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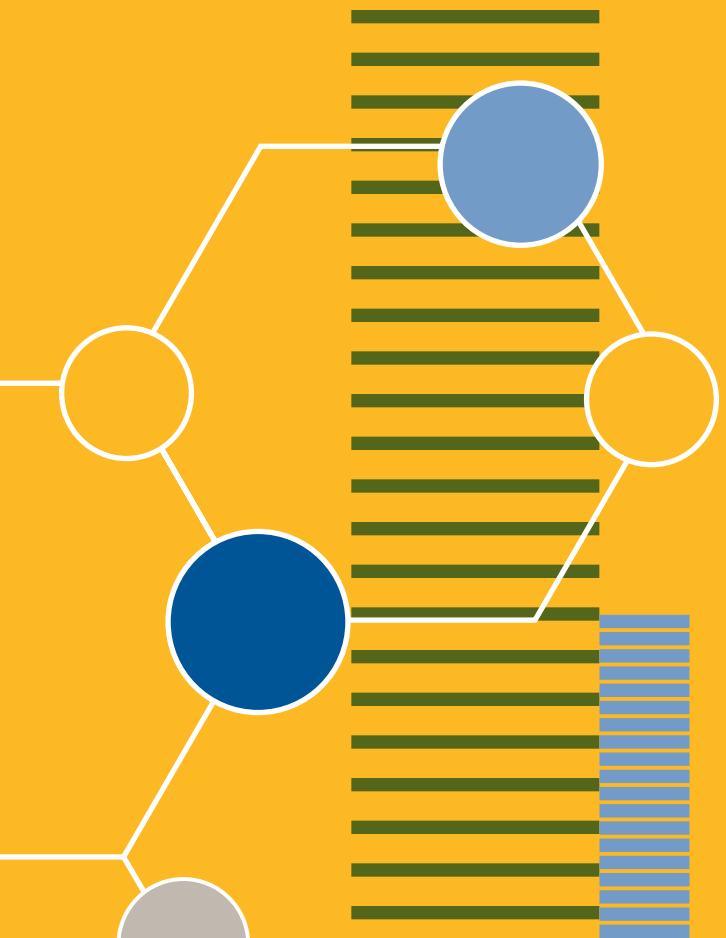
The Global Innovation Sweepstakes

A QUEST TO WIN THE FUTURE



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The Scowcroft Center for Strategy and Security works to develop sustainable, nonpartisan strategies to address the most important security challenges facing the United States and the world. The Center honors General Brent Scowcroft's legacy of service and embodies his ethos of nonpartisan commitment to the cause of security, support for US leadership in cooperation with allies and partners, and dedication to the mentorship of the next generation of leaders.

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Foreword

BY **FREDERICK KEMPE**

Geotechnology today is what geopolitics were to the nineteenth and twentieth centuries. A cluster of new technologies—namely artificial intelligence, robotics, green energy, and biotechnology, among others—will do more than just transform science. They will determine how we all live and function. Geotech—the race for technological leadership among the world's powers—will remake the global order.

Today, the world has many innovative places—countries and cities—that are in a fierce competition for global leadership in tech-based innovation. While the innovation ecosystem that the United States built after 1945 remains intact, it is at significant risk of erosion as China and other countries aim for "first mover" advantage in the next round of technological breakthroughs. Increasingly, countries around the world recognize that they must lead in tech-based innovation if they are to be prosperous and secure in the future.

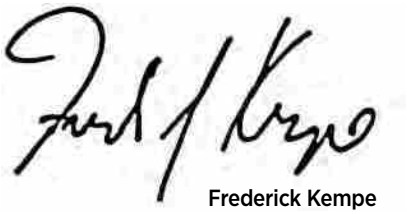
It is with this realization that twelve months ago the Atlantic Council's Scowcroft Center for Strategy and Security, in partnership with Qualcomm, embarked on a global tour of technology hubs to find out which ones are at the cutting edges of tech-based innovation and which are at risk of falling behind.

Although we could not travel everywhere, our research took us to China, Japan, South Korea, Singapore, Mexico, the United Arab Emirates, Saudi Arabia, Israel, Sweden, and France. We met with roughly two hundred individuals from diverse backgrounds and it is their thinking that drove the findings of this report—the second in a two-part series.

The Council's Scowcroft Center develops sustainable, nonpartisan strategies to address the most important security challenges facing the United States and the world. These strategies are informed by strategic foresight and forward-looking analysis of global trends—many of which can be found in this report.

The world is on the cusp of a technological wave that will shape the future of human civilization. Those countries that can create cutting-edge technologies—and adapt to those technologies at the same time—will realize enormous economic and geostrategic benefits in the decades to come. In that regard, this report comes at a very important time. We must realize that while the United States will remain innovative, the country cannot be placed on auto-pilot if it hopes to stay at the top.

I hope you will find this report as thought-provoking as I did and that it will help you understand and lead the way in today's global innovation landscape.



Frederick Kempe
President and CEO
Atlantic Council

Executive Summary

BY **MATHEW J. BURROWS**

Director of the Foresight, Strategy, and Risks Initiative, Scowcroft Center for Strategy and Security, Atlantic Council

The world is on the cusp of an unprecedented technological revolution, one that will have far-reaching social, economic, and geostrategic consequences. This tech revolution will change the way we live, work, manufacture goods, fight wars, and communicate. What is unfolding is a convergence of technologies, the melding of the digital with the real economy, in a synergy of artificial intelligence (AI), big data (the cloud), robotics, biotech, advanced manufacturing, the Internet of Things (IoT), nano-engineering and -manufacturing, and over the horizon, quantum computing.

How the United States and other major actors position themselves as innovators and adaptors of emerging technologies will determine their economic fate and geostrategic standing. And while the United States remains at the top of the global tech-innovation hierarchy, its position is in real jeopardy. Several nations are fast approaching.

In this century, the world's most advanced countries will be those best positioned to create and adapt to new and disruptive technologies. Whoever ends up on top will reap tremendous gains. Those who do not will fall behind. The authors of this report believe that countries fall into one of three general categories: those countries on the cutting edge of tech-based innovation, those that easily adapt to and absorb new technologies, and those that are lagging. These categories are not mutually exclusive—some countries straddle categories—but the gaps between leaders and those on the bottom rungs will grow larger.

The key recommendations in this report deal not just with the potential problems between states, but also address some of the inequities that are growing within societies due in part to emerging technologies. The entire world has become more prosperous than ever before; the digital revolution has played a key part in this development, accelerating the rise of China and other emerging markets. However, technology has increased income inequalities. Women and minorities are grossly underrepresented in tech firms and jobs. Will emerging technologies, such as AI, be different? Will inequalities widen further? How will the geopolitical landscape, indeed the global order *writ large*, change if China replaces the United States as the world's innovation leader?

This report seeks to answer the fundamental questions raised by the unfolding technological revolution. It follows an earlier one focused solely on US innovation that was also produced by the Foresight, Strategy, and Risks (FSR) Initiative of the Atlantic Council's Scowcroft Center for Strategy and Security in partnership with Qualcomm. The first report saw a United States that was losing its edge and recommended actions to help to shore up US leadership.

This report, which moves onto the global level, is by the same authors of the previous one—FSR's Robert Manning and Peter Engelke—with Samuel Klein. The research was conducted using a similar methodology of visiting innovation hubs and speaking with people on the ground. For this second report, the authors visited ten countries and conducted telephone interviews with scientists and technologists in other nations. They read hundreds of secondary publications and consulted numerous data sources. The country visits allowed the authors to meet with a diverse range of people across multiple points on the innovation ecosystem compass: entrepreneurs; government officials (at local and national levels); venture capitalists; owners of incubators, accelerators, and co-working spaces; academics and university administrators; and local tech-innovation "thought leaders." Altogether, the authors spoke with roughly two hundred people around the world, usually off-the-record to get the most uncompromised views. The interviewees' insights drive this report's findings, and a few of the interviewees contributed essays that are featured in this report.

Eighth-grade students explore DNA extraction with US Army scientists.

U.S. ARMY RDECOM/FLICKR

Recommendations

→ **Inclusion:** Governments should encourage participation in the technology sector by women and girls, ethnic and religious minorities, and lower-income groups, providing incentives to firms to recruit more people from these groups into their workforce.

→ **Human Capital:** The United States and some other countries have failed to provide low-cost higher education, vocational training, and retraining programs. Germany's apprenticeship program, now more than a century old, remains a template. All governments need to emphasize lifelong education and skills training.

→ **Social Safety Net:** Now is not the time to dismantle the social safety net. Minimum and supplemental income schemes, job guarantees, portability of benefits, and so on need to be tested in real-world conditions, with lessons learned and shared across borders.

→ **World Trade Organization (WTO):** The WTO should launch sector-specific comprehensive global trade rules on digital commerce, building on previous tech agreements and on Trans-Pacific Partnership (TPP) rules. Restarting negotiations for a US-EU Transatlantic Trade and Investment Partnership (TTIP) accord that adopted similar digital commerce provisions would be a big step toward setting global rules.

→ **5G:** Compatible global standards for 5G broadband will be critical to realizing the benefits of IoT. International Telecommunications Union (ITU) public/private working groups should be brought into a G20 dialogue if they fail to reach an outcome of harmonizing standards.

→ **Trans-Atlantic/-Pacific Cooperation:** Parallel US-China and EU-China bilateral investment treaties could provide a framework for reciprocity. The United States, in consultation with the European Union, should conceive a consumer digital bill of rights, compatible with General Data Protection Regulation (GDPR).

→ **New standards for AI/robotics and synthetic biology and genomics:** This should be started with a working group composed of the five major players—United States, Germany, China, South Korea, and Japan—perhaps under the auspices of the G20.

China and the United States

China's swift arrival at the innovation forefront is astonishing. A combination of long-term state planning and well-financed state-directed initiatives, targeting specialization in local areas (such as robotics, new-energy vehicles, and biotechnology) combined with its sheer size lies behind China's swift rise. In barely a decade, China has become the new Silicon Valley, with ambitions to dominate across a wide swathe of technologies.

China now accounts for 42 percent of global e-commerce, up from 1 percent just a decade ago. It is close to achieving a cashless society. China boasts one third of the world's unicorns (startups with $1 billion or more in valuation). The country's venture capital and private equity have exploded over the past decade. One US business source estimated that China has more than one thousand venture capital firms, each worth more than $100 million. Government tech funding is often combined with money from major state-run banks and tech firms.

Nevertheless, it is too early to tell whether China will outpace the United States anytime soon. Perhaps the most problematic part of China's tech revolution is the predatory industrial policies it is employing at the expense of competitors, which could end up degrading its own global competitiveness. The state-driven means of achieving innovation leadership contradicted the principles of market forces and open trade and investment—the very principles that Chinese President Xi Jinping claims to champion. These industrial policies feature multi-billion-dollar government funds targeting all ten technologies identified in the "Made in China 2025" industrial policy, while limiting foreign direct investment even as Chinese firms aggressively invest overseas.

Mobile payments in China. The country is on its way to becoming a cashless society.

The lack of outside competition limits China's ability to become a world leader. A McKinsey study concluded that "in industries where innovation is about meeting unmet consumer needs or driving efficiencies in manufacturing—appliances and solar panels, for example—China is flourishing." It points out, however, that "in industries where innovation requires original inventions or engineering breakthroughs," China's shares of global markets are much smaller.[1]

Other challenges exist, as well. Chinese industries are on average 3.7 times less digitized than those in the United States. One major study concluded that "upgrading the production process might result in job losses among the less skilled workforce," while "China's education system is not prepared for training skilled personnel capable of operating sophisticated smart manufacturing."[2] Moreover, by 2030, demographic shifts, including the "greying" of China, will become a new challenge to the country's development.

