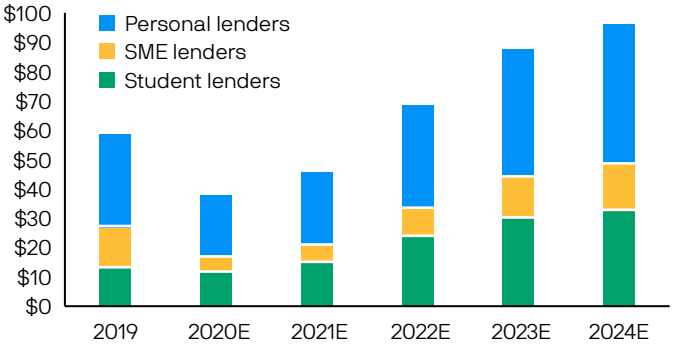
USD, billions



Source: S&P Global. January 3, 2021.

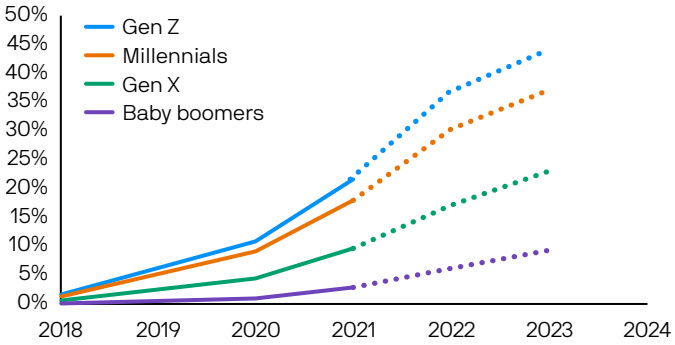
Projected digital loan originations by platform focus

USD, billions



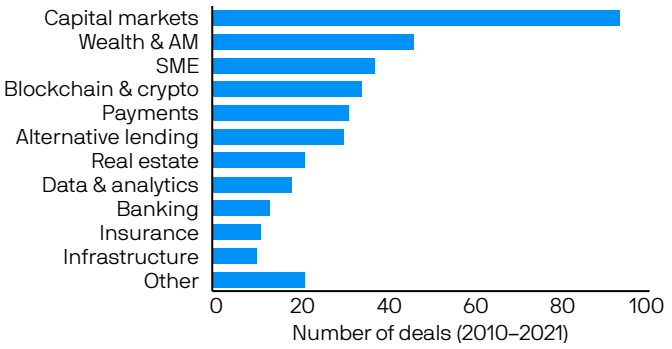
Source: S&P Global. January 3, 2021.

US "buy now pay later" user penetration by generation



Source: eMarketer. May 2021. Dotted lines represent forecasts.

US bank-backed fintech deals by category



Source: CB Insights. April 2021.

[6] FICO is a credit scoring model named after the Fair Isaac Corporation used to indicate to lenders how likely a consumer is to repay borrowed money based on their credit history.

When we look at winners in the fintech space, they tend to cultivate unique datasets and create organizational alignment that reflects the importance of having world-class machine learning and data science skills. In addition, they tend to have a purpose-driven mission to broaden access to credit, often servicing those rejected by traditional lending channels. While there's an inherent adverse selection issue, the upside is low customer acquisition costs and a chance to define a new market opportunity.

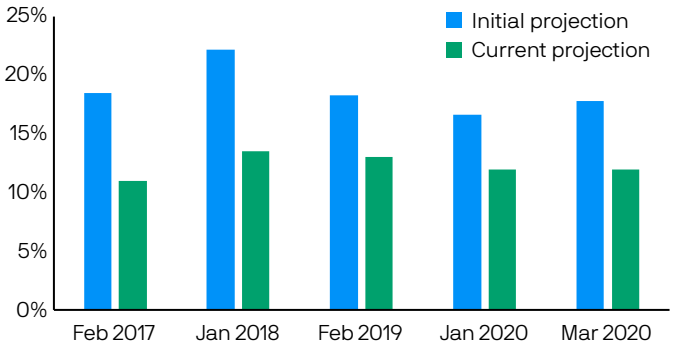
Since investors don't have access to internal fintech scoring models, we estimate prospective value creation by weighing indirect but observable performance data. Within iBuying, for instance, investors could observe that Zillow's owned inventories were extended relative to competitors, suggesting modeling inaccuracies but more importantly foreshadowing future losses for investors (Zillow has since exited the iBuying market). Within BNPL, we can track cohort default rates for Affirm, find incremental improvements across vintages and infer that additional data and model tweaks have improved lending accuracy.

Likewise, within AI-driven consumer lending, we actively follow loan performance over time. For those that securitize loans, we can track ABS structures and the quality of collateral, and monitor cumulative losses. Looking across fintech companies like SoFi, Lending Club and Upstart reveals considerable variation across loan performance and credit quality. Judiciously picking winners and monitoring performance as the competitive environment changes are key.

As an example, we can see that across Upstart's vintages from 2017 to 2020, the cumulative loss performance has been significantly better than anticipated at closing, using Kroll Bond Rating Agency projections. This also manifests itself in relatively lower projected cumulative loss rates for vintages relative to the structure's weighted FICO score at closing. Though lending platforms (incumbent and fintech alike) have been supported by a benign credit environment, this early data suggest Upstart can service lower FICO borrowers while offering superior relative loss performance.

Upstart cumulative net loss rates

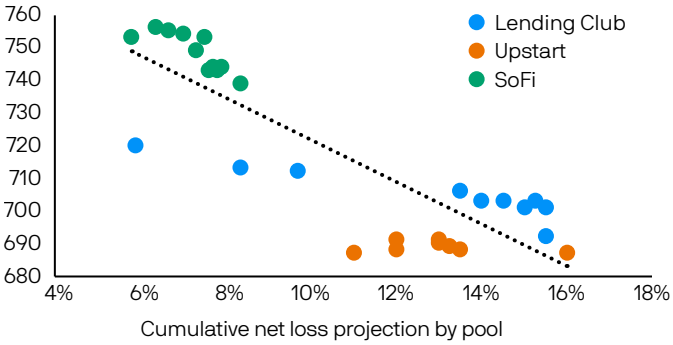
Loss rates by securitization vintage date



Source: Kroll Bond Rating Agency, DBRS Morningstar. August 2021.

