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Sustaining America's technology preeminence

The United States seems poised to lead the race for the technologies shaping the future but should ensure its advantage leads to lasting benefits for everyday Americans

Joe Mariani, Duncan Stewart, and Diana Kearns-Manolatos

KEY TAKEAWAYS

- **The United States leads the world in transformational technologies.** The nation fares well in its scientific discoveries, the talent needed to develop them, and markets in which to sell them, but competition is heating up. Many countries are investing heavily in emerging technologies and aiming to steer the market in new directions.
- **Public adoption is important to benefit real people.** Technological preeminence should not be an abstract competition. If adopted at scale, future technologies can improve the lives of everyday people in ways ranging from economic growth to the protection of individual rights and freedoms. But failing to drive development and adoption can similarly put economic wellbeing and civil liberties at risk.
- **The interdependencies between technologies and across different players *should* be understood.** One overlooked link could lead to an unfriendly country controlling a key technology or the failure of an entire technological project. But government can use its unique tools to improve coordination within ecosystems, increasing the chances of lasting public benefit from future technologies.
- But competition is heating up. Many countries are investing heavily in emerging technologies and aim to steer the market in new directions.

Artificial intelligence–written songs, communication with quantum particles, gene therapies: Today's headlines sound like the science fiction of only two decades ago. Recent innovations in areas such as quantum information technology, AI, biotechnology, and climate technology are likely to shape humanity's future. And while many of these breakthroughs may not see immediate mass adoption, the decisions of today's leaders will likely have an impact on who reaps the rewards once they do.

Consider AI: Generative AI alone is poised to contribute nearly $7 trillion to global GDP in the next 10 years.[1] And as it makes money, it can also *save* money. Deloitte's estimates indicate that AI could save the federal government up to 1.4 billion employee hours each year.[2] But its impact is expected to reach beyond the economy—AI is poised to affect everything from education to national security. The potential is so significant that the US National Security Commission for AI concluded that "No comfortable historical reference captures the impact of artificial intelligence on national security."[3]

But the impact of technologies like AI goes beyond just market size and national security. Developing emerging technologies can help boost the income of regular people, make public services easier to use, and even help embed our collective values into the structure of new technology, protecting vital freedoms.

Now remember, AI is just *one* of many technology capabilities and just a microcosm of how the United States is leading in the discovery, development, and deployment of new technologies. However, global competition is heating up, and maintaining global advantage will require leaders to manage technology complexity, drive public adoption, and actively engage in digital ecosystems to enable lasting public benefit. The race for technological preeminence is one America cannot lose.

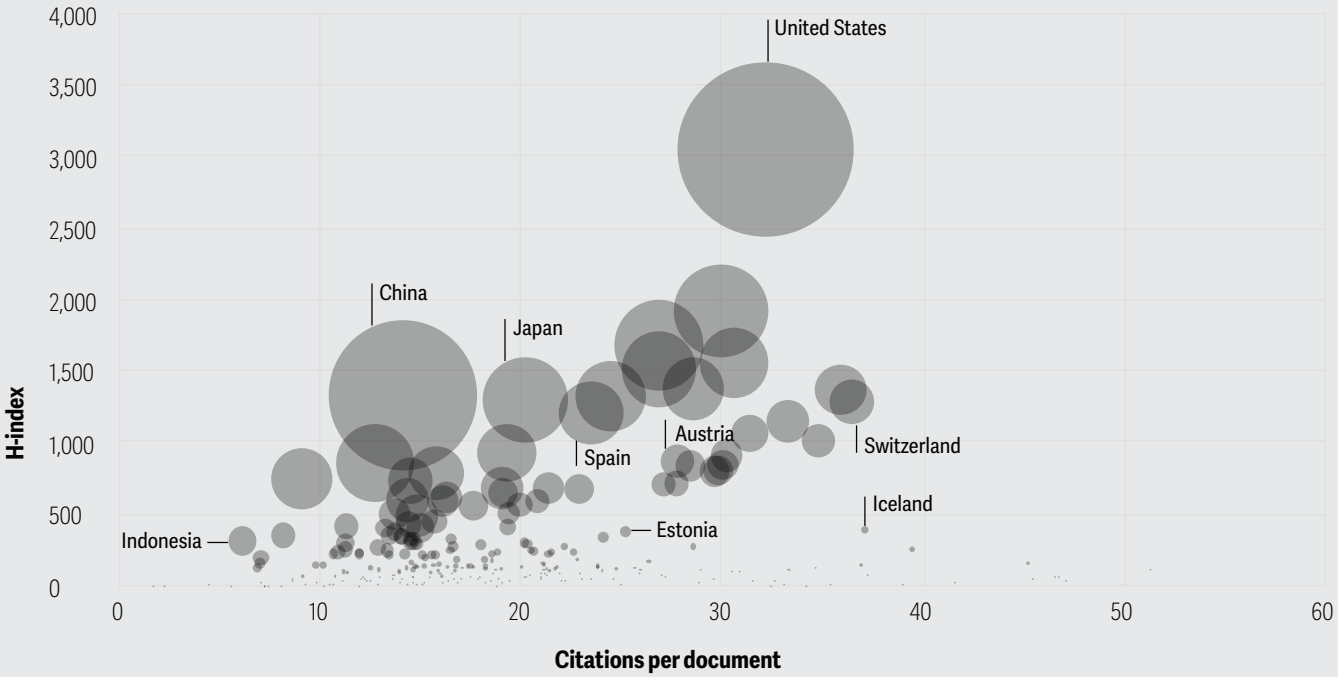
What's now: America is in a strong position to shape future technologies

Contrary to some narratives, the United States isn't necessarily lagging in cutting-edge technologies. By many measures, it still leads the world. But the creation of any transformational technology is a long and complex process, and this leadership can shift over time.