The United States remains the leader across the board, while China is more committed to reaching the top place. The rivalry centers around which system is more receptive to technological advance. China believes in planning from the top and a large role for the state in both funding and directing its effort. US culture has always favored a more free-wheeling, market-driven approach. Most Americans do not understand how scientific achievement can be reconciled with the heavy hand of an authoritarian state.

Even if one believes that an industrial policy would be detrimental, the United States and other governments need to take certain steps to boost a culture of innovation. Despite praising itself for its liberal market vocation, the United States engaged in strategic planning after the Second War World; this effort was intensified after the Soviet Union's launch of Sputnik in 1957. Furthermore, the Pentagon's Defense Advanced Research Projects Agency (DARPA) and its Internet and digital investment have been a critical ingredient in the success of Silicon Valley companies right up to this day.

Immigration is another key ingredient. The United States has benefited enormously from being a magnet for the world's talent. Anybody who has visited a large research

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university in the United States knows that a large proportion of graduate students are international. Even China, which benefits from an enormous population pool, increasingly understands the value of attracting world-class talent from outside its borders.

This study confirms the urgency of recommendations made in the authors' previous report regarding the risks to the United States' technological edge.[3] All the warning signs are even more lucid now than one year ago. Perhaps because of the absence of a single, shocking dramatic event—like the Soviet Sputnik launch—that crystallizes the challenge, perhaps due to the incremental and diffuse nature of the problem in an era of information overload, the present situation has not been the catalyst for the development of a targeted US strategy.

Clearly, the United States does not possess a sense of urgency. If anything, it is taking steps in the opposite direction of those bold initiatives taken by the Eisenhower administration. There is no guarantee that the United States will remain at the top of the tech-innovation world. This report makes it clear that there are fierce and capable contenders for global leadership, China first among them. For the United State, finding the right policy mixes will not be the biggest challenge. Rather, the biggest challenge is about willingness. To retain its prominence, the US needs to take a good hard look at itself. The question is whether it is capable of doing so.

There is no guarantee that the United States will remain at the top of the tech-innovation world... There are fierce and capable contenders for global leadership, China first among them.

Other Top-Tier Contenders

Asia's Other Giants

Japan (as well as South Korea) had a head start, but now inertia is an obstacle. One of the Abe government's larger challenges has been prodding Japan's major global companies to alter their business models. An interviewee at a major Japanese research institute told us that inertia remains strong within big firms, which is one reason why the government has launched so many tech initiatives. There is little doubt that Japan will achieve some cutting-edge achievements in certain niches and excel in adapting and absorbing many emerging and new technologies. Robotics, AI, and big data may be a few areas; immunotherapy and regenerative medicine and new materials are others.

The larger question, however, is whether Japan's centralized, top-down method of innovation can return the country to its postwar success. One potential hazard that several tech entrepreneurs pointed out to us is that Japan's market is big enough to insulate the country from outside competition with standards and regulations that make it harder to compete globally.

Although **South Korea** has not experienced Japan's "lost decade," its economy, used to a norm of over 6 percent annual growth, is losing steam. Since the 2008-09 great recession, the country's economic growth has fallen to 3 percent or less. South Korea is facing a demographic decline, though less pronounced than that of Japan. Apart from Samsung and the electronics sector, which is vital to the global electronics supply chain, many of the *chaebols* (large industrial conglomerates, typically run by one family) have been floundering, with profits sagging and corruption scandals and crises hitting shipbuilding, steel, and construction. Yet South Korea has a strong foundation on which to refurbish its economy. An emphasis on science and technology has been an element of its success. The government-funded Electronics and Telecommunications Research Institute (ETRI) has a large cadre of some 1,800 scientists, engineers, and technicians. It has whole divisions for intellectual property (IP) commercialization and is one of the most prolific institutions in garnering US patents—a record 833 in 2014. South Korea filed nearly 1,700 patents from 2011 to 2016, signed 2,785 tech transfer contracts, and earned $154 million in royalties during that period.

India's future role in the global tech-innovation ecosystem will be as much about adapting new technologies as creating them. India invests an anemic 0.8 percent of its GDP on R&D, giving rise to widespread concerns in the tech community about a research deficit. Universities, research institutes, and labs tend to be poor at tech transfer. How the process of urbanization unfolds in India will be a significant factor affecting the domestic market for high tech. India has a lot of potential, but the country also faces challenges due to its educational weaknesses, modest levels of R&D, and obstacles to doing business.

Europe: Rising to the Challenge?

Several European countries are in the global top tier of innovators, but the question is why Europe as a whole is not more of a competitor. Part of the problem is the poorly coordinated and/or funded research efforts across Europe's

universities and research institutions. The EU's Horizon 2020 program aims to send 80 billion euros over seven years (2014–2020) to European universities, research institutions, and even startups, to encourage collaborative research, skills training, technology prototyping, and more.

Another consistent European problem is that, despite having a significant amount of entrepreneurial activity, Europe has produced very few tech giants. In stark contrast to the United States and China, none of Europe's richest companies are tech firms. Explanations abound. One French investor told us that a big part of the explanation is cultural, involving ambition. European entrepreneurs, he said, have not set their sights high enough, preferring to sell their start-ups to corporations once they have scaled rather than trying to create the next Apple. An EU official had a different take, telling us that European startups that are trying to commercialize the most revolutionary technologies—the kind of technologies that created Google—face a chronic shortage of investment capital because the risk to private investors is too great. His solution was to have the EU assume some investment risk for these types of startups, based on the proposition that public institutions in the United States (DARPA, in particular) have played exactly this role in building the American system.

If one were to pick the most innovative country, it would be **Germany.** The United States may lead the world in inventing and financing new technologies, but Germany is in a class by itself in adapting technologies and injecting them into all sectors of the economy to increase productivity. The country coordinates key elements of innovation into a mutually reinforcing "virtuous circle." Germany emphasizes innovation to boost all sectors of the economy, has strong research and social institutions, and provides perpetual education and training.

Cultural shifts have been a critical element in **France's** resurgence. Interviewees stressed that entrepreneurialism has grabbed the French imagination, with entrepreneurs now celebrated and the nation's best STEM students much more willing to become entrepreneurs themselves. France is a case study in aggressive public policies applied to the knowledge economy. The government has few qualms about creating well-funded programs to support its tech-innovation ecosystem.

The **United Kingdom (UK)** remains Europe's leader in attracting investment capital to the tech sector. It also has some of the world's best universities, with four (Oxford, Cambridge, Imperial College London, and University College London) in the top twenty. Yet British universities struggle with tech transfer. Despite Brexit, the UK will remain a hub for tech-driven innovation. Whether it remains Europe's leader is a different question. One challenge is that other European countries are rising quickly.

Old Street roundabout in London, known as Silicon Roundabout.

Small States, Big Impact

Israel is an outstanding example of a small country (population 8.2 million) and tech-innovation ecosystem with a strong sense of community (place) and high global connectivity (flow). Israel's tech-innovation ecosystem is impressive not just for its number of startups (some four thousand in 2016), but even more for its increasing importance across multiple technology sectors. Israel is a serious player in cyber and IT, automobiles and transportation, AI, health and medical technologies, fintech (financial technology), blockchain, drones, IoT, greentech, and other technologies. In 2016, investors poured a record $4.8 billion into the country's tech sector, with foreign investors accounting for 60 percent of this figure.

Sweden, with a population of only 9.9 million people, has translated its high social welfare program, good government, outward orientation, social cohesion, and peaceful neighborhood into one of the world's strongest tech-innovation ecosystems. Sweden's vibrant ecosystem has produced thousands of startups and the second-largest number of unicorns in the world on a per-capita basis (after California's Bay Area).[4] Computer gaming, digital commerce, fintech, and health tech are well represented sectors within Sweden's knowledge economy.[5] One of the reasons for Sweden's success is the country's generous social welfare system. The youth talent pool is not weighed down by educational debt.

Skolkovo Innovation Center, a science park in Moscow, Russia.

The Struggling Second and Third Tiers

A host of large and small countries land in the next tier, consisting of those nations that are either still trying to move past faded industrial glory or are otherwise attempting to break out of middle-income status.

Russia has begun efforts to foster a tech-innovation ecosystem. It launched a National Technology Initiative in 2014, which is fueled by Russian Venture Capital (RVC), a fund of funds created in 2006 to lend to VC firms—28 at present—and generate a startup ecosystem. It created Skolkovo Academy, a massive science park, and Generation S, a major government-launched accelerator that has more than twenty corporate partners and a presence around Eastern Europe. Moscow State University and the Moscow Institute of Physics and Technology, known as FIZTEKH, are leading research institutions with their own incubators. However, the scope and scale of this activity is limited and much of it is state-driven.

Africa has no countries in the global top tier of leading innovators (South Africa, its best-placed country in the 2017 Cornell/INSEAD/WIPO index, is ranked fifty-seventh in the world). Nevertheless, Africa is home to a surprising number of countries with admittedly small, but robust and growing tech-innovation ecosystems. Like India, Africa has a large demographic youth bulge, with 60 percent of the population under twenty-four and the world's highest birth rate. **Kenya** has been building a digital tech-innovation ecosystem worthy of the country's "Silicon Savanna" designation. High mobile penetration is a big reason for this. On the other side of the continent, **Nigeria's** tech economy is booming. Much of this is in the digital space, owing to Africa's high mobile penetration rates and the ease of startup formation in this field. Centered in Lagos's Yaba district (sometimes called "Silicon Lagoon"), startups can tap into a pool of workers eager to upgrade their tech skills.

Like Africa, the Latin America and Caribbean (LAC) region features none of the world's top-tier knowledge economies. A problem is systematic underinvestment in R&D: in four of LAC's major economies (Brazil, Mexico, Chile, and Argentina), only Brazil at 1.2 percent cracks the top fifty countries worldwide (thirty-second).[6] A second obstacle is an overreliance on commodity exports. A third is demographic: although the region is still relatively youthful, it is aging fast. In global innovation and business rankings, **Chile** is consistently at or near the top of countries within the LAC region. **Mexico's** massive and vibrant capital, Mexico City, offers a rich cultural experience for both Mexican and foreign entrepreneurs, who can service a growing Mexican (and regional) e-commerce and mobile digital economy. Even so, Mexico invests a tiny percentage of its GDP in R&D (0.6 percent).

OPPOSITE PAGE: JACK TORCELLO/FLICKR;
THIS PAGE: MOSCOW SCHOOL OF MANAGEMENT SKOLKOVO

Lessons for Innovators

Unequal participation in the tech sector was a constant theme in our interviews. Almost without exception, interviewees expressed concern about inequality and uneven access. This has relevance to different parts of societies as well as between countries. For those societies seeking to move up the rungs, we offer these lessons from studying how innovation can develop and grow.

Strategic planning: Most of the world's leading innovators engaged in some form of long-range, "whole-of-government" strategic planning to get to where they are now. The United States followed this template after World War II, with the US government developing an aggressive tech-focused plan; that plan is now eroding, however.

Innovative culture: The best ecosystems are those that nurture a strong sense of place—people like to live and work in such ecosystems and develop a strong attachment to them. In addition, such ecosystems have high exposure to global flows of money, ideas, and talent.

Employees working on a drone. The extent to which countries innovate will be the key driver of their economies.

R&D: "There are no miracles," one prominent Israeli scientist said to us regarding R&D. He meant that no society can be in the top tier of tech-focused innovation if it does not invest in R&D.