Cumulative net loss projection vs FICO scores by lender

FICO score

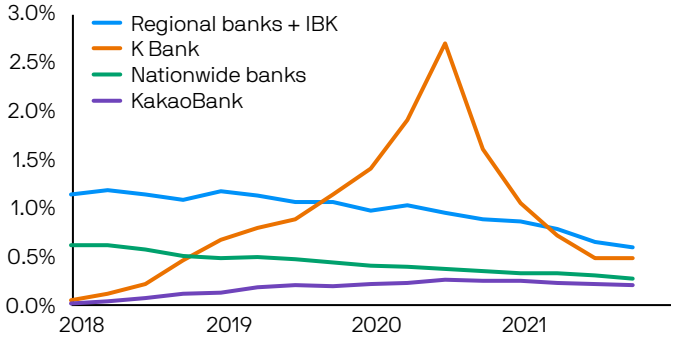


Source: Kroll Bond Rating Agency, DBRS Morningstar. August 2021.

Applying AI and machine learning have also been successful for emerging markets neobanks. In Brazil, Nubank has harnessed alternative data to help build a credit card portfolio in a country where credit bureaus are relatively thinly populated and have short data histories. Nubank's credit card book survived the worst Brazilian recession on record and currently shows better asset quality than the overall banking sector across all income brackets. In Korea, KakaoBank has harnessed the opportunity of alternative data through its relationship with KakaoGroup, which controls KakaoTalk, the dominant social media platform in the country. KakaoBank uses data and AI in credit scoring and fraud detection, and as a result asset quality has compared well with incumbents.

Non-performing loan trends

Non-performing loans as % of weekly total



Source: Company filings. Q3 2021.

On balance, while there's an indication that fintech lenders can add value at lower levels of perceived credit quality, we recognize that performance will truly be tested in a downturn and that underwriting standards must be improved as the industry evolves. Fundamentally, fintech companies that adhere to high underwriting standards with explainable model outputs are best positioned to work jointly with regulators, in turn creating a safer lending environment while raising their competitive differentiation. In that way, assuming these tech-enabled practices produce superior relative returns through a cycle, a downturn can become a proving event for data-driven business models and raise the market's appraisal of these innovative leaders. We would also caution that the regulatory barriers and credit risk to fintechs could result in many failed independent business models, which ultimately could provide an opportunity for the visionary incumbents to acquire next-generation technology. Stock selection will be extremely important given the risks.

A deep discussion on cybersecurity stocks is beyond the scope of this piece, but we do want to highlight the investment opportunities in cyber companies as fintech and other digital interfaces grow. As shown on the next page, COVID prompted increased digital product and service interfaces across all industries. As a result, global security spending estimates continue to climb. Almost every month, we read about another significant data breach, and in December 2021, the cybersecurity community discovered the Log4Shell vulnerability,[7] described by some as the single largest and most critical vulnerability to date.

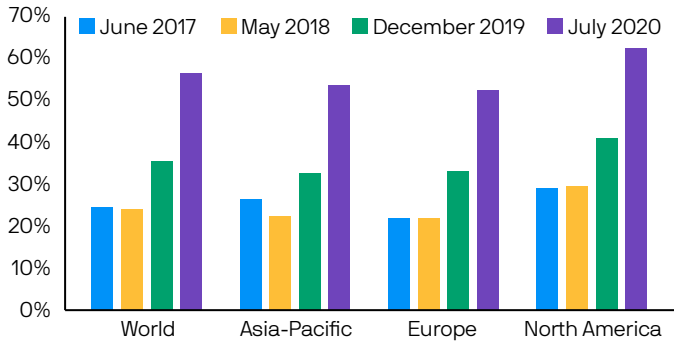
[7] Log4j is an open-source logging framework that reportedly allows requests to servers without checking responses, allowing attackers to execute Java code and/or leak sensitive information.

The cybersecurity industry has room to grow if the latest projections of cybercrime, online migration, corporate/government spending and current vulnerabilities are correct:[8]

- Annual cybercrime costs are expected to grow from $6 trillion today to $10.5 trillion by 2025
- The global cybersecurity workforce needs to grow 89% to effectively defend critical corporate assets
- 44% of workloads were expected to be on the cloud by the end of 2021, and 55% by 2022
- 82% of organizations claim traditional security tools don't work or have limited functionality
- 77% of remote employees use unmanaged devices
- There has been an 85% increase in phishing attacks targeting remote enterprise users vs pre-COVID levels

Within financial services, cyber risks are high, giving large bank incumbents regulatory advantages. Business-to-consumer, consumer-to-consumer, business-to-business and cross-border payments have their own security requirements, creating barriers to entry for fintech competitors. While simpler use cases (small consumer transfers) have been resolved, more complex use cases (i.e., large transactions where a fintech is the responsible party between two banks or other entities internationally) need more work to meet regulatory cybersecurity requirements. As a result, cybersecurity spending is a high priority area for many fintech companies.

The COVID-impact rising share of customer interactions, products and services that are digital, %



Source: McKinsey. October 2020.

Another notable cybersecurity growth sector: energy. Electrification of transportation, industrial energy use and commercial/residential winter heating offers the potential for decarbonization if more wind, solar, hydro and nuclear are added to the grid. But it raises the stakes even further regarding the security of the electricity grid, since even temporary disruptions would cause even greater economic and physical distress.

From an investment perspective, we remain optimistic on the long-term potential for cybersecurity spending. We are seeing upgrades of end-point protection toward next-generation AI-enabled solutions such as those that CrowdStrike provides. Companies such as Zscaler and Palo Alto Networks are well positioned to provide solutions for cloud traffic protection. We are also investing in security solutions that prevent software code from being built with vulnerabilities early on in the development cycle, which companies such as Synopsys play a key role in.

8 Source: Cybersecurity Ventures, ISC2 Cybersecurity Workforce Study, American Rescue Plan, Wedbush Securities, Cybersecurity Insiders' Cloud Security Report, Pitchbook Security Report, Warburg Pincus.

Author

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Head of Global Multi-Asset Strategy, Multi-Asset Solutions

Innovation and Macroeconomics

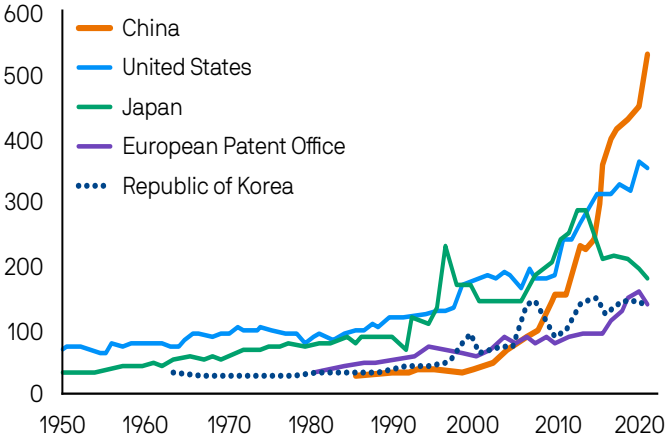
Do some macro environments favor innovation more than others?