Figure 1

The United States maintains the top position when it comes to quality scientific research

The quality of scientific output here is measured using metrics such as citations per article and the "h-index," a measure of the impacts of these citations on the scientific community



Source: Scimago Journal & Country Rank.

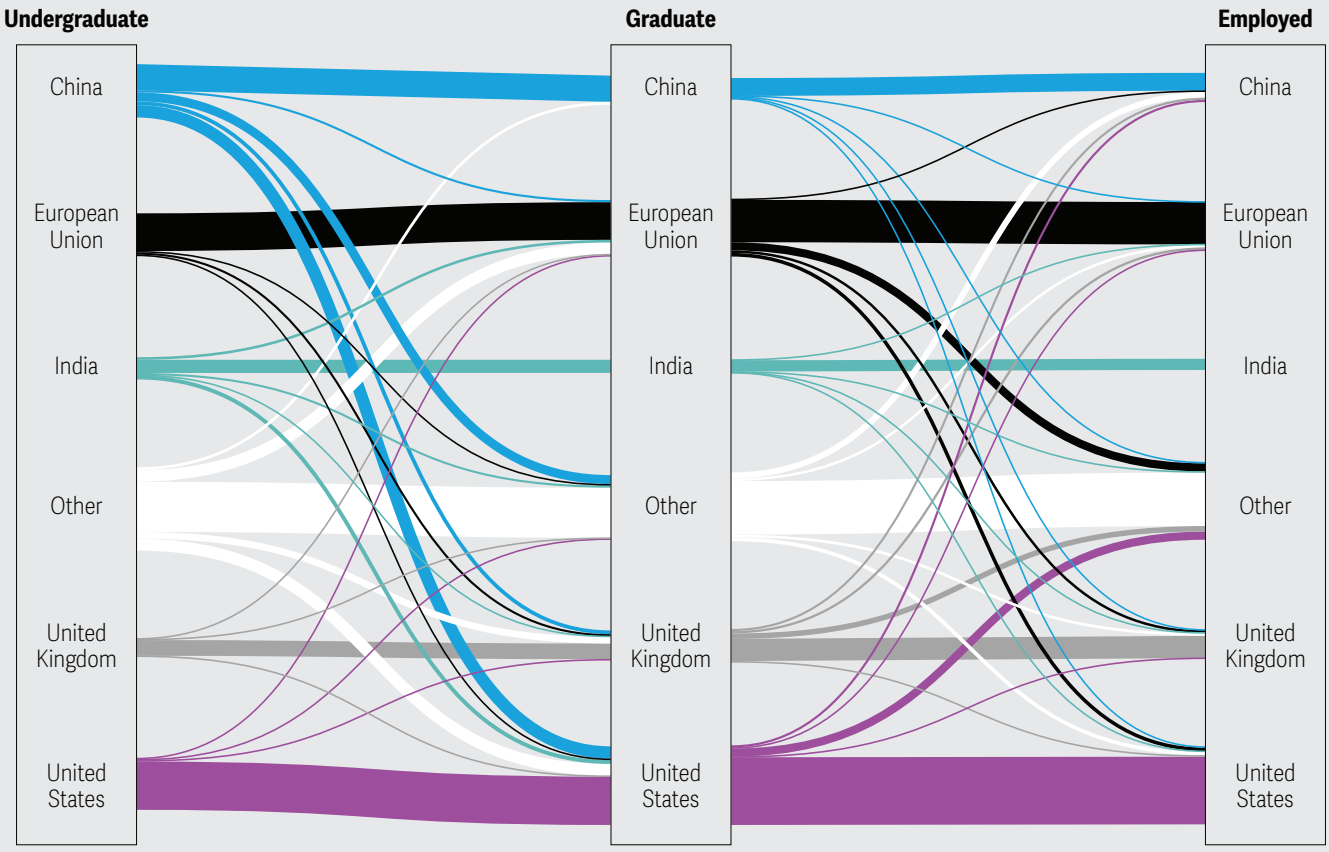
While technology innovation can be measured in many ways, new technologies require scientific discoveries, the talent to develop them, and markets in which to deploy them.

The science to discover new ideas: New technologies begin with new ideas, whether they're about improvements to an existing product or insights into how the world works. The scientific journals that publish those new ideas can provide a good measure for this phase of technological preeminence. In recent years, China has received a lot of attention for its massive investment in its research and development infrastructure, and now leads the world in its scientific output in many areas such as chemistry and computer science.[4] Despite the *quantity* of this output, the United States remains the world leader in the *quality* of its scientific output, by metrics such as citations per article and the "h-index," a measure of the impacts of these citations in the scientific community (figure 1).[5]

Figure 2

The United States' strength in graduate education is a structural advantage in the competition for talent on emerging technologies

Analysis of the careers of 46,504 researchers working across 44 critical technologies depicting the brain drains and gains across countries



Sources: Australian Strategic Policy Institute; Deloitte analysis.

The World Intellectual Property Organization ranks the United States first in market sophistication and above China in all metrics related to national innovation.

The talent to develop new technologies: But scientific output is only one variable in the race for technological preeminence. Talent is another key factor, and here again the quality of its institutions puts the United States ahead. The United States has the world's largest share of *graduate* students across 44 key technologies tracked by the Australian Strategic Policy Institute (figure 2).[6] And while those students come from all over the world, many build their careers in the United States, helping keep employment in key technologies strong.