Tech transfer: There is a difference between discovery and innovation. The former is about lab-based science, the latter about transferring scientific knowledge into practical and commercially viable technologies. Universities need to learn to promote commercially applicable research by faculty, staff, and students.

Intellectual property: States should recognize that strong IP protection will lead to more prosperity over the long run. The best IPR systems involve effective management, where governments have invested in the capacity to run their IP systems well. Countries should focus on bilateral and regional agreements in near-term; global accords are a long-term challenge.

Immigration: In nearly every leading case examined in these pages, immigration has been a major factor accounting for their success. Immigrants need to feel welcomed if they are to stay and invest in their talents over the long run.

The economic, social, and geopolitical implications of the uneven distribution of innovation are profound. As the first report in this two-report series documented, for much of the period after World War II, the United States had been the undisputed leader of the global knowledge economy. This report documents how that leadership position has eroded to the point where the United States is no longer the undisputed number one. China, detailed at length in these pages, is at least number two in the world if not number 1B to the United States' 1A. Other states besides China are also upping their game, and their leadership position in the global knowledge economy is limited only by their smaller sizes.

How this multi-layered system evolves, and how policymakers manage the consequences of the technologies whose development they have fostered, will shape much of this century. During the coming two decades, the extent to which countries innovate, absorb, and adapt emerging technologies will be the key driver of their economies, shape social dynamics, and help determine their respective military capabilities. The strategic and foreign policy impacts of the technology revolution will be profound, changing how wars are avoided and fought as well as the respective weight of major powers in shaping the global order.

Introduction
The Global Innovation Sweepstakes

Innovation: the process of transforming an idea, concept, or knowledge into a product or service that delivers significant new value.

The world is on the cusp of a technological wave that will shape the future of human civilization. How the United States and other major actors position themselves as innovators and adaptors of emerging technologies will determine their economic fate and geostrategic status. This report assesses the status and effectiveness of tech-driven innovation ecosystems around the world in order to ascertain how countries are positioning themselves to ride this technological wave. It explores which ecosystems are at the cutting edges of tech-based innovation; which are at risk of falling behind; and a few that may surprisingly achieve success, at least in certain niche areas. This report assesses all of the elements of innovation ecosystems, including research and development (R&D), science education, government policies, investment and venture capital, startup cultures, and patents and intellectual property (IP).

After trying on an early version of virtual reality goggles in the mid-1990s, the science fiction writer William Gibson famously quipped that "the future has already arrived, it's just not evenly distributed yet." Gibson was correct and incorrect at the same time: correct in his assessment that the profound impacts of futuristic technologies were already here; incorrect in his belief that the tech-centric future would be evenly distributed.

This report shows that tech-driven innovation is in fact unevenly distributed. Although all states aspire to compete in the "knowledge economy" (the term invented by Austrian economist Fritz Machlup), global competition for leadership in this space is intense, akin to competitors seeking to win a sweepstakes race. The world's largest and richest economies have an obvious advantage in that they have more resources to throw at innovation—including people, money, infrastructure, and institutions. Yet small countries can be highly competitive because they can possess some advantages. In the most innovative small countries, governments are nimble, the density of talented people is much higher, and the sense of purpose can be far greater than in large countries.

Sophia, a social humanoid robot.

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Finally, although poor countries generally perform less well on global innovation indexes than rich ones, they can create dynamic, tech-based innovation ecosystems. For all states, the challenge is finding the right mix of culture, policies, talent, institutional structures, and other inputs that foster technological innovation to stay at the top or get there.

As the first report in this two-report series documented (*Keeping America's Innovative Edge*, published in April 2017), for much of the period after World War II, the United States was the undisputed leader of the global knowledge economy. This report documents how that leadership position has eroded to the point where the United States is no longer the undisputed number one. China, detailed at length in these pages, is at least number two in the world if not number 1B to the United States' 1A. Other states besides China are in some respects better at this game than the United States as well, with their leadership position in the global knowledge economy limited only by their smaller sizes.

How these systems evolve—and how policymakers both encourage them and manage the consequences of the technologies that are created by them—will shape much of this century. During the next two decades, the extent to which countries innovate and/or absorb and adapt emerging technologies will be a key driver of their economies, shaping social dynamics and determining countries' respective military capabilities.

Box 1: Global Innovation Indexes

Given the importance of innovation to economies the world over, numerous institutions have created indexes to measure innovation ecosystems at the national and local levels. A few of these are comprehensive, designed to measure the entirety of a country's (or city's) innovation ecosystem and rank them accordingly. Many others do the same, but only for a narrow piece of innovation. This table lists some of the most important of these indexes, and briefly explains their relevance for innovation.

INDEX	INDEX DESCRIPTION	RELEVANCE TO INNOVATION
Cornell/INSEAD/WIPO, Global Innovation Index 2017	Ranks 127 countries by innovation inputs (institutions, human capital, infrastructure, market sophistication) and outputs (knowledge, creativity).	Highly regarded global index of innovation ecosystems. Quantitative, comprehensive assessment of countries' ecosystems.
Bloomberg Innovation Index 2017	Innovation measures include R&D intensity, manufacturing value-added, productivity, high-tech density, and patent activity.	Like the Cornell/INSEAD/WIPO index, this index measures and ranks countries based on the strength of their innovation ecosystems.
Startup Genome, Global Startup Ecosystem Report 2017	Measures innovation ecosystems at city rather than national level. Assessed 55 cities (ranks only top 20) on likelihood of startup success.	Tech hubs—cities—are this index's level of analysis, based on the proposition that cities matter as much or more than countries for innovation.
World Economic Forum, Global Competitiveness Report 2016-2017	Innovation "pillar" assesses capacity, science, R&D spending, patent applications, and IP protection.	Innovation is one of 12 "pillars" of competitiveness in this exhaustive index of national economic competitiveness. Other pillars include institutions, infrastructure, and financial markets.
World Bank, Doing Business 2017	Ranks 190 countries by 11 areas of business regulation, including starting a business, getting credit, paying taxes, and contract enforcement.	This index is of interest to entrepreneurs because it provides a measure of how difficult or easy it is to start and operate a company.
ETH Zurich, KOF Globalization Index	Ranks countries by exposure to economic, social, and political globalization.	High-performing innovation ecosystems are well integrated into global networks and flows of people, capital, and ideas. This index measures degree of integration.
US Chamber of Commerce, US Chamber International IP Index 2017	Measures intellectual property (IP) standards in 45 of the largest economies across six categories, including patents, copyrights, trademarks, trade secrets, IP enforcement, and participation in international IP agreements.	IP production and protection are important bases of innovation ecosystems. This index gives higher scores to "strong" IP systems, based on the argument that robust protection of IP rights will lead to more innovation.
Global Entrepreneurship Research Association (GERA), GEM Global Entrepreneurship Monitor Global Report 2016/2017	Assesses but does not rank 65 countries on entrepreneurialism. Measures include self-perceptions of entrepreneurship, level of entrepreneurial activity, gender equality, and societal perceptions.	Focuses on entrepreneurs, among the most important actors in innovation ecosystems. Includes survey data from experts and the public on entrepreneurialism.
2017 World Press Freedom Index	Various press freedom indicators, including media independence and abuse of journalists, for 180 countries.	A proxy measure of a society's tolerance for free speech and thought. Only a loose correlation with national innovation performance.
Fund for Peace, Fragile States Index 2017	Assesses vulnerability of states to collapse from conflict.	A measure of national political risk, important for firms and individuals making locational decisions.
Transparency International, Corruption Perceptions Index 2016	Measures 176 countries on levels of corruption: press freedom, transparency, integrity of public officials, and rule of law.	Countries that score high on this index are more likely to have innovative economies. The opposite is true at the low end.
World Bank, Logistics Performance Index 2016	Ranks 160 countries on trade logistics, including customs performance, timeliness of shipping, infrastructure quality, and others.	Logistics performance is one indicator of a country's global competitiveness and of interest to firms seeking to locate in a country.
International Telecommunications Union (ITU), ICT Development Index 2016	Assesses ICT access, use, and skills in 175 countries across eleven indicators.	One of several indexes measuring digital competitiveness at the national level, based on digital market penetration (e.g., household Internet access) and educational levels.
IMD World Digital Competitiveness Ranking 2017	Digital competitiveness defined by three factors: knowledge (talent, education, science), technology (regulation, capital), and future readiness.	One of several indexes measuring digital competitiveness at national level. Based on idea that digital performance is critical for all aspects of a knowledge economy.
World Economic Forum, Global Information Technology Report 2016	Produces a Networked Readiness Index that measures 139 countries by tech use, supportive tech environment, ICT readiness, tech adoption levels, and impact of new technologies.	One of several indexes measuring digital competitiveness at national level, based on "readiness" of countries to benefit from digital technologies.
WWF International and the Cleantech Group, Global Cleantech Innovation Index 2017	Measures innovative activity around cleantech. Measures supportive policies, public R&D levels, cleantech funds, "green" patents, and more.	Explores countries' innovative activity around "green" technologies.
EF Education First, English Proficiency Index 2016	Measures and ranks 72 non-English- speaking countries by English proficiency.	Based on idea that English is important for global business, especially in science- and technology- related sectors.
Reputation Institute, 2017 Country RepTrak	Measures 55 countries' global reputations based on popular image, government, and economy.	Like the Made in Country Index, the RepTrak index is a measure of a country's image abroad.
Statista, Made in Country Index 2017	Measures global attitudes toward products 'Made In' different countries.	Like the RepTrak index, this index attempts to measure a country's commercial reputation abroad.

Method: A World Tour

This report examines the world's innovation systems in comparative fashion. The authors pursued a similar research strategy as that used for the first report in this two-part series. They read hundreds of secondary publications and consulted numerous data sources, but their primary methodology for gaining new insights was to speak with people on the ground in as many innovative locations around the world as possible. They believe that the best way to understand the reality of any tech-innovation ecosystem is to speak with the stakeholders who live and work within it.

The authors identified a number of leading innovators (countries and cities) for a world research tour of in-person visits. The countries they visited included China, Japan, South Korea, Singapore, Mexico, the United Arab Emirates, Saudi Arabia, Israel, Sweden, and France. (All of these countries are discussed in this report; a few are featured at greater length in the report's Special Section.) The city list included Brussels (for interviews at the European Union) and Geneva (for interviews at the World Intellectual Property Organization (WIPO). The authors conducted telephone interviews with people in India and Russia. Unfortunately, owing to time and financial constraints, the authors could only travel to a limited number of countries. They could not get to Africa, were limited to the major players in Asia, and were unable to visit much of Latin America.

The authors met with individuals from a diverse range of backgrounds: entrepreneurs; government officials (at local and national levels); venture capitalists; owners of incubators, accelerators, and co-working spaces; academics and university administrators; and local tech-innovation "thought leaders." In all, they spoke with roughly 200 people around the world, usually off the record in order to get the most uncompromised views. The interviewees' insights drive this report's findings at least as much as the literature and data because they gave the authors subtle insights that they could not have distilled from the published record alone.

The authors invited a few of the interviewees to contribute sidebar essays to this report. These essays are sprinkled throughout the document, several on specific countries, others on more general topics.

The authors cannot thank all of the interviewees enough for taking their valuable time to offer their diverse perspectives on this critical topic. The reader is encouraged to consult the Acknowledgements section for a review and listing of interviewees.

An exhibition on intellectual property at the World Intellectual Property Organization in Geneva.

The Sweepstakes

To paraphrase a famous quote, you may not be interested in this century's rapidly unfolding technology revolution, but it definitely is interested in you.[7]

The world is in the early stages of an unprecedented technological transformation, a period of exponential change that some have compared, with considerable exaggeration, to the Cambrian explosion some 600 million years ago when most modern species appeared.[8] This is the disruptive chapter of the digital revolution that began with the Internet in the 1990s. It has been dubbed the "Fourth Industrial Revolution," though it is more an extension of the Third, the digital Information and Communication Technology (ICT) revolution.