Over the full sweep of economic history, several key innovations have shaped today's capital markets, from fractional reserve banking in 17th-century Amsterdam to the concept of limited liability corporations in early Victorian England to the formation of the Federal Reserve in the early 20th century to the digitization and internationalization of finance in the 21st century. But while important innovations shaped companies and markets over history, in modern times the US stands out as a global powerhouse for innovation.

While in recent years the number of patent grants in China has accelerated, the American capital market continues to nurture innovation from idea to commercialization in a fashion unparalleled elsewhere. Note as well that, according to some patent law firms, Chinese patents are of lower quality: After five years, 91% of Chinese design patents are discarded. Furthermore, as per a 2018 analysis from the St. Louis Fed, a greater share of Chinese patents are for design reasons (i.e., shape or ornamentation) rather than invention. There's also a stark difference between patent jurisdiction activity in the US and China: US firms *apply* for far more patents globally than Chinese firms, and also *receive* more patents outside their own borders than Chinese firms.

Patent grants for top 5 patent offices

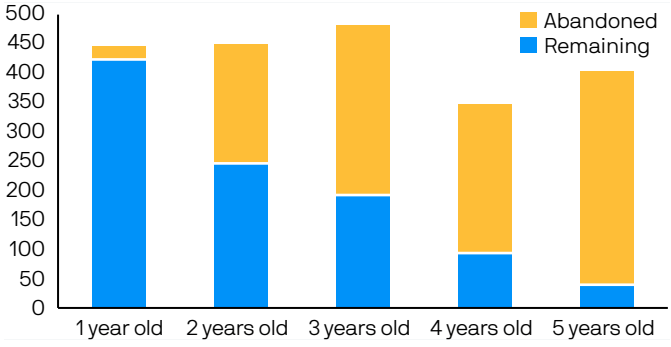
Thousands of grants



Source: World Intellectual Property Organization. 2020.

China worthless patents by age

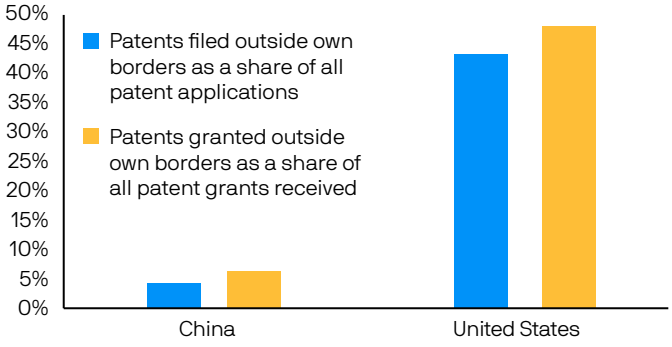
Thousands of design patents



Source: JZMC Patent and Trademark, China National IP, Bloomberg. 2018.

US patents survive outside their own borders, unlike China's

Percent of total patent applications or grants



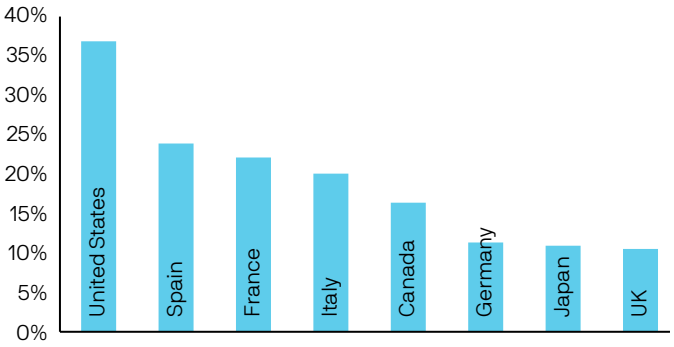
Source: World Intellectual Property Organization. 2016.

The structure of US capital markets lends itself to supporting innovation in several key ways: depth of domestic capital markets, equity culture of savers (illustrated on the right), international demand for USD assets, strength of property rights and bankruptcy regulation. Over the last 50 years, the US equity market has represented, on average, 47% of global equity market cap: just over 60% in the early 1980s, a low of just under 30% by the end of that decade and around 50% today.

Capacity for financial sponsors and entrepreneurs to exit in a deep and liquid public market is a crucial consideration in venture financing. Unlike the comparably sized European economy, US savers have a high tolerance for equity investment; while the US has an equity market roughly twice the size of its economy, the European equity market is barely half the size of its economy. Recycling household savings into equities creates a persistent and long-duration source of capital, and the status of the US dollar as the world's reserve currency creates consistent international demand. While most of this comes via bill and bond markets, a secure money market removes an element of risk for capital inflows.

Household equity ownership

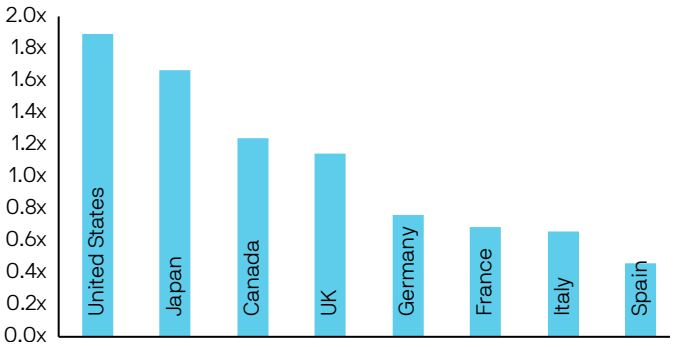
Shares and other equity as % of total financial assets



Source: OECD. 2020.