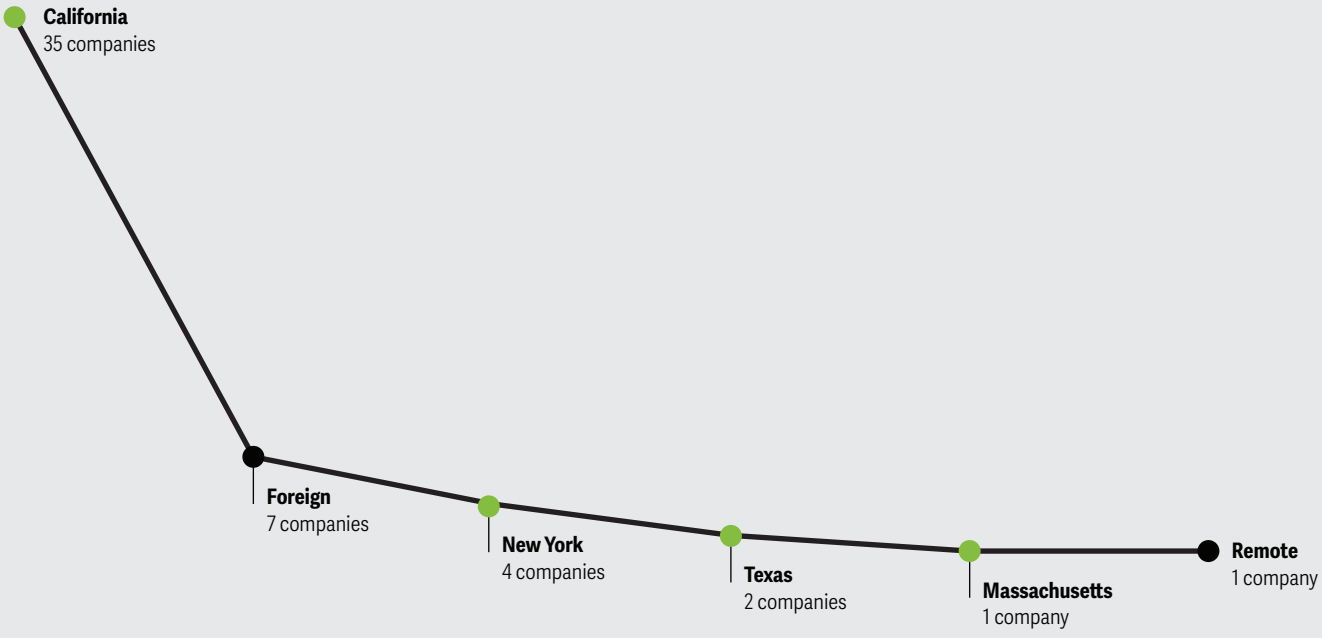
Markets to deploy new solutions: Research dominance doesn't always translate into real-world results. It is not enough to simply have the best ideas; those ideas need to be scaled and adopted widely to improve lives. Consider jet engines, for example. China dominates research in advanced aircraft engines, with seven institutions among the top 10 most cited.[7] Even so, it has struggled to produce reliable, high-performance engines; its WS-10 engine reportedly lasts only a quarter as long as its Western counterparts.[8]

One critical element to scaling new technologies is building markets for them. The biggest competitive strength of the United States may be the size and maturity of its markets. The World Intellectual Property Organization ranks the United States first in market sophistication and above China in all metrics related to national innovation.[9]

Such metrics can have a real impact on national economies. Due to the strength of its capital markets and technological prowess, for instance, the United States leads all nations by a significant margin in the number of major AI companies and global AI Innovation Index (figures 3 and 4)[10]

Figure 3

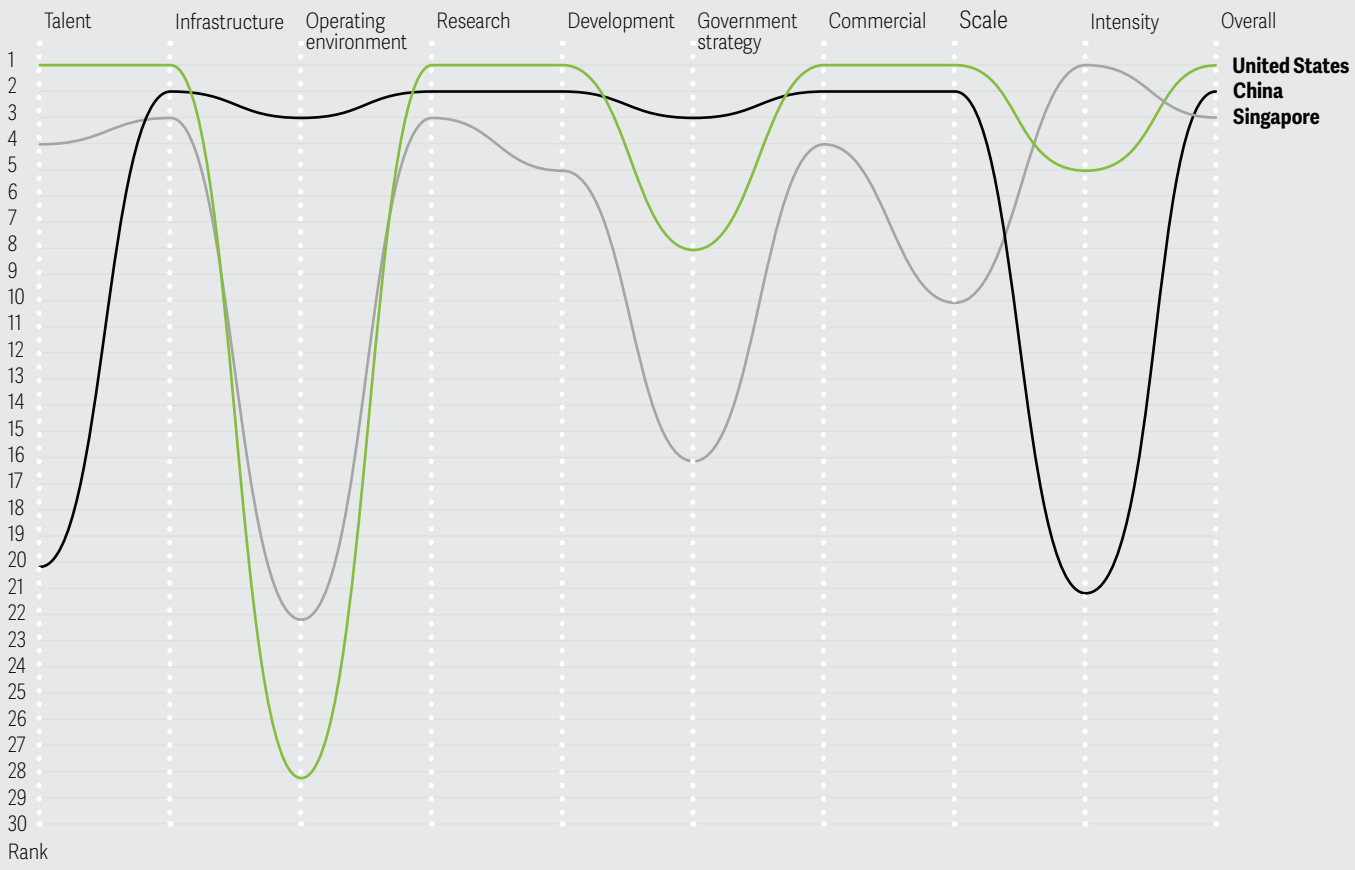
The United States leads in top AI companies