Substantially more technology-driven social and economic change will take place during the coming decades than in the first ICT-based revolution. What is unfolding is a convergence of technologies, a synergy of artificial intelligence (AI), big data (the cloud), robotics, biotech, advanced manufacturing, the Internet of Things (IoT), nano- engineering and -manufacturing, and over- the-horizon, quantum computing.

Those societies and governments that have the capacity to be at the leading edges of this technology will win a global sweepstakes. Winners will enjoy economic and geopolitical benefits, but losers will fall behind on both counts. Which societies and governments are prepared to cope with the changes that these technologies will bring is another question entirely, and an unsettling one as there are few answers to such profound questions.

The Knowledge Economy...

The digital and physical economies are merging (called "online-to-offline," or O2O), transforming business models, transport, healthcare, finance, manufacturing, agriculture, and the nature of work. The IoT, a new dimension of connectivity being ushered in by fifth generation (5G) wireless technology, features download speeds up to 10 gigabits a second—fifty times faster than current networks.

Owing to dramatically faster computing power, the cloud, and enhanced algorithms, artificial intelligence is now being applied to IoT-connected applications, such as drones, robots, driverless vehicles, automated warehouses, customized healthcare, and precision agriculture. AI's capabilities are still in a relatively early stage: machine learning is based on neural networks, yet knowledge of the human brain remains limited. Flying cars have not been developed yet, but driverless vehicles will soon be ubiquitous. AI/big data/robotics will replace or augment many jobs of many kinds—not just repetitive ones.

You may not be interested in this century's rapidly unfolding technology revolution, but it definitely is interested in you.

...With New Business Models

These new technologies are changing the nature of business. Consider, as Zenith executive and LinkedIn whiz Tom Goodwin has observed, "Uber, the world's largest taxi company, owns no vehicles. Facebook, the world's most popular media owner, creates no content. Alibaba, the world's most valuable retailer, has no inventory, and Airbnb, the world's largest accommodation provider, owns no real estate. Something interesting is happening."[9] The "sharing economy" portends a shift from owning to accessing, disintermediation (eliminating the middle person in commerce) and dematerialization (as in 3D printing, turning computer-aided designs into physical objects, or vice-versa for virtual reality, turning the physical into the virtual).

Indeed. In today's wired economy, platforms have redefined business models; the smallest startup can now compete in global markets. Mobile phones have become ubiquitous, with some five billion worldwide.[10] Similarly, nearly four billion people, over half the world's population, use the Internet.[11] Chinese mobile payments have reached $9 trillion—more than in the rest of the world combined—spearheaded not by banks, but by Alibaba and TenCent fintech apps.[12] If China is the first cashless society (with India not far behind), tiny Estonia has become the world's first entirely "digital republic," with both government and society pushing relentlessly for digitized services of every kind.[13]

In this emerging universe, data is the coin of the realm.[14] Many have argued that data is the new oil. US technology policy expert Alec Ross describes data as the "raw material" of the new Industrial Revolution.[15] Some 7.7 billion searches are made on Google every single day.[16] The vast majority of the world's data has been created during just the past few years, and that amount is increasing exponentially.[17] The cloud has given enormous computing power to the 4.16 billion people across the globe with Internet access.[18]

Transformative Bursts

This technological transformation will not develop in linear or incremental fashion, but in bursts. Electric cars, for example, are still a tiny fragment of the global market, but

OPPOSITE PAGE: U.S. MISSION PHOTO/ERIC BRIDIERS/FLICKR

Scientists work in the IBM Q computation center, which houses advanced quantum computers.

this is set to change: China has set a target of 20 percent electric cars by 2025, while the United Kingdom (UK) and France will ban the sale of internal combustion engine autos by 2040. As prices drop, as batteries become more capable and recharging stations more convenient, and the market responds, the electrification of transport will hit a critical mass.[19]

Although many emerging technologies are not yet on the public's radar, their economic applications during the coming decade are mind-boggling. For example, the Internet of Things (IoT) will monitor and manage farms, factories, driverless vehicles, oil rigs, and energy grids, adding value worth perhaps $3.9 trillion to $11.1 trillion *per year* by 2025. The increased productivity of ICT-connected sensors will warn of factory equipment needing maintenance; monitor energy use in buildings; give farmers real-time information on soil conditions; maintain and operate driverless vehicles; optimize energy grid performance; and monitor individuals' health.[20] Yet presently, vast amounts of data are only partially or not at all digitized. In the healthcare sector, for example, only some 54 percent of office-based physicians have basic electronic records.[21]

Artificial Intelligence will power much of the promise behind IoT. Although AI has yet to reach a tipping point—whether it is IBM's Watson winning on TV's "Jeopardy" or Google's Alpha Go defeating the world champion at Go—the technology is developing rapidly. This trend line reflects large and growing investments, mainly by US and Chinese tech firms (nearly $40 billion in 2016 and 2017), and by large firms buying AI startups (e.g., Google buying Deep Mind, which generated AlphaGo).[22] The bulk of AI investment is in machine learning, particularly deep learning (a subset of machine learning).[23] AI is already becoming part of individuals' daily lives via "personal assistant" robots like Amazon's Alexa and Google Home. By 2030, AI will be in every imaginable app and pervasive in robots, reshaping industries from healthcare to education to finance and transportation.[24]

Observations

These trends lead to three gigantic observations about the future:

1 Because these technologies increasingly are driving the global economy, all countries should have the highest interest in ensuring that they are competitive in these tech sectors. Failing to do so would mean missing out on the enormous economic benefits that will accrue to those countries that do well in the sweepstakes.

2 Emerging technologies will have a profound impact on how the future unfolds. The next wave of innovation will be Schumpeter-like in bringing spontaneous and "creative" disruptive changes that will alter the previous equilibrium. These technologies will transform society in ways that are scarcely imaginable, with both positive and negative effects. Employment, wages, incomes, inclusiveness and exclusiveness, privacy, education, and governance—all will be reshaped. Moreover, emerging technologies will have profound security implications, at both national and international levels.[25]

3 The use of new technologies will not be evenly distributed, but rather, clustered geographically. For example, 74 percent of the 294,000 industrial robots sold are concentrated in just five countries: Japan, China, United States, Germany, and South Korea.[26] This does not include some forty-eight thousand service robots that do everything from milking cows, to detecting landmines, to monitoring submarines, to facilitating telemedicine.[27] That advantage might accelerate as a result of the concentration of scientists, engineers, and technologists in those locales. This has been the pattern regarding the geography of innovation in the United States, and it is occurring globally as well. The economic, social, and geopolitical implications of the uneven distribution of innovative ecosystems are far-reaching and may be more disruptive than many anticipate.

CONNIE ZHOU/IBM RESEARCH/FLICKR

Mapping Global Innovation

Countries and cities visited by Atlantic Council experts for this report.

During the 2020s, the most economically successful nations will be those that best position themselves to create, absorb, and adapt to new technologies. The most innovative nations fund basic R&D, provide quality scientific and engineering education, craft economic incentives around innovation, ensure access to startup capital, and nurture an entrepreneurial culture. Based on trends evident in all key metrics of innovation, global technological development by 2030 will continue to be uneven, with varying degrees of success and failure.

There are broadly three tiers of nations: those that are leading innovation, those that are adapting and absorbing new technologies, and those that are struggling. These categories are not mutually exclusive—some nations will be leading innovators in some technologies and massive tech adapters at the same time. For example, India (broadly speaking) straddles the innovator and adapter category. Many other countries exhibit characteristics that allow them to straddle more than one of these groupings.

At the very top of the first tier of the tech-innovation leadership list are the world's two biggest economies, China and the United States. A number of mostly wealthy countries from around the world account for the rest of the leadership club. These include the Asian heavyweights Japan, South Korea, and India plus the larger European economies: the United Kingdom (UK), France, and Germany.[28] Numerous small countries can be included on the list of leading innovators. Sweden, Israel, Switzerland, and Singapore are just a few such examples.

A large number of countries arguably land somewhere in the second tier: they are neither clear tech-innovation leaders nor stragglers, seeking to compete. Many of these countries are either still trying to move past faded industrial glory or are otherwise attempting to break out of middle-income status. These states typically land somewhere in the middle of the various global innovation indexes, which

rank countries according to various quantifiable metrics of innovation-related performance. (Some of the most important such indexes are discussed in Box 1 on page 11.) A good example is Russia, which was late to see the knowledge economy as key to its economic future but is starting to generate an innovation ecosystem. Other states include several Southeast Asian economies such as Taiwan and Malaysia; the larger Latin American countries such as Mexico, Chile, and Brazil; and a few states in Africa, such as South Africa.

In the third tier, lagging behind these countries is an even larger grouping of countries, mostly in South and Central Asia, Latin America and the Caribbean, sub-Saharan Africa, and the Middle East and North Africa. This group frequently consists of countries that are poor, with low levels of economic development; such states are often facing difficult if not extreme governance and security challenges. However, even among states in this group, some countries have managed to pull themselves out of the worst conditions and begin to build promising, if still formative, innovation ecosystems. Rwanda, which in 1994 suffered one of the worst genocides in recorded history, is a prominent example. After the genocide, the government began emphasizing tech-driven innovation; science, technical, engineering and math (STEM) education; and practical use of technology as key components of a national economic development strategy. Two decades after the genocide, this tech-and-innovation-centric agenda has helped Rwanda become a small but important and hopeful success story.[29]

This section draws a global map of tech-driven innovation. It explores why China has become the new Silicon Valley, transforming itself from copycat to innovation leader. Why relatively tiny nations like Sweden, Israel, and Singapore have enjoyed outsized success as global tech standard-setters. How countries like Japan, Germany, and South Korea are trying to maintain their postwar economic success in the coming era of tech-driven economic change. How historically underdeveloped nations are adapting to the technological revolution and trying to leapfrog ahead (as has happened in Africa with mobile phones, for example). Unfortunately, those in the last category risk falling behind in a new multi-tiered, tech-haves and have-nots global economy.

The big missing case is the United States, which was the subject of the entire 2017 Atlantic Council report, *Keeping America's Innovative Edge: A Strategic Framework*. The reader is encouraged to consult that document. We believe its findings are, if anything, more relevant today than they were a year ago.

In keeping with the argument that economies can straddle multiple categories, showing some aspects of tech-innovation leadership while struggling in other areas, this section does not attempt to rank the world's countries. Rather, it highlights some of the more important and interesting cases in the world. Although not the only tech-innovation leader, China is by far the most critical and receives the most attention. For even more in-depth treatment of a few of these cases, the reader is encouraged to consult this report's Special Section.

China and the United States

China and the **United States** are clearly the top contenders in the sweepstakes, but it is still too early to tell whether China will outpace the United States. China's swift arrival at the innovation forefront is astonishing. It is a leader across major technology categories including autonomous vehicles, education tech, virtual reality, robotics, advanced manufacturing, AI, and machine learning. China now accounts for 42 percent of global e-commerce, up from one percent just a decade ago. The country is close to being a cashless society, with more than two thirds of its over 750 million Internet users using mobile payments. China boasts one third of the world's unicorns (startups with one billion dollars or more valuation).[30]

China: From Copycat to New Silicon Valley

In a dramatic 2018 illustration showcasing China's technological edge in genetics and bioscience, two Chinese scientists revealed that they had successfully cloned the first primates, two identical monkeys.[31] Ethics aside, this achievement exemplifies Beijing's relentless quest to gain technological superiority. The drive comes from the top and has rippled through Chinese society: "Innovation is the prime driving force behind development: it is the strategic underpinning for building a modernized economy," Chinese President Xi Jinping explained to China's nineteenth Communist Party Congress in 2017.[32] The authors discovered this themselves while touring Chinese tech hubs, finding a buzz and excitement in Beijing, Shenzen, and Shanghai as fierce as anything found elsewhere in the world.