Household financial assets vs non-financial assets

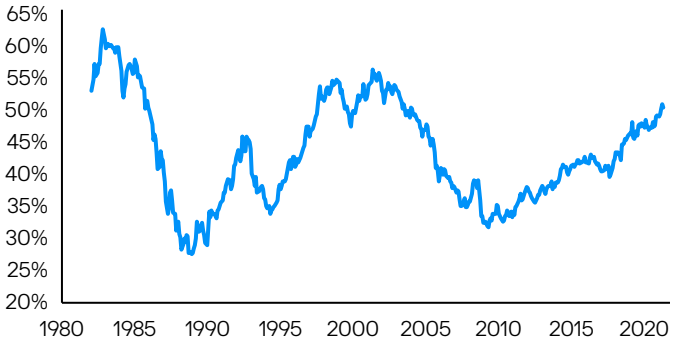
Ratio of financial assets / non-financial assets by country (2016)



Source: Bank of Italy. 2019.

US share of global equity market capitalization

% US / Global market capitalization



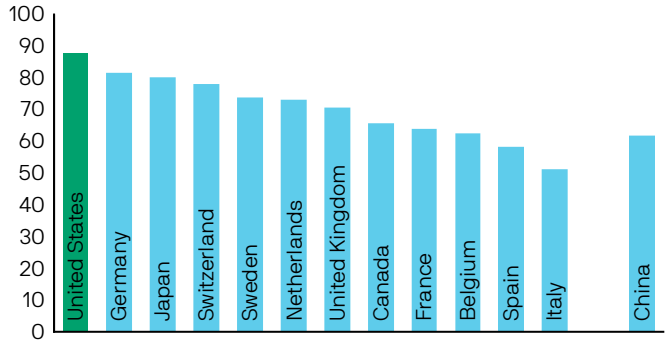
Source: Datastream. January 2022.

Legal structures are also critical for innovation. As shown below and at right, the US ranks highly on measures of insolvency efficiency, legal frameworks to settle disputes and the incentives for intellectual property to be commercialized. These factors show some of the highest correlations to overall measures of innovation.

While strong property rights and enforcement of patent and copyright laws are important for innovation, there are other aspects to innovation as well. A unique benefit of the US system is the lack of stigma or repressive legislation surrounding corporate bankruptcy. Unlike many other regions, the US has a flexible code that does not unnecessarily penalize failed ventures. This enables learning from failed ventures and discourages "zombie" projects. The ability to "fail fast or scale big" is a unique component of the US macro and capital market ecosystem, which currently has few rivals.

Strength of insolvency and legal framework

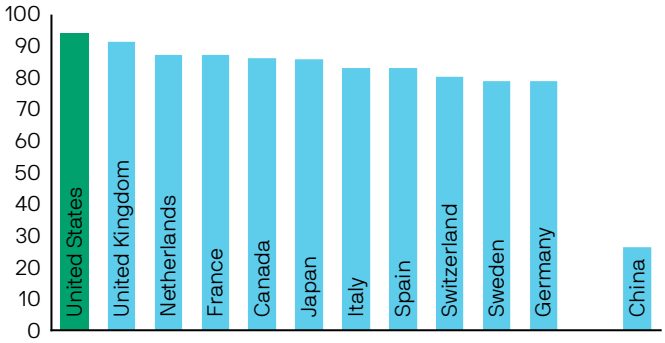
Score (100 = stronger insolvency & legal framework to settle disputes)



Source: World Economic Forum. 2018.

Commercialization of IP assets

Score (100 = stronger incentives for commercialization of IP assets)



Source: US Chamber of Commerce Global Innovation Policy Center. 2018.

Some regions that do not have the same private sector advantages as the US benefit from private-public partnerships. In Europe, there are 10 such PPP programs focused on modernizing factories, energy-efficient buildings, green vehicles, photonics, robotics, high performance computing, 5G networks and cybersecurity.

All things considered, a deep capital market and secure property rights are necessary but insufficient macro preconditions for fostering innovation. Efficient bankruptcy frameworks and forgiving investors that are not permanently scarred by failure are critical components as well. As shown above, the US model ends up with the greatest degree of intellectual property that gets commercialized.

Why don't all good ideas make it, and can we better spot the ones that might?

There can be myriad reasons a good idea doesn't become a profitable one, from poor execution to lack of capital to simply having the right idea but at the wrong time. However, there are considerations that are not well captured in economic or corporate financial models that may offer some insights. Typically, financial and economic models are linear in their construction and fail to account for externalities, such as network effects or speed of adoption, that can lead to nonlinear growth.

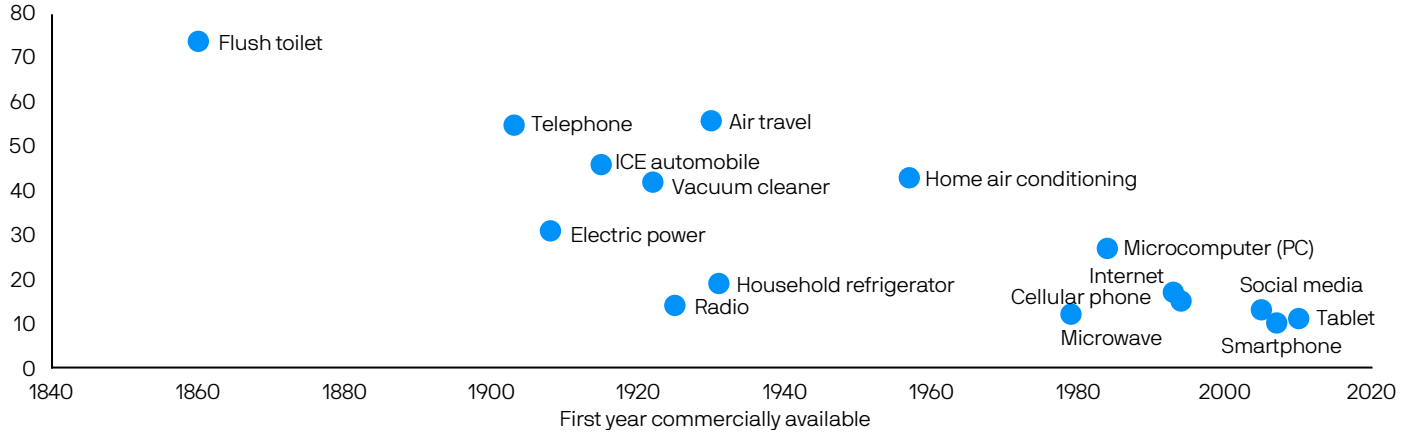
Amazon's success in conquering the last mile is an example of innovation that achieved nonlinear growth by harnessing network effect externalities. Mobile communications and social media are more recent examples of how this works. A single cellphone or a handful of social media accounts may have limited value, but as the number of nodes and linkages grows, the inherent value of the network to its users grows exponentially. This nonlinear increase in utility relative to a more linear growth in users represents a powerful externality but is difficult to build into economic frameworks or most corporate financial analyses.