Sources: Forbes; Sequoia Capital; Meritech Capital.

Figure 4

Country rankings for AI development and competitiveness



Note: The remaining countries ranked in the top 10 overall are United Kingdom, Canada, South Korea, Israel, Germany, Switzerland and Finland.

Source: Tortoise, "The Global AI Index," accessed on March 18, 2025.

While the United States has an advantage in shaping tomorrow's technologies, global competition brings new challenges that require decisive action.

What's next: But global competition is rising

While the United States may be a front-runner today across various metrics, the race for technological preeminence is heating up.

Competition is increasing. Investment in key emerging technologies is accelerating globally. For example, five nations—including the United States—invested more than $1 billion each to boost quantum information technology development in 2021. Yet, China invested a massive $10 billion stake—more than the other four nations combined.[11]

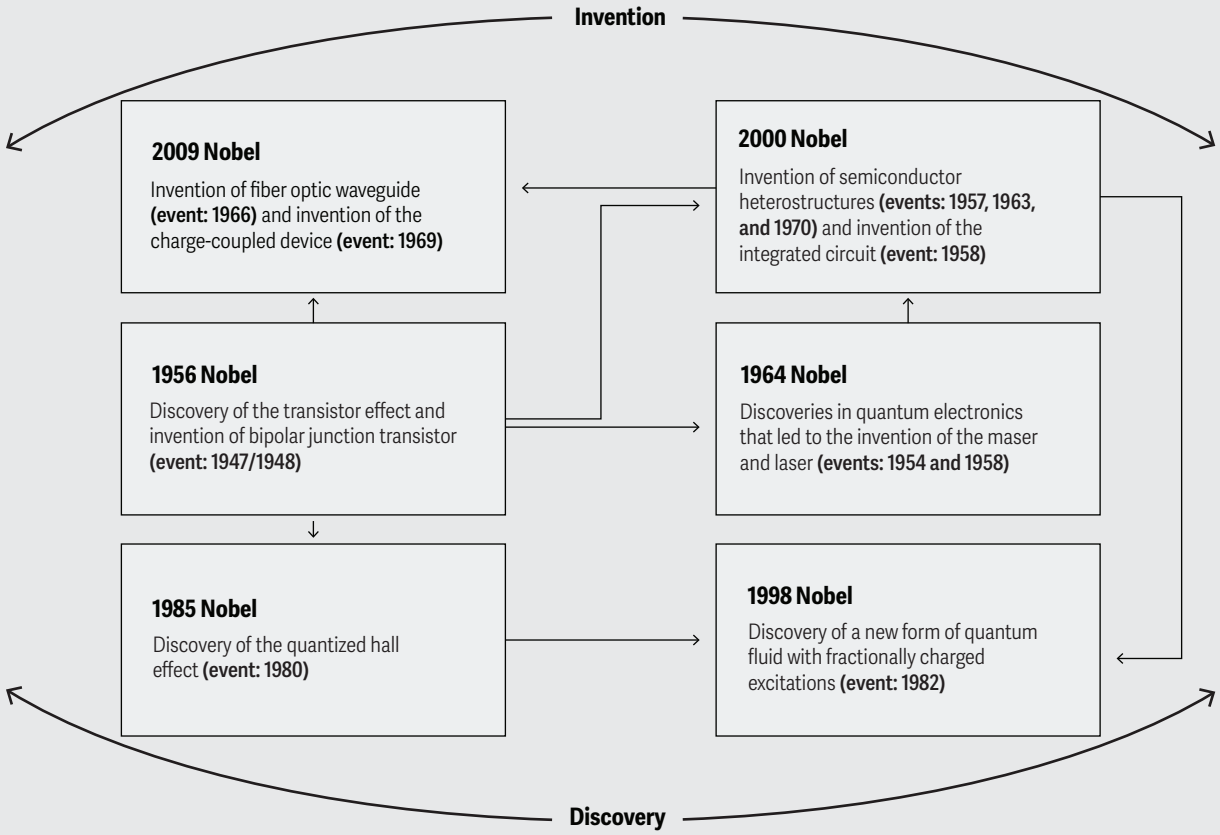
Since then, more than $23 billion in quantum funding has been announced internationally, with countries including Australia, Canada, China, Germany,

Israel, Japan, the Netherlands, Russia, Singapore, South Korea, and the United Kingdom all investing competitively. And quantum is just one area. Governments' spending on AI has grown significantly more. The US federal government alone has increased spending on AI by more than 150% in 2024, reaching upward of $4 billion *each year*.[12] No nation should expect to reap the full benefits of emerging technologies without the investments needed to steer the market in new directions.