The scope and scale of China's technology efforts are still not fully appreciated. China's swift rise is due to a combination of long-term state planning, well-financed state-directed initiatives, targeted specialization, and the country's sheer size. In barely a decade, China has become the new Silicon Valley, with ambitions to dominate across a wide swathe of technologies. Yet China still tends to be viewed as a copycat, accused of stealing intellectual property and business models (e.g., Alibaba, built on Amazon's business model;

Alibaba Headquarters in Hangzhou, China.

Baidu, China's answer to Google; Tencent to Yahoo).[33] Alibaba and Tencent now rank in the top ten global firms, valued at over $400 billion each.[34] Alibaba, Tencent, and Baidu have innovated their e-commerce offerings around Chinese tastes to make them one-stop shopping places—think of eBay, Uber, Instagram, Paypal, Spotify, healthcare monitoring, food delivery, Facebook, Netflix, and Stubhub all on a single website.[35] China's big-tech companies are scooping up startups around the world, much like their US counterparts.[36]

The country's remarkable ascension up the tech-innovation ladder is an extension of its stunning economic success. Over the past three decades, China's economy has leapt from $395 billion GDP in 1990 to $12 trillion, from 3 percent of global GDP to roughly 15 percent. It has become the world's second largest economy, biggest trading power, and leading exporter of capital, holding $3 trillion in foreign reserves, nearly half the world total, with the renminbi (RMB) becoming a major global currency.

China's venture capital (VC) and private equity have exploded over the past decade. Scott Kennedy, a leading authority on China's economic policies, points out that in 2000, there were 249 VC firms in China with $7.6 billion under management, but by 2015, there were 1,775 VC firms managing $99 billion, and by 2016 the country had 46,505 private equity (PE) firms with $1.2 trillion in capital (many increasingly focused on advanced technologies).[37] One US business source estimated that China has more than one thousand VC firms, each with more than $100 million.[38] A *Wall Street Journal* analysis found that Chinese-led Asian venture funding, now at 40 percent of global VC funding, is fifteen times larger than it was in 2013, and now rivals that of Silicon Valley, currently at 44 percent.[39] Government tech funding is often combined with money from major state-run banks and tech firms. For example, a substantial part of a $190 billion fund for information and communications (ICT) infrastructure investment from 2016-18 came from banks and Chinese telecom firms.[40]

China has steadily increased its R&D spending over the past decade, now 2.1 percent of its GDP with a goal of 2.5 percent, and is second only to the United States in R&D spending at $233 billion.[41] Like the United States, 78 percent of China's R&D comes from the private sector, the bulk of it focused on the "D" rather than on basic research. China's tech giants—Alibaba, Tencent, Baidu—are investing heavily, particularly in AI research.[42] The country's R&D is concentrated in Beijing, Shanghai, and the Shenzen/Hong Kong hub. China produces more STEM graduates each year than the United States, including 1.2 million with engineering degrees—half of all degrees—and a 300 percent increase since 2000.[43]

Beijing's Techno-Nationalism

China's techno-nationalism is not new. Its origins reach back to the Mao Zedong era, when threats from the United States and the former Soviet Union led Chinese leaders to the conclusion that technology was a source of national strength and that they needed to invest in strategic technologies.[44] In 1979, when Chinese leader Deng Xiaoping launched economic reforms, Deng saw the success of Japan's industrial policies and understood technological development as vital to China's modernization. In a first phase of reforms, in 1986 Deng approved a high-tech R&D program focusing on technologies such as IT, robotics, space, biotechnology, and lasers.[45] This was followed by a similar program in 1997.

In 2006, China formally adopted "indigenous innovation"—state-backed industrial policy. This was followed in 2013 by a "Made-in-China 2025" (MIC2025) plan, which targeted ten strategic technologies including semi-conductors, robotics/smart manufacturing, autonomous vehicles, biotech, and artificial intelligence.[46] In July 2017, China's State Council announced a plan to dominate AI by 2030.[47] Xi Jinping has been clear about intent: "We will move Chinese industries up to the medium-high end of the global value chain and foster a number of world-class advanced manufacturing clusters."[48] Beijing's predatory, mercantilist industrial policy stands out from more open efforts like Germany's 2014 "Industrie 4.0" through subsidizing national champions and selectively barring foreign competition from strategic sectors.[49]

Still Trying to Climb the Ladder...

Despite its unique advantages of enormous scale and resources, China is still far from becoming the tech superpower of its ambitions.[50] In many respects, it remains

SAM CHURCHILL/FLICKR

FIGURE 1. China is in the global top three for venture capital investment in key technologies

Source: McKinsey Global Institute. https://www.mckinsey.com/global-themes/china/chinas-digital economy-a-leading-global-force

relatively low on the value chain, more an assembler of technology than a creator. In a 2015 report, longtime China resident Jim McGregor described China's race for self-reliance as a method to "enhance original innovation through co-innovation and re-innovation based on the assimilation of imported technologies."[51] China defines "innovation" as absorbing and/or adding features to foreign technology acquired by hook or crook. As author and China expert Evan Feigenbaum points out, "the acquisition of foreign technology has always been a central part of China's economic reform. But until recently...it was characterized mostly by technology purchases or in some cases, out-and-out intellectual property theft."[52] Many of China's "purchases" have been forced technology transfer as a condition of foreign investment.

China's tech innovation ecosystem is a mixed picture. A McKinsey study concluded that "in industries where innovation is about meeting unmet consumer needs or driving efficiencies in manufacturing—appliances and solar panels, for example—China is flourishing." It points out, however, that "in industries where innovation requires original inventions or engineering breakthroughs," China's shares of global markets are much smaller.[53]

...But Tripping

Close inspection of China's innovation ecosystem reveals key shortcomings, challenges, and vulnerabilities. Indeed, various global innovation indexes show that China has yet to reach the apex of the global order. For example, the 2017 Cornell/INSEAD/WIPO innovation index places China twenty-second, the 2017 Bloomberg innovation index twenty-first, and the World Economic Forum ranks China thirtieth on its 2017 Global Competitiveness Index innovation "pillar."[54]

China's innovation system must be viewed in the larger context of the government's effort to transform the country's economy from an investment-driven, state-centric one into a new growth model based on consumption, services, and innovation. This process is moving incrementally, however. The Communist Party's emphasis on political stability reflects a tension between Xi's goal of having the market be a "decisive" force in the allocation of resources and his commitment to "support state capital."[55]

The massive size of China's workforce, the availability of relatively inexpensive labor, and the country's high ratio of workers to dependents have been key ingredients in China's tech development since the 1980s. Those advantages are eroding rapidly, however, owing to China's aging society. By 2040, China's population aged 60 or older will more than double, rising to 402 million people (28 percent) from 168 million (12.4 percent) in 2015. This "greying" of China—occurring at a much faster pace than in France, Sweden, or the United State—will pose new challenges to the country's development and social safety net.[56] China, it should be emphasized, is hardly alone in confronting this demographic shift, as nearly all wealthy countries face aging populations. A few, such as South Korea and Japan, are aging even more rapidly than China.

Talent Pool

Although it is difficult to quantify, much of China's tech leadership consists of alumni from roughly three hundred thousand students who study in the United States each year, dubbed "sea turtles." Many have, like AI star Kai-Fu Lee of Sinovation, started careers in the US and then returned to China.[57] In the two decades since Microsoft opened its research lab in Beijing, it has been an important catalyst for China's tech talent, including AI.[58] China faces an uphill battle to realize its plan to dominate AI by 2030: it has a chronic shortage of AI talent, with the United States dominating in R&D and the number of AI startups.[59] China has only a few world-class universities, Tsinghua, Beijing University and Fudan among them. This concern has led to a Chinese crash spending program to create 42 world-class centers of learning by 2050.[60]

China's growing government debt (25 percent of GDP) and corporate debt ($18 trillion, 170 percent of GDP) highlight a difficult balancing act.[61] The country's economy has an unusually large debt-to-GDP ratio, meaning that the return on fixed investment is declining.[62]

Against that backdrop, it is easy to see why Xi has emphasized tech innovation. Making innovation a high priority has led Beijing to mobilize resources that have been key to its tech success. Xi also seems to be allowing more political and economic space (though recent moves to force tech firms to sell shares to the Communist Party is troubling). However much the lavish flow of resources into innovation has accelerated China's transformation, this move also reflects inefficiency—the gap between input and output endemic in much of the economy.

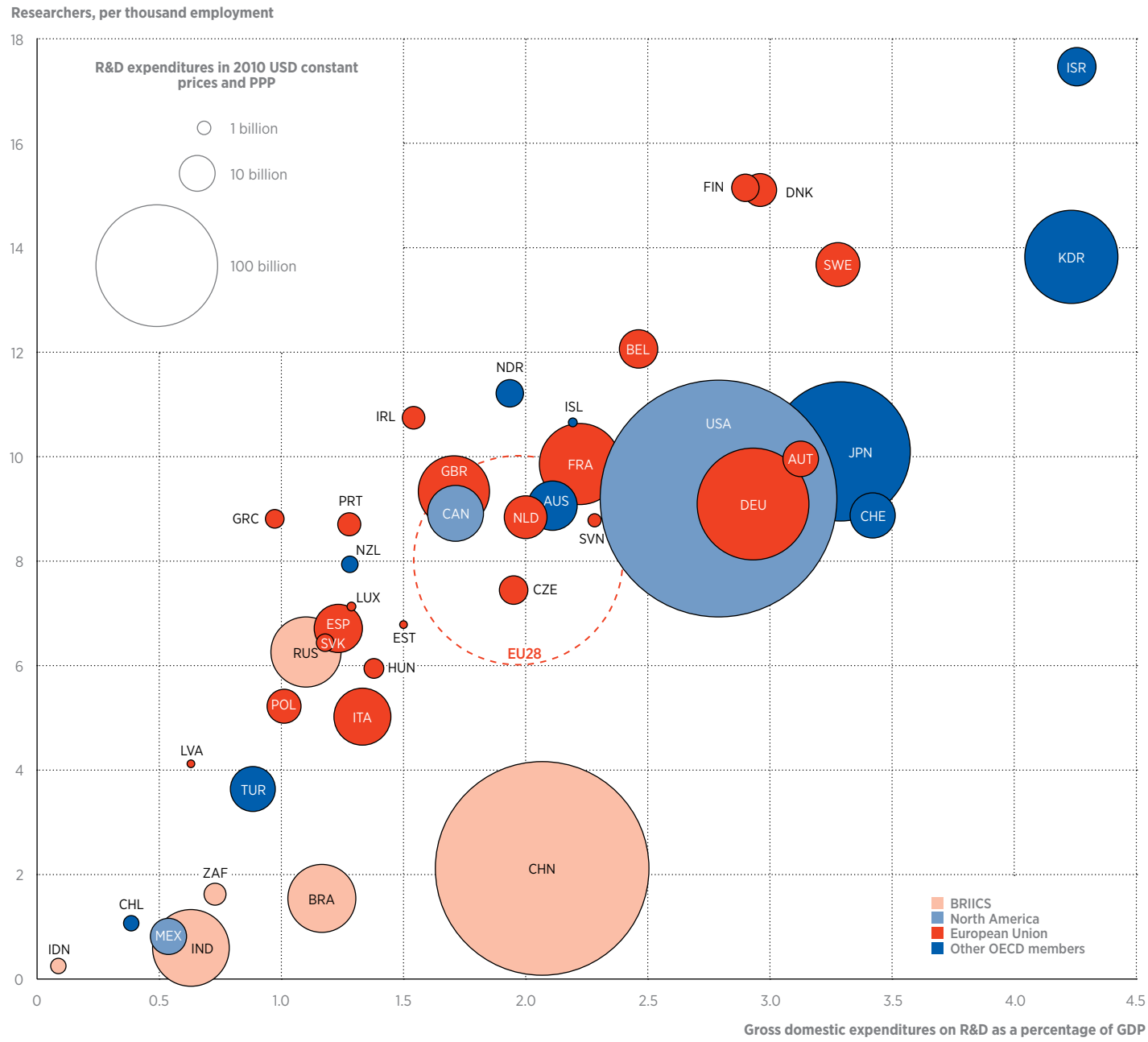
Making innovation a high priority has led Beijing to mobilize resources that have been key to its tech success.