Both the ability to scale fast and the capacity to build a network or otherwise unlock positive externalities can be a function of the speed of adoption of a new innovation. Today, technology is often assumed to be software, AI, robotics or a similar niche, but we would do better to consider that technology in fact represents the "new new thing"—150 years ago, flushing lavatories were the height of technology, 100 years back it was flight, and 50 years ago it was the computer mainframe. While today's technology is heavily linked to computation and communications, we can't say with certainty what will constitute technology 50 years from now. Renewable and sustainable energy, nanotechnology, genetics and many other fields may all be in contention.

Whatever the technologies of the future may be, there's a clear pattern suggesting that technology is being ever more rapidly adopted and commercialized. The critique of modern innovation from Robert Solow is that all the important innovations have already happened—flight, radio, antibiotics, etc.—and hence there are fewer true opportunities for innovation today. It may well be that Victorian-era advances in sanitation were more beneficial than the ability to harvest "likes" for household pet videos, but **today's faster speed of adoption concentrates that utility for users, and for investors.**

Adoption time of inventions by year of commercial availability

Years to 75% adoption rate since made commercially available



Source: J.P. Morgan Asset Management. 2022.

Isn't innovation simply a synonym for disruption? Not always.

Backing disruptive technology or upstart companies is one way of investing in innovation, but it is not the only route. In some industries, incumbents may have more ability to leverage positive network effects than new entrants. They may also be in a situation where regulation—by accident or design—favors incumbents. For example, in the lightly regulated tech sector a handful of firms with powerful positive network effects have been allowed to operate in near-monopolies for some time. While this is not popular with policymakers, some may prefer a domestic firm earning a monopoly rent to weakening its position and inviting in foreign competition. In an industry that harvests huge quantities of users' data as part of its business model, this consideration may even have national security implications.

Once innovation achieves commercial success, investors may have to consider new challenges that emerge for these companies. For example, many mega-cap tech companies successfully exploit their network to far outcompete competitors. So while such firms, notably the FAANG stocks, are perceived as having high valuations that may be vulnerable to regulation and antitrust enforcement, there is a counterargument: The monopoly rents these firms earn may be more persistent than previously assumed, given the large and established networks they are uniquely able to exploit. Network effects manifest themselves in many ways across technology firms, from the obvious cases of social media where advertising revenue relies on growth of users to exchange platforms like eBay to more specific and sophisticated examples, such as Amazon's web services business, AWS, where substantial fixed costs are justified by Amazon's massive e-commerce network.

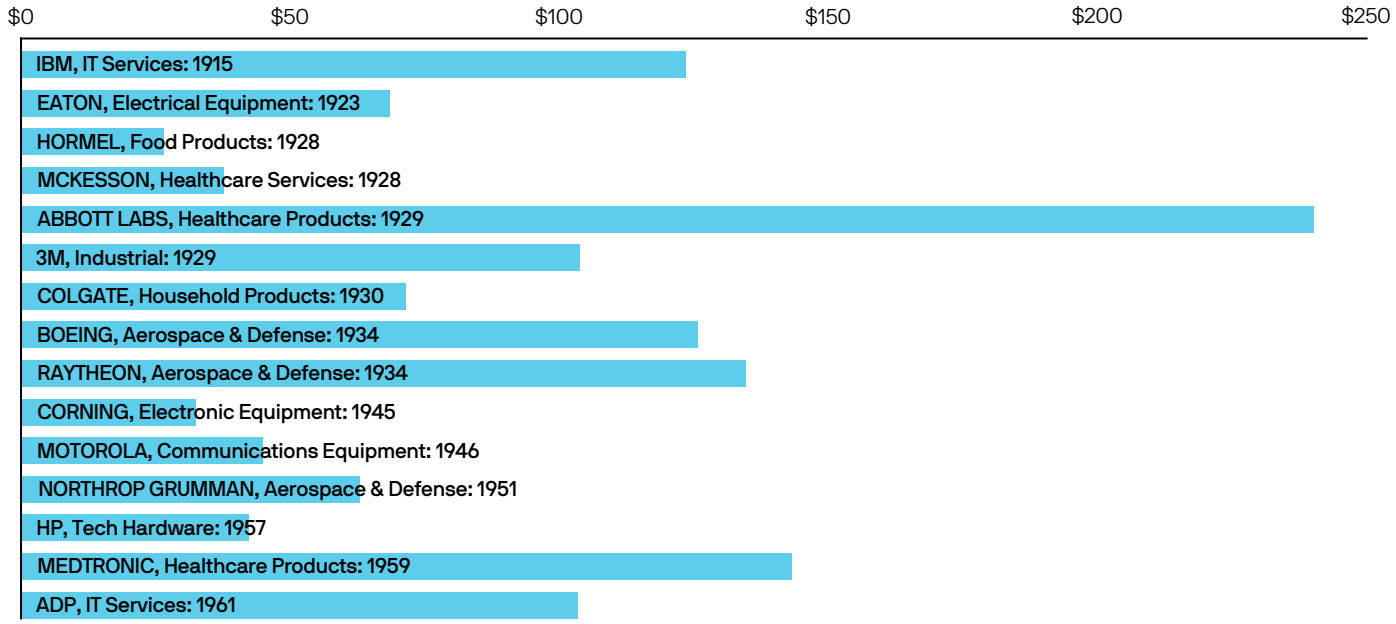
Simply put, exploitation of network effects is a common trait across mega-cap tech. But paradoxically, while venture and private equity financing frameworks often expressly seek out positive network effects, many analysis frameworks for public equities do a less thorough job in accounting for them. Hence, a case can be made that prevailing valuations for the tech firms that enjoy positive network effects are not in fact excessive.

While some incumbents have erected powerful and possibly undervalued barriers to entry, there are other sectors where disrupters are exploiting inefficiencies in the network or industry value chain that incumbents have been unable to respond to. A good example is financial services, where significant regulatory changes hampered big incumbents. Fintech has brought the "fail fast or scale big" philosophy of Silicon Valley to Wall Street; the result is an innovative ecosystem where new entrants operate in niches or gaps in the network that incumbents cannot quickly or cheaply enter. Meanwhile, incumbents effectively have a marketplace of beta-tested innovations that can be bolted onto existing networks. The chart below shows a select group of such incumbents: members of the S&P 500 that went public at least 60 years ago and have consistently navigated around or absorbed competing innovations in their respective industries.