Commercialization roadblocks lie ahead. Few technologies move quickly from the lab bench to market. Instead, their routes are circuitous, ping-ponging back and forth between new scientific discoveries and new engineering advances (figure 5).[13] Innovation is iterative with a high risk that a finished product may never emerge. As a result, governments have a critical role to shoulder and shepherd innovation for the most advanced technologies.

Figure 5

Modern electronics emerged along a circuitous path



Source: Venkatesh Narayanamurti, Tolu Odumosu, and Lee Vinsel, "The discovery-invention cycle: Bridging the basic/applied dichotomy," Science, Technology, and Public Policy Program, February 2013.

Progress is critical. Despite the costs, continued attention to the development of emerging technologies is all-important. Several expected breakthroughs could convey immediate and perhaps *lasting* advantages to whoever makes them. For example, quantum "supremacy"—the point at which quantum computers can greatly outperform classical computers—may give a nation an immediate intelligence advantage by granting it access to data not protected by post-quantum cryptography.[14] While the advantage might be fleeting, access to decades of data downloaded in "steal now, decrypt later" attacks could have significant impacts on national security and economic competitiveness.[15]

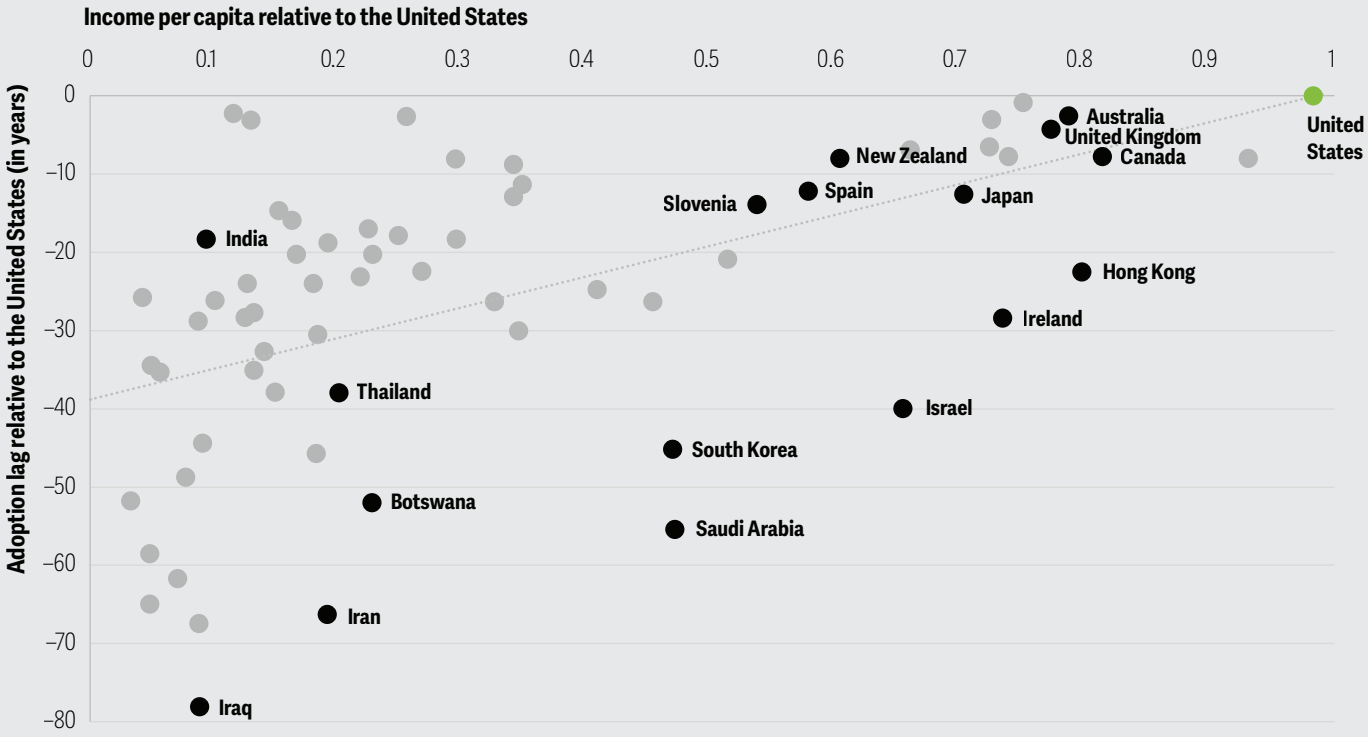
But emerging technology matters for people's everyday lives (figure 6). Key technologies can build entirely new industries. Global positioning systems, for example, lie at the heart of everything from cellular communications to agriculture and have contributed more than $1.4 trillion to the US economy alone.[16]

While these innovations are often made available to the public, being *first* comes with first-mover advantages. Research suggests nations that develop or adopt a technology benefit the *most*. One study of global technology diffusion found that the faster and more widely a nation adopts new technologies, the better the improvement to its people's standard of living.[17]

In the past, technologies failed not because they didn't work, but because they were dependent on other less well-developed technologies that failed to meet expectations.