Scientific Research: Quantity vs Quality

Although China has surpassed the United States in the volume of scientific papers published, it also leads in science fraud. In 2017, one science journal alone retracted 107 articles, and a Chinese government investigation revealed that

STUART ISETT/FORTUNE BRAINSTORM TECH/FLICKR

FIGURE 2. R&D in OECD and key partner countries, 2015



Source: http://www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017_9789264268821-en#page26.

500 researchers were guilty of misconduct.[63] There is a cottage industry of fraudulent peer reviews for sale on Chinese e-commerce sites.[64]

This reflects an extreme input-centered incentive structure affecting research and patents. While Western scientists are under pressure to publish, in China the pressure to publish scientific studies is enormous, with increased funding, bonuses, and career advances dangled amid cutthroat competition. China's share of the world's published scientific papers has risen exponentially since the beginning of this century, now accounting for some 20 percent of the world total, including roughly one-third in engineering. Yet in terms of quality, the measure of citations in the top one percent of papers cited shows China modestly improving over the past decade; in all fields save mathematics, China is still cited only less than half as frequently as the United States.[65]

Similarly, China now leads the world in patents filed, with 1.3 million in 2016.[66] Nevertheless, the gap between quantity and quality is evident. An incentive structure involving subsidies, increased funding, and career advancement encourages quantity over quality.[67] Though it is changing, China is known for poor-quality patents, many of which are "utility" patents,

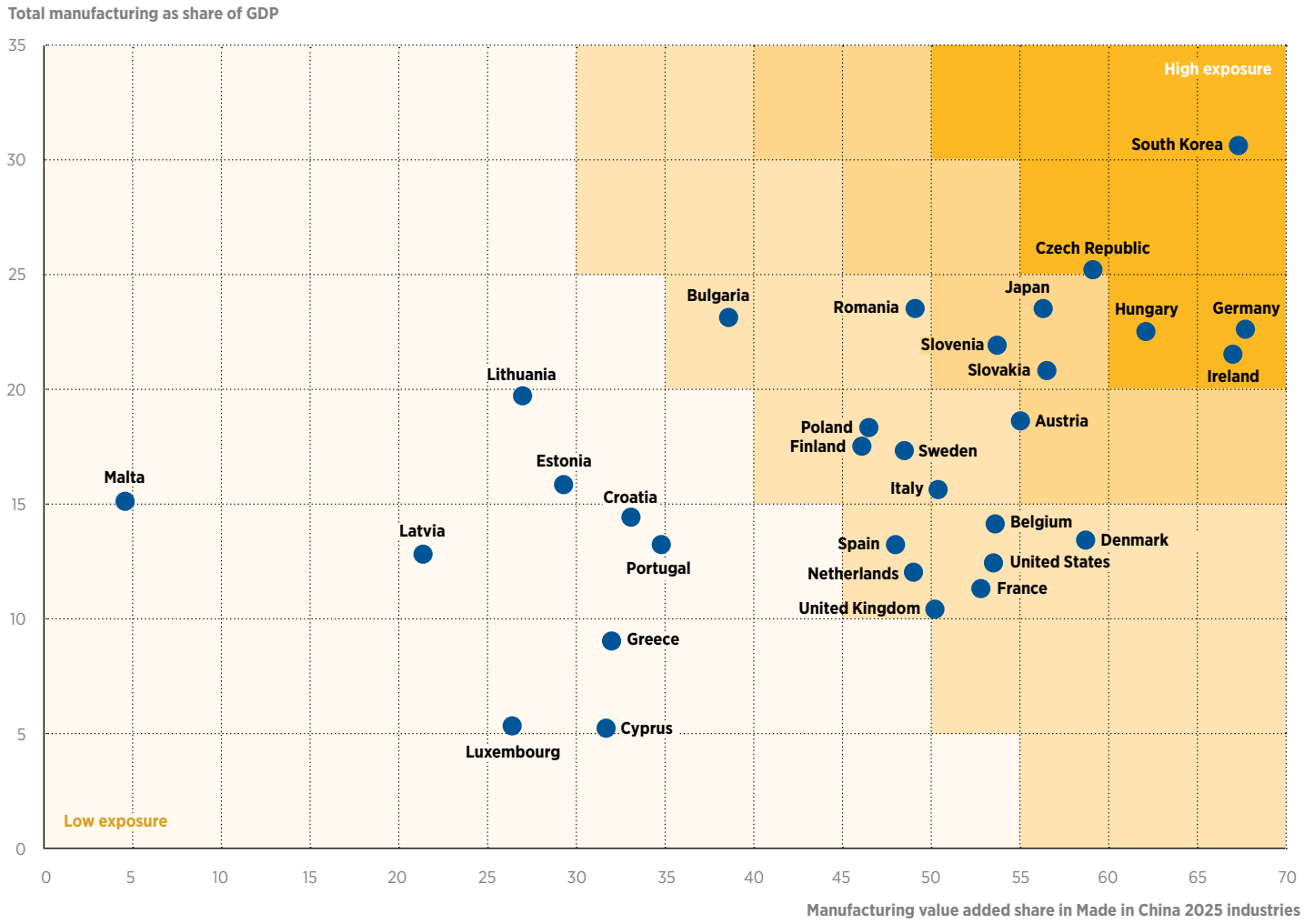
easier to obtain and shorter in duration, and of little commercial value.[68] Patents of substantial value tend to be known as "triadic" patents, those filed in the United States, European Union (EU), and Japan. China is barely on the map of such patents, as 95 percent of Chinese patents are only filed domestically.[69] Moreover, the commercial value of Chinese patents is less than five percent of US patents.[70]

One important positive sign of change toward international standards is a dramatic shift in Chinese intellectual property and policies. The vast majority of software in China (70 percent) is pirated.[71] As China has become more of a producer of IP in areas such as gaming and apps, it has developed more stringent IP protection standards and norms. In 2014, it set up separate IP courts that have earned global respect.[72]

Perhaps the most problematic part of China's tech revolution is the predatory industrial policies it is employing at the expense of competitors—potential partners—and thus degrading global standards, not to mention its own global competitiveness. The problem is not MIC2025's objective of turning China into a global leader. Government stimulus for innovation—from funding R&D and financing startups to private sector incentives—is a feature of the economic policies of the United States, European Union, Japan, and most major economies. The problem is the state-driven means of achieving innovation, contradicting the principles of market forces and open trade and investment—the very principles Xi Jinping claims to champion. These industrial policies feature multi-billion-dollar government funds targeting all ten[73] technologies, while limiting foreign direct investment even as Chinese firms aggressively invest overseas. This will distort China's domestic markets and create a mismatch between political goals and industrial needs.

Other challenges exist, as well. One involves automation and human capital. Chinese industries are on average 3.7 times less digitized than those of the United States.[74]

FIGURE 3. Vulnerability of select industrial countries to Made in China 2025



Source: MERICS. https://www.merics.org/sites/default/files/2017-09/MPOC_No.2_MadeinChina2025.pdf

ASSESSING TOP-DOWN INNOVATION IN CHINA

BY **DR. YANG GAO**

At the end of 2013, the Third Plenary Session of the eighteenth Chinese Communist Party (CCP) Central Committee set China's development path for the coming decade. President Xi Jinping announced China's five development concepts featuring "innovation" (Chuang Xin) in his report. Since then, China has officially put building a national science and technology innovation ecosystem at the very top of its policy agenda, aiming to boost the state's strategic competitiveness and sustained economic growth.

Perhaps both the greatest strengths and the most obvious weaknesses of China's ecosystem is its state-driven characteristic. Without a strong and mature private sector, the state plays a fundamental role in the innovation ecosystem by providing funds and policies. In China, virtually all basic research and most R&D rely on state funding. Governments, from central to the local level, directly or indirectly inject huge state assets to build the innovation ecosystem and keep it running through the state-owned financial system and state-owned enterprises (SOEs). For instance, almost all Chinese startups depend on state subsidies, tax refunds, special bank credits, and government venture capital investments to survive at the early stage. In Chinese universities and research institutes, there has been a tendency that quantity, not quality is rewarded—those with more papers published, more patents filed, however mediocre—tend to garner more funding.

Thus, on the one hand, the Chinese state can mobilize enormous resources and issue strategic policies (such as "Made in China 2025") to support a "great innovation campaign." The Chinese leadership closely watches the development of Germany's "Industry 4.0" and strives to leapfrog the West in two critical areas: big data technology and high-end equipment manufacturing. On the other hand, China faces the challenge of making its innovation campaign ecosystem more efficient because absent the full discipline of the market, there is no effective way to evaluate the actual performance of this effort.

A key component of China's innovation drive is to educate the country's people about entrepreneurship and encourage technological startups. Although the state continues to dominate the strategic upstream of the innovation value chain where most technological and engineering breakthroughs and IPs are created and transferred, the private sector has been permitted more economic and social space and encouraged to play a major role downstream where non-sensitive technologies are commercialized to create jobs and GDP. The burgeoning private sector is deeply involved in both China's venture capital market and tech-based service industries like Technology, Media, and Telecom (TMT). A considerable share of Chinese startups concentrate in TMT industries due to their relatively low entry barrier and operating cost. Many of these startups have the goal of merging with established Internet giants like Baidu, Alibaba and Tencent (the BATs), as is also the case with US big tech (Amazon, Google, Facebook, Microsoft, IBM). The BAT's markets in China are so consolidated that there is not too much point in competing with their products and services. In fact, the BATs themselves are proactively encouraging startups based on the TMT ecosystem they have constructed.

Tsinghua University Science Park in Beijing.

SAMUEL KLEIN

However, those startups that target industries beyond TMT, like new materials, smart manufacturing, and healthcare—where no obvious industrial champion dominates the market—seek more independence and control over their own growth by fast fundraising to achieve initial public offering. For them, to become the BAT in their own specialized areas is an essential drive.

In China, Silicon Valley presents an ideal image of what China's innovation ecosystem could look like in the future. For instance, almost all the national-level innovation enterprises, like the Zhongguancun National Innovation Demonstration Park (Z-Park), describe themselves as "China's Silicon Valley." In my view, China's great innovation campaign would probably create an innovation ecosystem with equal vigor and dazzling technologies to change people's lives, but in profoundly different ways.

Silicon Valley is a self-governed innovation ecosystem based on the entrepreneurship of the private sector and a relatively free market. In contrast, the state, not the market, plays a vital role in China's innovation ecosystem. How this largely state-driven innovation ecosystem will be structured to combine an authoritarian state's power and private entrepreneurs' ideas and capital during the coming decades is still an unfolding process. The success or failure of this process may depend on the degree to which it deepens reforms to let markets be "the decisive factor," as Xi has said, in the allocation of resources.