In short, innovation may well be a disruptive force, but in some cases it represents an opportunity and not just a fundamental survival challenge.

Current market cap of select S&P 500 survivors, with industry and year of IPO

USD, billions



Source: Bloomberg, J.P. Morgan Asset Management. January 5, 2022.

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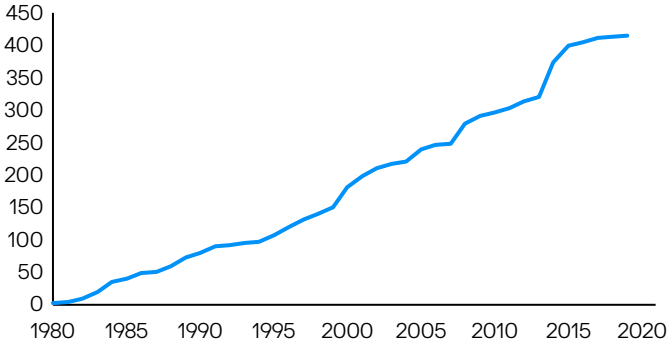
Innovation's victims: How long do investors have to respond before the fall?

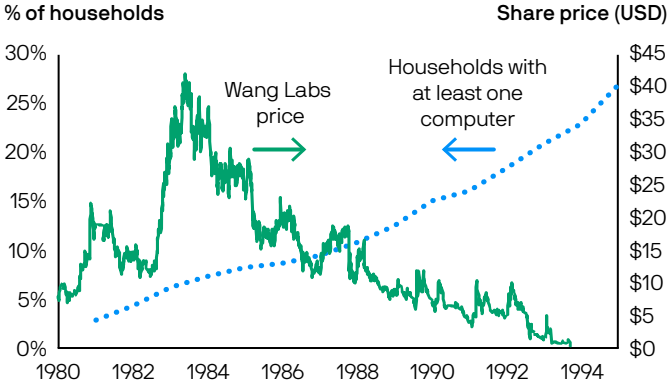
At the same time that investors position to benefit from innovation, they need to be equally mindful about what happens to victims of innovation in their portfolios. **Investors usually will not have a lot of time to respond: Markets tend to anticipate the worst, having lived through quite a lot of creative destruction.** As shown in the first chart, since 1980 hundreds of companies have been removed from the S&P 500 due to failure or distress. For those of us in our 50s and 60s, some of our earliest memories of creative destruction involved **Wang Labs**. In the early 1980s, Wang was at the top of the technology food chain, with top-of-the-line data processing equipment. Personal computers were a novelty and not seen as a threat. But in retrospect, the best time to have sold Wang Labs was back in 1983, when less than 10% of households owned a PC.

Cumulative number of companies removed from the S&P 500 due to distress, 1980-2019



Source: Bloomberg, FactSet, J.P. Morgan Wealth Management. 2019.

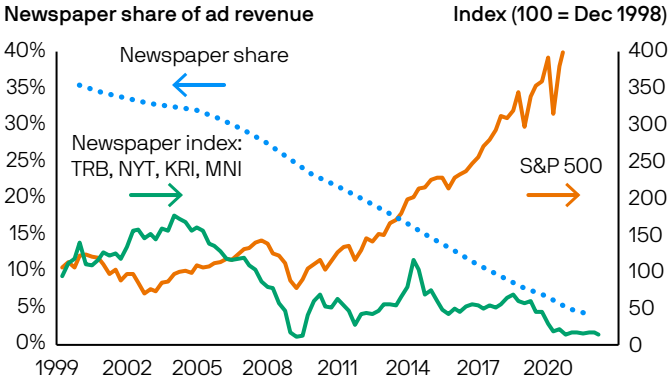
Wang Labs and the demise of data processing equipment



Source: FactSet, IBISWorld, J.P. Morgan Asset Management. 2022.

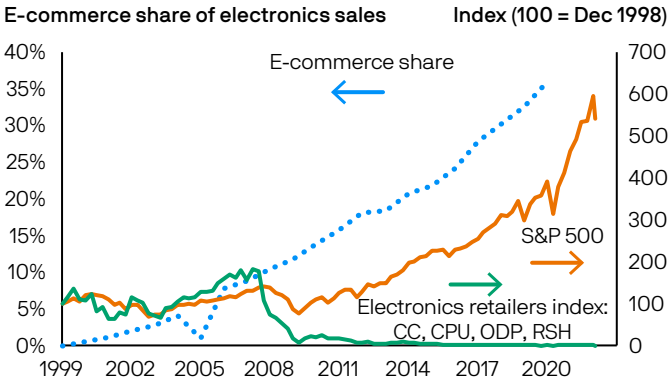
The failure of many newspaper chains and electronics retailers two decades later tells a similar story. The newspaper share of ad revenue underwent a gradual decline starting in 1999 that is still ongoing. But for investors, the best time to have reduced exposure was back in 2004, when the newspaper ad share was still 33%. In other words, **investors benefited by extrapolating decline trends into the future and expecting the worst.** Similarly, investors in many electronics retailers would have been better off not waiting around to see what the e-commerce share of sales would eventually rise to and selling in 2007, when this share was just 10%. Best Buy declined as well at this time and didn't start recovering until 2016, when it figured out e-commerce as well.

Newspapers



Source: Bloomberg, GroupM, J.P. Morgan Asset Management. February 23, 2022.

Electronics retailers

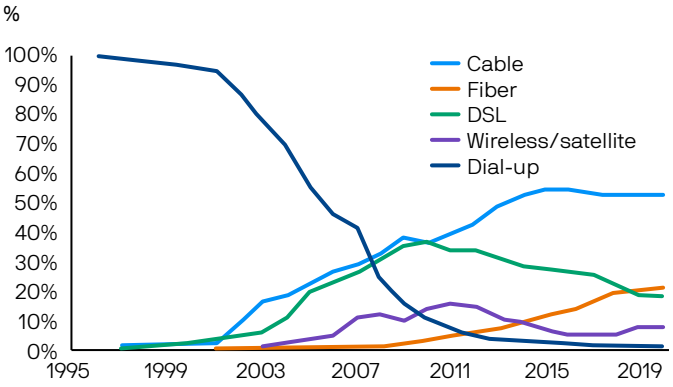


Source: Bloomberg, FactSet, Census, J.P. Morgan Asset Management. February 23, 2022.

A similar story is seen in the decline of wireline telecom stocks.