Figure 6

The rate at which a country adopts new technology is a strong predictor of its standard of living



Source: Diego Comin and Bart Hobijn, "An exploration of technology diffusion," *American Economic Review* 100, no. 5 (2010): pp. 2031–2059.

Finally, rapid adoption of new technologies isn't the only important outcome. *Who* develops it also can affect the lives of everyday people, because the values of the technology's inventors often are baked into their creations. For instance, the ideal of open, free-flowing information held by so many of the internet's early architects was ingrained into its structure, which later made it difficult to improve its security.[18]

Today, we are faced with a similar situation where the values of designers are inherently integrated into AI, quantum, and other systems every day. With countries that are competing for cutting edge technologies simultaneously passing legislation that criminalize criticism of the military or other institutions, falling behind technologically could pose a significant threat to fundamental rights like free speech.[19] Winning the race for technological preeminence isn't simply an exercise in national pride. It's the foundation for ensuring the freedom and prosperity of future generations.

Complex dependencies demand coordinated action

So, what can the US government do to better position America in the race for technological preeminence? History shows that funding alone isn't enough. From direct-current power distribution to consumer augmented reality glasses, history is littered with well-funded failures. In many cases, these technologies failed not because they didn't work, but because they were dependent on other less well-developed technologies that failed to meet expectations.

Therefore, a first important step along the path to technology preeminence is understanding the interdependencies between the key technologies and their enabling technology. One small, overlooked linkage could lead to a failed investment or the concentration of key supply chain nodes in another country, leading to national security risk.

Tech dependencies

Pivotal technologies are not monolithic. Rather, they depend on other technologies, often in overlapping patterns. The development of quantum computing, for example, may be held back by a lack of progress in the cryogenics needed for quantum systems, which in turn may be limited by advances in the materials science needed to create components that can operate reliably at such low temperatures. Similarly, AI relies on graphics processing units and other specialized chips, while the manufacturing of such chips increasingly relies on AI to place all the features needed within a limited 3D space. Some new technologies are even subject to natural resource constraints, such as the need for rare-earth metals in battery and semiconductor production.

Since different technologies have different manufacturing requirements, manufacturing can become a roadblock to technological development. The history of the jet engine shows this clearly; its inventors in the United Kingdom missed out on this emerging industry due to manufacturing capacity constraints during World War II. Even today, these dependencies are creating economic and security risks due to foreign control over key nodes such as lithography machines needed for advanced chips.

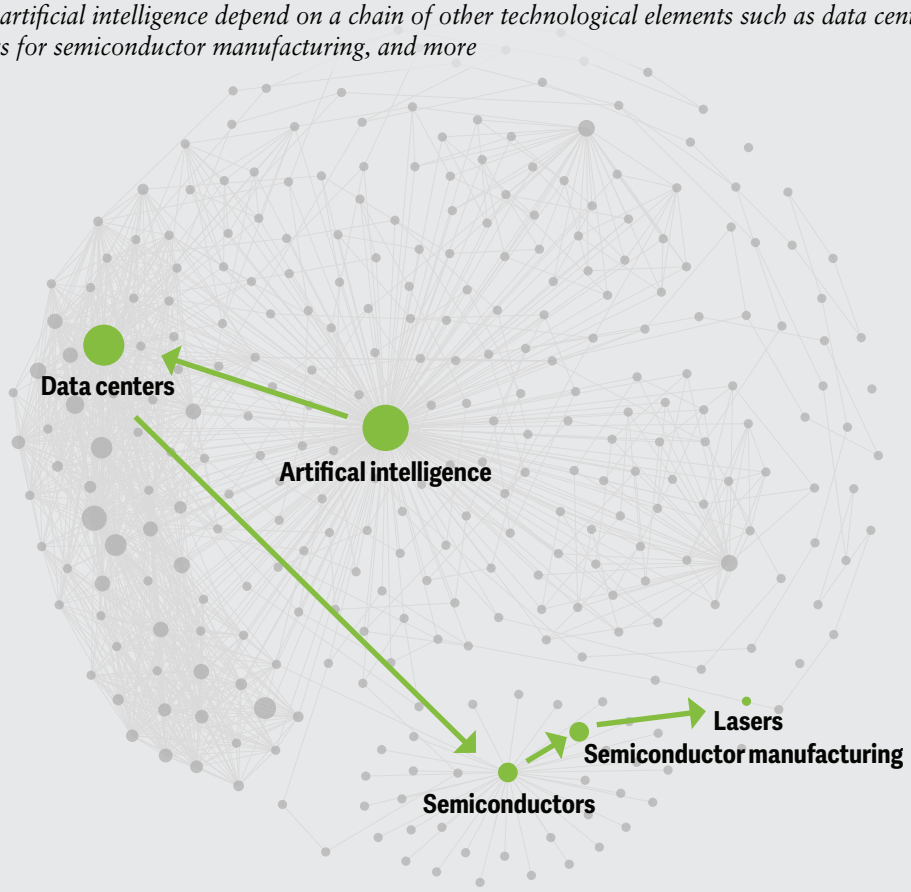
Fully capturing the benefit of a technology requires manufacturing capabilities and capacity up and down the supply chain. This is one reason why investments aim to boost manufacturing capacity to help scale key technologies. Yet, finding exactly where additional capacity is needed in a particular supply chain can be extremely complex.

To help future policymakers navigate such hurdles, we have mapped the interdependencies for four key technologies (quantum, AI, biotechnology, and climate technology) and their enabling technologies. Success with any one of these critical technologies relies on concerted investment in the underlying technology dependencies (figure 7).