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One major study concluded that "upgrading the production process might result in job losses among the less skilled workforce," while "China's education system is not prepared for training skilled personnel capable of operating sophisticated smart manufacturing."[75]

Yet if China achieves a substantial portion of its stated goals, to the degree that Beijing defines norms and standards, doing so could pose major global challenges. Members of the foreign business community are already anxious. As one interviewee said, "[foreign] companies are still making money, still investing. But they're worried about long-term sustainability, mainly because of innovation, IP rights, and Chinese companies—you see the central government put a lot of money and resources beyond these industrial policies… It's concerning because as part of those plans, 80 percent of market share will be owned by Chinese companies by 2025."[76] Beijing's efforts to dominate the global semi-conductor industry could, if successful, disrupt global supply chains key to South Korea, ASEAN, and Japanese economies over the coming two decades.[77]

Detailed assessments of the potential impact of China's policies are beyond the scope of this report.[78] Nevertheless, one prominent example, digital commerce, is illustrative. Cloud computing, AI/big data, and the infrastructure of digital commerce and increasingly digitized manufacturing industries require a free flow of data. A 2017 US Chamber of Commerce report argued that China's "efforts to exert greater control over where commercial data is stored and how it is transferred are skewing the decision-making process for companies that must decide where products are made and innovation takes place."[79] Digital commerce and emerging technologies are areas where global rules need to be updated. The eleven-member Trans-Pacific Partnership (TPP) was the first attempt at shaping comprehensive rules for open digital trade.[80] Yet China's legal and regulatory framework to date is the precise *opposite* of the provisions in TPP.

Finally, one irony is that like US big tech, China's big tech pursues global competitiveness, but a lack of reciprocity may limit Beijing's global reach. As the United States discovered in the 1980s during disputes with Japan's auto industry, protectionism is an obstacle to global competitiveness: would the US auto industry's modernization have occurred if Japanese auto exports (and factories built in the US) had been prohibited? It may be that Xi Jinping has made a strategic choice that economic control rather than open markets and competition is preferable—even if it means that China's tech industry is not cutting-edge. Some suspect that Xi has opted for a "good enough" China, one that cuts corners (the term comes from a major study of China's mobile phone industry).[81] If so, the consequences would be felt not only by China, but the tech revolution writ large.

The United States: Losing Its Edge?

As the authors of this study point out in their 2017 report, the United States—long the world's leader in technological innovation—is at risk of losing its position for two key reasons: the growing likelihood that China and other emerging economies will leapfrog US advances in key areas and declining US commitment and resources for technological innovation. This is already occurring in mobile payments, biotech, supercomputers, and the gap is fast closing in AI/big data, robotics, self-driving vehicles, 5G, and semiconductors.[82]

To retain its edge as the global tech leader, the United States needs to recommit to the strategy that it followed with great success during the Cold War. That strategy, which committed the US to excellence in R&D and public education, was instrumental in creating the conditions for innovative places such as Silicon Valley to arise. An updated strategy for the twenty-first century should include ensuring that the critical role played by the federal government in funding basic R&D across the United States is maintained and even strengthened. The US also should recommit to providing high-quality education, including STEM education, to its citizens at low cost (for decades, the US increasingly has been transferring the cost of higher education onto students). The US also needs to ensure that it remains an attractive and welcoming place for foreign talent. America's postwar tech-innovation success was driven to a large extent by its ability to attract first-rate talent from abroad. As this study shows, other countries have become far more aggressive at competing for that talent, which in turn means that the US, for arguably the first time in the postwar era, risks losing its premier position in this critical global competition.

Recently, there have been some encouraging signs of urgency. In May 2018, the White House hosted a summit on AI that focused on: strengthening the national AI R&D ecosystem; placing renewed focus on STEM education and skills; removing barriers to AI innovation in the US; and facilitating sector-specific AI applications for industry.[83]

As the authors further detail in their 2017 report, the US should invest in twenty-first century infrastructure and amenities in order to help create more tech hubs in more places around the country. These investments should coincide with policies designed to encourage startup formation in and around research institutions such as universities and federal research labs.

Finally, the United States needs to pay much greater attention to inclusiveness, with policies directed at enabling more types of people in more regions of the country to participate in the tech-innovation economy. The US should be focusing on providing workers with the skills and knowledge necessary to compete in a fast-moving labor market while at the same time ensuring that people have portable benefits (health insurance, etc.) to support them within a dynamic economy.

First grade class in Japan. The country has one of the world's highest rates of STEM graduates.

EIGHTYDAYSJET/FLICKR

Asia's Other Giants

Japan and **South Korea** are both intent on renovating their respective economies and being in the forefront of the tech transformation that has the potential to propel their economic growth in the 2020s and beyond. Yet China casts an immense shadow over the technology futures of both countries. China's rise as a technology power comes as both Japan and South Korea are in the midst of trying to adapt their state-orchestrated, large conglomerate-centered industrial models to the agility, creativity, and risk tolerance of the unfolding technology revolution. Ironically, Japan's success as Asia's first advanced industrial society was a key motivator of the Chinese economic reforms launched in 1979 by Deng Xiaoping; South Korea's stunning transformation into a world-class industrial power—a global force in autos, shipbuilding, and electronics in little more than a generation—also was a role model for China.

Both Japan and South Korea have strong technological and scientific/industrial bases; thirteen Japanese individuals have won Nobel Prizes for science compared to one Chinese winner. Japan and South Korea are both in the top tier globally in terms of the core elements of innovation ecosystems and are highly ranked in innovation indexes. Both have high rates of STEM graduates and are leaders in R&D spending as a percentage of GDP (4.3 percent for South Korea, 3.5 percent for Japan).[84] Nonetheless, to put this in perspective, the United States spends three times the amount that Japan does on R&D ($496 billion), and China ($409 billion) more than two times as much. Similarly, looking at patents filed, though Japan and South Korea ranked third and fourth globally in 2017, China files more patents than the United States, Japan, and South Korea combined (as mentioned earlier, their quality is a matter of much debate).[85]

Honda, Toyota, Hyundai, Samsung, and LG all have labs in Silicon Valley, representing just a small number of the hundreds of Japanese and South Korean firms with a presence there. Japan has mobilized no less than four ministries in a major national AI strategy as a centerpiece of the effort it calls "Society 5.0," a headlong plunge into the fourth industrial revolution. Yet the tide has turned in China's favor. "In ten years we will be overwhelmed by the scale of China," an official of a leading South Korean government research institute told the authors, summing the dilemma facing both South Korea and Japan.

Meanwhile, another Asian giant—**India**—is trying to scramble up the ladder. In terms of population, India is the world's largest country. Its economic growth over the past decade or so has also been strong. As in China, a combination of massive population size and a flourishing economy means that India could become a great power in tech-based innovation. Yet, as this section shows, while India has some considerable strengths, it also has real challenges and weaknesses, including in education and skills, basic and applied R&D, and lingering obstacles to doing business. How India deals with these challenges will determine its role as a global tech player.

Japan Passing?

Japan's "lost decade" from the 1990s into the new century has led many to write off the world's third largest economy ($7 trillion GDP).[86] As Stanford University research scholar Kenji Kushida points out, the trajectory of the ICT revolution (the move to operating systems, platforms and software, and the smartphone revolution) migrated away from Japanese strengths.[87] Some traditional features of Japan's economic landscape, such as lifetime employment and the tight financial-corporate *kereitsu* (networks of cross-holdings), are fading. Moreover, Japan is the world's oldest society, with roughly 25 percent of its 127 million over 64, raising financial and labor shortage issues.[88]

Nevertheless, many factors that produced Japan's remarkable post-World War II economic success have not disappeared, including skill at adapting (reverse-engineering) and refining US technologies, as well as the capability to develop innovative manufacturing and management techniques (e.g., 'just-in-time' delivery). Some of Japan's areas of excellence, such as robotics (Japan delivers 52 percent of global supply) and sensing technology, remain strong.[89]

The foundations of a more innovative Japanese economy have gradually taken shape. Much of the impetus has come from the national government. In 2015, Prime Minister Shinzo Abe launched an effort to revitalize R&D, with one billion dollars for universities to better commercialize their research (university-industry ties have historically been very weak). During the past decade, leading universities such as Tsukuba, Tokyo, and Keio have begun tech innovation initiatives, funding dozens of startups.[90] A notable success, the startup Spiber, was spawned by one of Keio's labs.[91] The century-old RIKEN, Japan's premier R&D institution, has also begun to step up commercialization activities.

The Abe government's biggest tech-related challenge has been prodding Japan's major global companies to alter their business models. An interviewee at a major research institute told us that inertia remains strong within big firms—thus the government has launched many tech initiatives.

Nonetheless, a shift is under way. Dubbed "open innovation," major Japanese firms are pursuing links with startups and research institutions in Japan and abroad. A recent study by Japanese business associations reported the presence of 770 Japanese firms in the Silicon Valley-San Francisco area, such as a Honda-opened AI research lab.[92] Another example is of a group of one hundred Japanese CEOs who formed the Japan Innovation Network, an accelerator for innovation.[93] Some Japanese analysts argue that a hybrid system dubbed "syncretism" has taken shape and point to anecdotal evidence of major firms partnering with startups and small businesses.[94]

The Abe administration's effort to advance and scale up the "Fourth Industrial Revolution" is most evident within the vaunted Japanese bureaucracy itself. Various ministries and national agencies such as the Ministry of Economy, Trade and Industry (METI) have elaborate plans and strategies. The capstone might be a 2017 Artificial Intelligence Technology Strategy to coordinate R&D across different ministries and major research institutions.[95] The strategy has already yielded some impressive results including *Voicetra*, an app that does real-time translation in more than thirty languages.[96]

The Japanese government and private sector both recognize that, with a rapidly aging population and an ambitious China, mobilizing Japan's resources to accelerate the country's technology transformation is critical. Japan's dominance in robotics is aimed at caring for its aged. Tokyo plans to launch 5G communications at the 2020 Olympics and is likely to move quickly to deploy the IoT in industry. Japanese officials say that their long track record in global industries like autos and electronics provides a substantial data base upon which to develop AI. With a nearly fully digitized national healthcare system and dominance in such areas as immunotherapy and regenerative medicine, Japan is likely to be a player in health and medtech. In a cash-centered society, it is unlikely to compete with China in areas like fintech.

In contrast to other efforts at tech innovation, there is a dearth of incubators or startup hubs. Japan's innovation efforts are Tokyo-centric (greater Tokyo has 37 million people), with fledgling efforts to create tech hubs in the Kansai region (Osaka-Kobe-Kyoto) and Fukuoka. There is little doubt that Japan will achieve some cutting-edge achievements in certain niches and excel in adapting and absorbing many emerging technologies. Robotics/AI/big data may be one such area, immunotherapy/regenerative medicine and new materials are others. The larger question is whether Japan's centralized, top-down method of innovation can return the country to its postwar success.