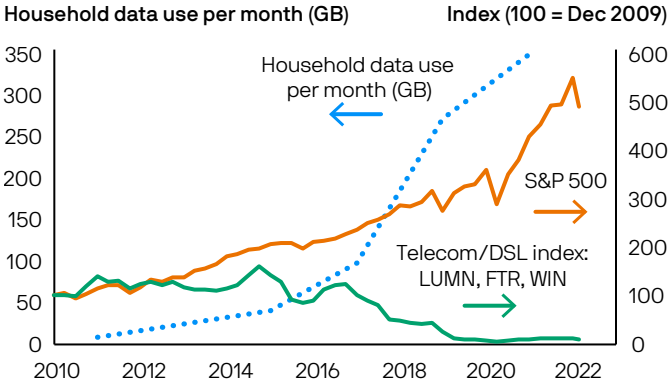
As recently as 2009, telecom's DSL (digital subscriber line) and cable's coaxial/fiber broadband technologies had similar market shares in US households. However, household data consumption began to rise sharply with the advent of streaming services and video consumption. DSL technology struggled to meet consumer demand for more and faster bandwidth: Using 2017 data as a proxy, DSL performance speeds (13 mbps) are substantially slower than both cable (80 mbps) and fiber (70 mbps). The gap between DSL and cable/fiber performance has widened since. In any case, it's another example of the "sell early" doctrine; while wireline telecom companies sought to catch up by investing in fiber to offset voice and DSL losses, these stocks began to underperform in 2015, just as the surge in household data consumption began.

Broadband market share by type



Source: RVA, Fiber Broadband Association. 2019.

Wireline telecom stocks

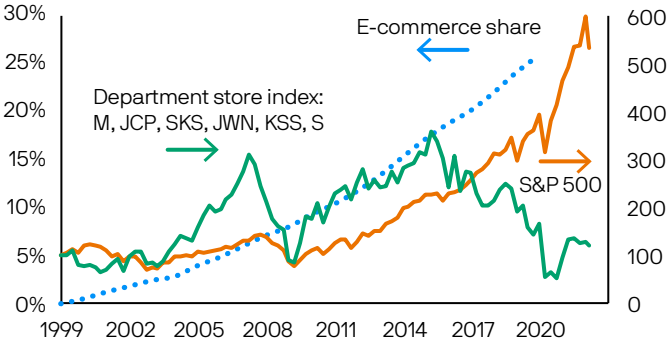


Source: Bloomberg, FactSet, J.P. Morgan Asset Management. February 23, 2022.

Sometimes investors have longer to think things over. Department stores have underperformed the market, particularly in the aftermath of COVID changes to mobility, clothing preferences and work-from-home patterns. But as recently as 2015, department store stocks were still performing in line with the market, despite e-commerce shares of clothing sales that were rising sharply. Investors appeared to give the big chains a chance to develop online offerings of their own with sufficient profitability that would not cannibalize their in-store sales (the market might also have given these companies the benefit of the doubt, given the value of their owned real estate). After it became clear that most of them couldn't deliver, the department store stock decline set in starting in 2015. This is the anomalous case; investors usually don't give companies this much time.

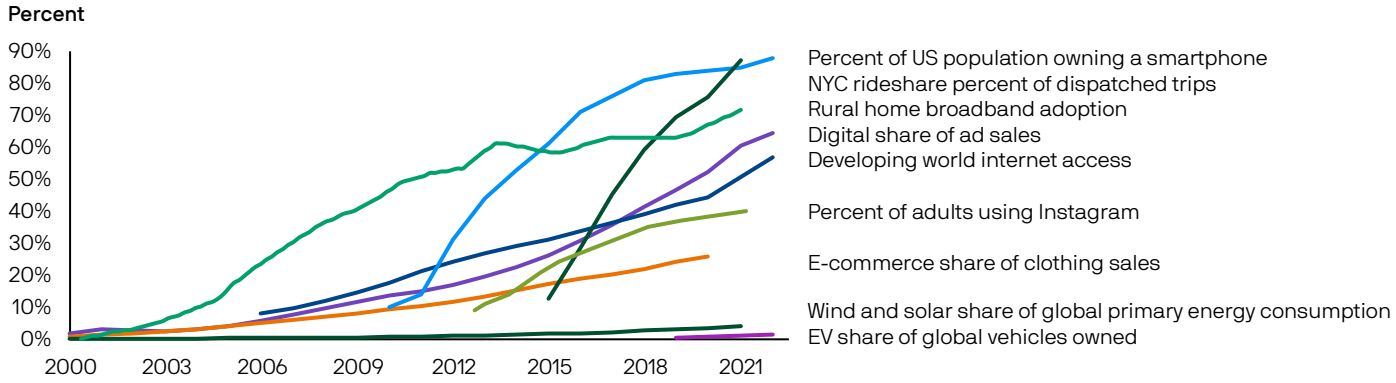
Department stores

E-commerce share of clothing sales **Index (100 = Dec 1998)**



Source: Bloomberg, FactSet, Census, J.P. Morgan Asset Management. February 23, 2022.

Speed of disruption: some of these things are not like the others



Source: GroupM, Census, BP, IEA, FHV, Pew Research, NYC Taxi & Limousine Commission, J.P. Morgan Asset Management. 2021.

What about innovation in energy?

Readers of our annual energy paper, launched over a decade ago, will recall that not all innovation ecosystems are the same. Sectors discussed previously changed since there were few obstacles in the way of their adoption. New products and services appealed to consumer tastes, and buying behavior shifted rapidly. Energy innovation is, unsurprisingly, a very different story.

The chart above shows the bottom line: Renewable energy penetration is rising but faces hurdles in reaching faster levels of adoption. The usual suspects:[9]

- **Intermittency.** Wind and solar power costs have declined sharply, but their electricity generation is intermittent. As a result, high penetration of renewable energy on the grid requires either (a) overbuilt wind and solar capacity combined with large amounts of electricity storage, from which power can be drawn when wind speeds and solar irradiance are low, or (b) sufficient backup thermal power to complement wind and solar power when needed. Neither (a) nor (b) is included in standard levelized cost of electricity estimates (LCOE), which is why we consider them to be of little value in understanding the pace of decarbonization.
- **Transmission.** Another option to deal with intermittency would be a national electricity grid, since the larger the interconnected region, the greater the chance that it's sufficiently windy or sunny enough someplace to provide sufficient power. But the politics and regulatory constraints on grid expansion are intense; many hydroelectric and wind/solar projects have been canceled or delayed due to lack of a federal eminent domain policy on transmission. Local governments and community groups effectively exercise veto power.
- **Transportation.** Electric vehicle adoption is rising but at a much slower pace than most futurists predicted a decade ago. Battery costs continue to decline, and overall EV costs are slowly converging with the price of many internal combustion engine vehicles. But the average life of a car on the road has increased since the 1980s, to over 12 years. As a result, EV adoption will be gradual absent large government incentives to switch sooner.
- **Industrial energy use.** On a global basis, the industrial sector uses more energy than transportation, residential HVAC and commercial HVAC. The production of steel, cement, plastics, ammonia, chemicals and other industrial goods is difficult to electrify, and when this can be done, in most countries the cost of electricity per unit of energy is much higher than the cost of natural gas. This is the next frontier in climate/energy research.