Figure 7

New technologies depend on other technologies

Technologies such as artificial intelligence depend on a chain of other technological elements such as data centers, semiconductors, lasers for semiconductor manufacturing, and more



Source: Deloitte analysis.

Ecosystem dependencies

Achieving the benefits of a new technology often requires more than the creation of a working device. The British invented jet engines and the Germans radar, yet their massive economic benefits accrued largely to the United States due to its innovation and the optimum post–World War II manufacturing ecosystem. Taking ideas from the lab bench to market scale requires academia, industry, government, and nonprofits to work together to fill the critical roles of R&D, funding, engineering, and market shaping.

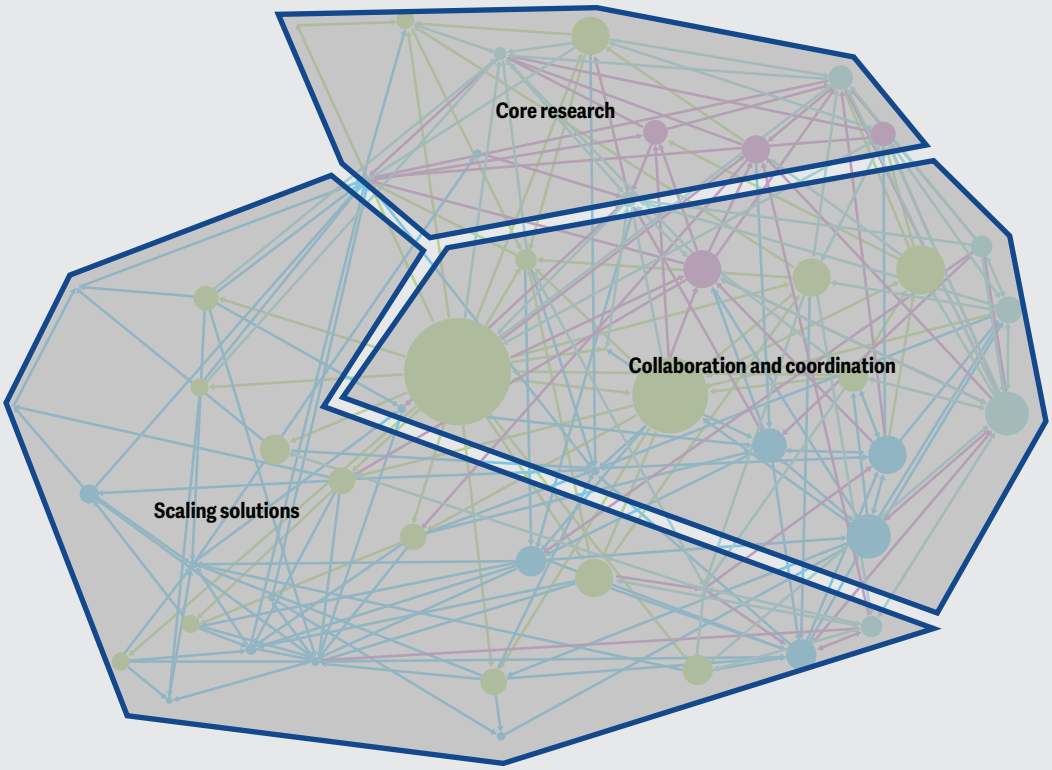
Each player filling those roles may have different tools; governments, for instance, can use tax credits to fill the funding role. And interventions from one player can cause downstream reactions in other players, as when government spurs industry to invest in workforce training or provides R&D grants to encourage new fields of academic study.

In addition to mapping technological interdependencies, policymakers also should consider the interdependencies of the tools available to the different players (figure 8). With this knowledge, they can move from single-shot interventions to sequencing a series of interventions by different players.

Figure 8

No single player can achieve an end without influencing (and therefore working with) another player

A network map of innovation tools highlights how actions by one player can influence actions by another



Source: Deloitte analysis.

How can government manage technological and ecosystem dependencies?

Technological and ecosystem dependencies can block both technological development and public benefits. Government's unique tools allow it to play a critical role in surmounting these challenges. From taxation to regulation to purchasing, government can use its tools to improve coordination within innovation ecosystems, potentially increasing the chances of public benefit from future technologies.

Reduce friction in ecosystems

- **Create information-sharing platforms to facilitate collaboration.** Catena-X, for example, is a data-sharing platform created by 28 partners in the German auto industry. Built upon a framework that allows for data exchange without exposing proprietary information, automakers can coordinate with many suppliers to see who can take on a new project or surge some extra production. One manufacturer has already used Catena-X to identity a quality issue in its supply chain, reducing the number of cars it would have to recall by 80% and saving millions.[20]

- **Pursue regulatory clarity to speed technologies such as AI, semiconductors, and biotechnology.** Uncertainty about future regulation and export controls may hamper development. To avoid falling behind, regulators should focus on the outcomes the public desires from new technologies and find ways to encourage them. Research into global AI regulations indicates that most nations haven't yet adopted such outcome-based, risk-weighted regulations.[21]

- **Address energy needs of the whole ecosystem.** Emerging technology is literally fueled by energy, and as demand and development increase, so too do energy needs. Deloitte research estimates that the AI boom will cause electricity demand from data centers alone to more than double between 2025 and 2030, ballooning to account for 3.7% of all electricity consumption. As a result, there is a need not just for national energy policy, but also for ecosystem-level solutions such as resource sharing, colocation of generation and use, as well as creative solutions to problems such as waste heat.