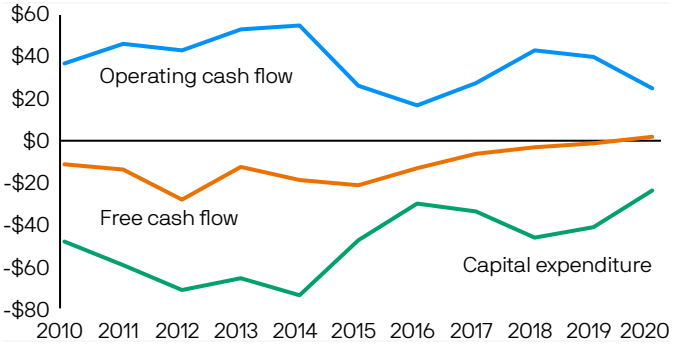
[9] Please see our 2021 Eye on the Market annual energy paper, titled "Future Shock," for more details.

To be sure, oil and gas stocks underperformed the market substantially over most of the prior decade. But based on our research, this has less to do with stranded asset risks and more to do with a supply glut resulting from the shale boom. As shown below, the 2010s were a disaster for investors in shale companies: In aggregate, there was not a single year of positive free cash flow as companies drilled to gain market share irrespective of cost. After a lot of stress and bankruptcies, the survivors eventually refocused on investors and began to deliver free cash flow instead, and at a pace much higher than investors had seen in a very long time.

So that's why we don't see much causality between the renewable share of energy consumption and underperformance of oil and gas stocks in the chart below. In our view, **it was a management performance story rather than inexorable change due to innovation.** What about the future? Decarbonization will continue and accelerate in the years ahead. That said, stranded asset risks for oil and gas companies might be overstated. See the tables below; the first table shows the IEA's Sustainable Development Scenario. If this were to occur, cumulative extraction of oil and gas through the year 2070 would be a fraction of proven reserves, stranding one quarter of natural gas reserves and more than 40% of oil reserves. However, this is a very aggressive scenario.[10] If the IEA's Stated Policies Scenario were to occur instead, no oil and gas would be stranded at all. As a result, while oil and gas companies will eventually be victims as well, the timing for investors is far from certain.

Shale revolution: a revolution in supply, not profit

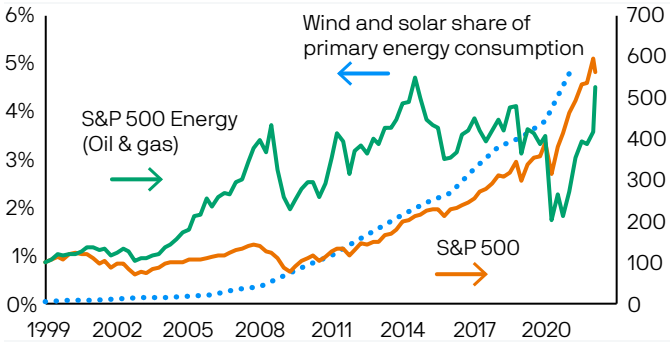
Select cash flow measures for 29 shale companies, USD billions



Source: Bloomberg. 2019.

Oil and gas stocks

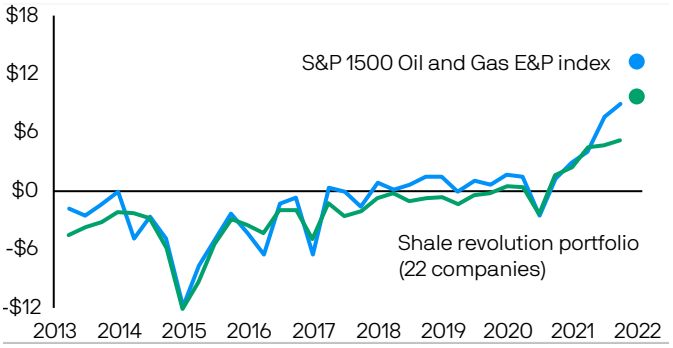
Wind and solar share of primary energy **Index (100 = Dec 1998)**



Source: Bloomberg. BP, J.P. Morgan Asset Management. January 15, 2022.

Energy sector free cash flow

USD, billions



Source: Bloomberg. Q4 2021. Dots represent estimates.

Comparing stranded asset risks in IEA scenarios

	Proven reserves, 2018	Cumulative extraction, 2019-2070	Stranded in 2070	Percent stranded
Sustainable Development Scenario: large amounts of stranded oil, gas and coal				
Oil	**235,931**	**137,478**	**98,454**	**42%**
Nat gas	**169,334**	**125,259**	**44,075**	**26%**
Coal	**596,540**	**77,560**	**518,980**	**87%**
Stated Policies Scenario: only coal assets stranded				
Oil	**235,931**	**265,353**	**0**	**0%**
Nat gas	**169,334**	**228,266**	**0**	**0%**
Coal	**596,540**	**197,890**	**398,650**	**67%**

Source: BP, IEA, JPM. Units shown are million tons of oil equivalent. 2019.

[10] **The IEA Stated Policies scenario is not the status quo;** it reflects some far-reaching and ambitious targets that have been legislated or announced by governments around the world. **The IEA Sustainable Development scenario** is much more ambitious and assumes the following by 2030: Global primary energy use declines by 7% from 2019 to 2030 (compared to a 20% increase over the prior 11 years); solar generation grows by a factor of 5.6x; wind generation grows by a factor of 2.4x; nuclear generation increases by 23% (no decommissioning); coal use for power/heat declines by 51%; and electric vehicle sales reach 40% from today's 4.5% levels.

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If you're interested in discussing this topic in more detail, please contact your J.P. Morgan Client Advisor.

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