Support the human element

- **Clarify education pathways to encourage leading researchers in pivotal technologies to perform postgraduate work in the United States and then stay on to work in industry.** The strength of US graduate education is an important advantage; attracting students into these fields from across the United States and across the globe is a great way to boost technological competitiveness.

- **Build knowledge of technologies within government.** Government investment can provide a key lifeline for emerging technologies as commercial markets develop, as was the case with commercial satellite communications. Specialized expertise among government staff who can see the potential of new technologies makes such purchases more likely. Building a cadre of such staff will require investments in internal training as well as new approaches and authorities to hire employees who already have these skills.

Ensure the public benefit from new technologies

- **Balance intellectual property and monopoly protections for emerging technologies to spur innovation and ensure that the benefits accrue more broadly to the public rather than only a few companies.** This challenge can be seen acutely in generative AI, which can produce a wide variety of media including text, audio, and video. Intellectual property concerns arise both around the data used to train large models and the ownership of the end products. Greater clarity on intellectual property–related issues can accelerate innovation and ensure that creators at every stage are rewarded for their work.

- **Address the digital divide: Access barriers may rise as new technologies evolve, threatening even deeper valleys of digital access.** As new technologies build upon existing ones—such as AI building upon cloud, which is built upon fast broadband—inadequate access to the underlying technologies in rural and other areas could be exacerbated. It should be important to address access not just to broadband but also to new devices and the skills needed to use them, to ensure that as many as possible can benefit from new technologies.

Transformational innovations are already shaping our future. Governments can help ensure these innovations benefit tomorrow's regular people by working today to support ecosystems that produce them.

Endnotes

1. Goldman Sachs, "Generative AI could raise global GDP by 7%," April 5, 2023.
2. Tasha Austin, Joe Mariani, Thirumalai Kannan, and Pankaj Kishnani, "Generative AI and government work: An in-depth analysis of 19,000 tasks," *Deloitte Insights*, April 25, 2025; Building on our analysis on the impact of Gen AI on government tasks, we used two different methods to estimate the time savings possible based on the type of tool, task, and scale of automation. This allowed us to estimate the overall time-savings potential from AI and gen AI by summing the detailed time savings possible in each agency and occupation.
3. National Security Commission on Artificial Intelligence, *Final report*, October 5, 2021, p. 7.
4. SRG S.L., "Country comparison," accessed June 5, 2024.
5. SRG S.L., "Subject bubble chart," accessed June 5, 2024.
6. Jamie Gaida, Jennifer Wong-Leung, Stephan Robin, and Danielle Cave, *ASPI's Critical Technology Tracker: The global race for future power*, Australian Strategic Policy Institute, February 2023. Please note that quality of institutions is one of the metrics for talent.
7. Australian Strategic Policy Institute, "How is the United States performing against China in advanced aircraft engines," accessed June 5, 2024.
8. Peter Wood, Alden Wahlstrom, and Roger Cliff, *China's Aeroengine Industry*, China Aerospace Studies Institute, April 15, 2020.
9. Soumitra Dutta, Bruno Lanvin, Lorena Rivera León, and Sacha Wunsch-Vincent, eds., *Global Innovation Index 2023: Innovation in the Face of Uncertainty*, World Intellectual Property Organization, 2023, p. 58.
10. Ryan Heath, AI boom's big winners are all in four states," Axios, Jul 24, 2023, The Global AI Index 2024, accessed, November 25, 2024.
11. Scott Buchholz, Kate Abrey, and Joe Mariani, "Sensing the future of quantum: How quantum computing could benefit the public sector," *Deloitte Insights*, February 22, 2023.
12. Jacob Larson, James S. Denford, Gregory S. Dawson, and Kevin C. Desouza, "The evolution of artificial intelligence (AI) spending by the US government," Brookings Institute, March 26, 2024.
13. Venkatesh Narayanamurti and Toluwalogo Odumosu, *Cycles of Invention and Discovery: Rethinking the Endless Frontier* (Cambridge, Massachusetts: Harvard University Press, 2016).
14. Scott Buchholz, Joe Mariani, Adam Routh, Akash Keyal, and Pankaj Kamleshkumar Kishnani, "The realist's guide to quantum technology and national security," *Deloitte Insights*, February 6, 2020.
15. Greg Noone, "Are harvest now, decrypt later cyberattacks actually happening?," Tech Monitor, October 30, 2023.
16. Alan C. O'Connor, Michael P. Gallaher, Kyle Clark-Sutton, Daniel Lapidus, Zack T. Oliver, Troy J. Scott, Dallas W. Wood, Manuel A. Gonzalez, Elizabeth G. Brown, and Joshua Fletcher, *Economic Benefits of the Global Positioning System (GPS): Final Report*, RTI International, June 2019, p. ES-2.
17. Diego A. Comin and Bart Hobijn, *An exploration of technology diffusion*, Harvard Business School, accessed June 5, 2024.
18. See for instance: Ian Brown, David D. Clark, and Dirk Trossen, *Should specific values be embedded in the internet architecture?*, paper presented at the ReArch 2010 Conference, November 30, 2010.
19. For example, Russia's law that imposes stiff penalties for "discrediting" the Russian military. See The Associated Press, "Russia will consider property confiscations for those convicted of discrediting the army," Jan. 20, 2024.
20. CIO Journal by Deloitte, "Ecosystem collaboration accelerates data exchange," *The Wall Steet Journal*, April 12, 2022; Frank Farrall, Nitin Mittal, Chandra Narra, Juan Tello, and Eli M. Dow, "Data-sharing made easy," *Deloitte Insights*, December 7, 2021.
21. Joe Mariani, William D. Eggers, and Pankaj Kamleshkumar Kishnani, "The AI regulations that aren't being talked about," *Deloitte Insights*, November 10, 2023.

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