Until the mid-1990s, there was no such thing as independent venture capital in Japan. Globis Capital Partners, now one of Japan's leading private equity and VC firms, was only founded in 1996. Globis, which specializes in early

OPPOSITE PAGE: FLORIAN VOGGENEDER/ARS ELECTRONICA/FLICKR

stage, pre-IPO (initial public offering) funding, now has four separate VC funds and has invested more than $7 billion in dozens of new companies. There are some 50 VC funds in Japan, some government-funded, many created only in the past five years, but these are relatively small in scale, averaging in the $50-100 million range.[97] Yet VC investment in Japan is still a small percentage of VC in the United States (less than $5 billion vs $72 billion in 2017).[98] One encouraging sign that "open innovation" may be taking hold: Japanese startups raised a record $2.5 billion in 2017, and Japanese corporate venture capital spending reached nearly $700 million, also a record.[99]

Finally, one potential hazard that several tech entrepreneurs pointed out is that Japan's market is big enough to insulate the country from outside competition with standards and regulations that make it harder to compete globally. For example, Toyota and Honda are making large investments in hydrogen fuel cell autos while the global industry is betting on electric vehicles.[100]

South Korea 2.0: From Chaebol to Gangnam Style

In the 1980s, South Korea was one of several rapidly industrializing economies (along with Singapore, Taiwan, and Hong Kong) viewed as "flying geese," with Japan in the lead. South Korea's stunning progress from the ashes of the Korean War, with an economy the size of Ghana in 1957 to the twelfth largest economy in the world ($1.5 trillion GDP in 2017) is one of the most remarkable development stories of the modern era.[101] Things tend to happen fast in South Korea. They may be doing so again.

The country's economic path to advanced industrialization is a broadly similar variant of Japan's *keiretsu* story, though with different local dynamics. Beginning in the 1960s, the government orchestrated financial sector investments to several dozen family-owned business groups. These grew into large, mostly family-controlled conglomerates (as opposed to Japan's cross-holdings run by professional managers). Known as *chaebols* (e.g., Samsung, Hyundai, LG, SK Holdings, Lotte), these have dominated the South Korean economy. The top five *chaebols* account for half the Korean Stock Exchange and more than 60 percent of South Korea's economy.[102]

Although South Korea has not experienced Japan's "lost decade," its economy, which has typically experienced about 6 percent annual growth, is losing steam. Since the 2008–09 great recession, South Korea's growth has fallen to 3 percent or less. The country is facing a demographic decline, though less pronounced than that of Japan. Apart from Samsung

The Big Robot Project at the University of Tsukuba in Japan.

Mori, a facial-recognition robot designed by students at the Korea Advanced Institute of Science and Technology (KAIST).

SWISS PAVILION FLICKR

and the electronics sector, which is vital to the global electronics supply chain (South Korea produces 17 percent of global semi-conductors, 64 percent of mobile chips, and 40 percent of LCD displays), many of the *chaebols* have been floundering, with profits sagging and corruption scandals and crises hitting shipbuilding, steel, and construction.[103] This led the *Financial Times* to conclude in 2014 that the *chaebol* economic growth model had run its course.[104]

Chaebol fatigue has cascaded across the economy, impacting small-and-medium-sized businesses (SMEs), which provide more than 80 percent of the country's jobs.[105] Youth unemployment surged, in 2017 hitting over 11 percent at one point.[106] A nation where 67 percent of the population goes to college, good jobs have become increasingly scarce.[107] This trend has sparked an ongoing effort to restructure the economy and find alternative sources of long-term growth.

Yet South Korea has a strong foundation on which to refurbish its economy. An emphasis on science and technology has been an element of its success. The country's research institutions have a solid track record. The Korean Advanced Institute for Science and Technology (KAIST) is the country's premier research facility—South Korea's version of MIT and Japan's RIKEN rolled into one. Its emphasis is on basic research, but scientists there also do some applied research. In 2015, KAIST had 429 international patents. It has been averaging about 1,800 domestic patents and 20,000 commercial licensing agreements annually. A senior official and researcher there said that KAIST is trying to foster more entrepreneurship and innovation, including launching its own incubators.[108] South Korea's big three universities, known as SKY (Seoul National, Korea, and Yonsei) are world-class institutions, though there is a discernable drop off beyond a small coterie of top schools.

Not surprisingly, the South Korean government has institutionalized foresight and strategic planning in S&T, embodied in the Korean Institute for S&T Evaluation and Planning (KISTEP). KISTEP is a two-decade-old organization with a comprehensive approach to assessing technology trends, setting the research agenda and budget priorities for government, and evaluating S&T outcomes.[109] President Moon Jae-in wants KISTEP to shape a Fourth Industrial Revolution initiative.[110]

An agency under the Ministry of Science, the Electronic Technology Research Institute (ETRI), has been an important part of the "secret sauce" enabling South Korea's success as a leading global player in industrial and consumer electronics

(see discussion of the "secret sauce" on page 59). The government-funded ETRI has a large cadre of some eighteen hundred scientists, engineers, and technicians. ETRI has a noteworthy track record in applied research and commercialization. It has whole divisions for IP commercialization and is one of the most prolific institutions in garnering US patents—a record 833 in 2014— and has filed nearly 1,700 patents from 2011-16, signed 2,785 tech transfer contracts, and earned $154 million in royalties over that period.[111]

ETRI's research and development background has included 4MDRAM memory chip; commercialization of CDMA; 4G LTE (the current high-speed data access technology used by mobile phones); and advanced Digital Multimedia Broadcasting needed for high-resolution, large-screen TVs. In an effort to catch up to US big-tech firms in AI, it has invested in Korean-English translation apps and Exobrain, designed to compete with IBM's Watson.[112]

India: A Mixed Bag

Tech innovation in **India** defies easy categorization. There is little question that the broad trajectory of India's tech innovation system is steadily moving forward, but the massive country is marked by many contradictions. If the tremendous success of Indian ex-pat tech entrepreneurs in the United States, or India's world-class software industry and thousands of ICT startups, or even Prime Minister Narendra Modi's Digital India vision were the measure, India should be rivaling China as a tech superpower. Yet the country's tech-innovation system has just as many vulnerabilities as strengths.[113]

India's metrics are mixed. It invests an anemic 0.8 percent of its GDP in R&D, giving rise to widespread concerns in the tech community about a research deficit.[114] Universities, research institutes, and labs tend to be poor at tech transfer. Although India is one of the top ten nations in terms of patents, relative to China and the United States it remains small and, despite improvement, India's patent process still lags far behind leaders.[115] In absolute terms, India is among the top ten nations for STEM PhDs, but relative to its population it educates about one-third as many STEM PhDs as China.[116] In 2017, Indian startups garnered $17.6 billion in investments, a figure that compared well relative to China.[117] As the Modi government has dismantled regulations, India has moved up 45 positions on the World Bank ease of doing business list—but it is still only ranked one hundredth in the world.[118]

Although India has elite schools and twenty Indian Institute of Technology campuses, it faces major challenges in education. Indian schools are failing, with half of the country's fifth-grade students unable to read second-grade-level books.[119] Several academics and entrepreneurs interviewed for this study explained that teaching is considered a low-status profession in India, with low pay and poor training. The potentially good news is that, unlike other leading innovators, India remains youthful: half of its 1.25 billion population is under 25.[120] Modi, working with NASSCOM (the ICT industry association), has launched a "future skills" effort to train two million people in skills necessary to develop and adapt to emerging technologies.[121]

India's middle-class consumer market may be less buoyant than often believed. Depending on what income criteria is used, India's middle class may be far smaller than the 300 million often cited, perhaps closer to the 150 million range if a $10-per-day standard is applied.[122] The scale and pace of urbanization in India will determine the size of the country's market for high-tech products and services. India's rural-urban proportion—70 percent rural, 30 percent urban—is almost the opposite of China's, which is benefiting from a rising urban middle class and resulting digital economy.[123] Yet India's digitization is advancing: 462 million people have access to the Internet (roughly one in three people), second to China (751 million of China's 1.3 billion people).[124]

The STEM talent in India's tech sector, its ICT services, and the country's growing middle-class market has long attracted US tech firms.[125] Microsoft, IBM, Google, and Amazon are all active in India. Microsoft has had a campus in Hyderabad for twenty years, and IBM employs more people in India than it does in the United States.[126] Amazon India is becoming a force in e-commerce, a fact that spurred former Amazon employees to launch Flipkart, an e-commerce platform that not only has become one of nine Indian unicorns but also is rivaling Amazon's sales.[127] Several interviewees mentioned that the Indian tech community objects to the outsized US big-tech presence in India.[128]

India's startup ecosystem is still maturing. Beyond boasting nine of the world's 268 unicorns, the country has 142 incubators or accelerators and has spawned some five thousand startups.[129] Bangalore remains India's premier tech hub, though Hyderabad and Delhi are becoming players. Other cities—Mumbai, Chennai, and Ahmadabad—are beginning to attract startups. The VC funding landscape is also maturing, even if such funding is still some years off from the ideal.[130]

India's tech portfolio is becoming more diverse. At the government level, Modi has launched Digital India to create an e-payments cashless economy. He has also moved to digitize government services as a more efficient way to deliver them. These efforts have begun to boost fintech. India's space program has pioneered telemedicine. Complementing telemedicine are a host of Indian health and medtech startups, some with innovative diagnostic apps.

India's future role in the global tech-innovation ecosystem will be as much about adapting new technologies as creating them. Regarding the Internet of Things, one interviewee said that India did not want to fall behind with 5G, as it did with 4G, but the country has much to offer in this space going

forward (IoT is a combination of software and sensors, which are Indian strengths). Whether or not India produces new IoT technologies, it will definitely be adapting them, for example, through precision agriculture for enhanced productivity in the country's agricultural sector.

Europe: Rising to the Challenge?

"Europe" is neither a single country with a unified political and economic system nor a conventional world region with fully independent countries. The ongoing struggle to transform 27 sovereign countries into a single market via the EU, plus European economies' longstanding and highly visible economic difficulties, as well as the continent's demographic challenges (widespread aging combined with low immigration), have led observers to write off Europe's economies as lost causes. Others buy into the notion that Europeans are simply too enamored with *la dolce vita* (long vacations, short workweeks, etc.) to be competitive in the cutthroat global knowledge economy. Europe, one hears, is a kind of living museum: it may contain many beautiful glories worth seeing, but time simply has passed it by.

The Europe-as-museum idea is a prejudice more than an objective reality. Even a cursory review of the major innovation indices shows considerable European strengths. In the 2017 Cornell/INSEAD/WIPO rankings, European countries occupy eight of the top ten places globally. Switzerland, Sweden, and the Netherlands are ranked first, second, and third in the world, and Europe's biggest economies (United Kingdom, Germany, and France) are ranked fifth, ninth, and fifteenth globally.[131] Other leading indexes tell similar stories. Bloomberg's Innovation Index 2017 places five European countries (Sweden, Germany, Switzerland, Finland, and Denmark) in the global top ten, with another seven European countries, including France and the UK, in the top twenty.[132]

Europeans also score well on indexes that assess niche aspects of innovation, in particular those measuring corruption, rule of law, lifestyle, and reputation. Seven European countries are in the top ten in Transparency International's 2016 corruption index, seven of the top ten in the 2017 "RepTrak" index (which surveys national reputations around the world), and eight of the top ten in the 2017 World Press Freedom index (which we treat here as a proxy for a society's openness).[133]

Europe's cities also get high marks, with five in the global top twenty in Startup Genome's 2017 rankings of startup ecosystems. These are London (third), Berlin (seventh), Paris (eleventh), Stockholm (fourteenth), and Amsterdam (nineteenth). In comparison, the United States has seven, China two.[134]

Atomico, a European venture capital fund that conducts thorough surveys of Europe's tech scene, documents much of this progress. Its 2017 survey found that Europe's tech sector was creating jobs faster than the larger economy (Ireland's 5.3 percent rate of tech sector job growth was the fastest), forcing tech firms to compete for the continent's highly mobile talent. A record amount of investment capital flowed into the European tech sector ($19.1 billion), besting 2016's previous record of $14.4 billion and nearly five times the amount invested in 2012.[135]

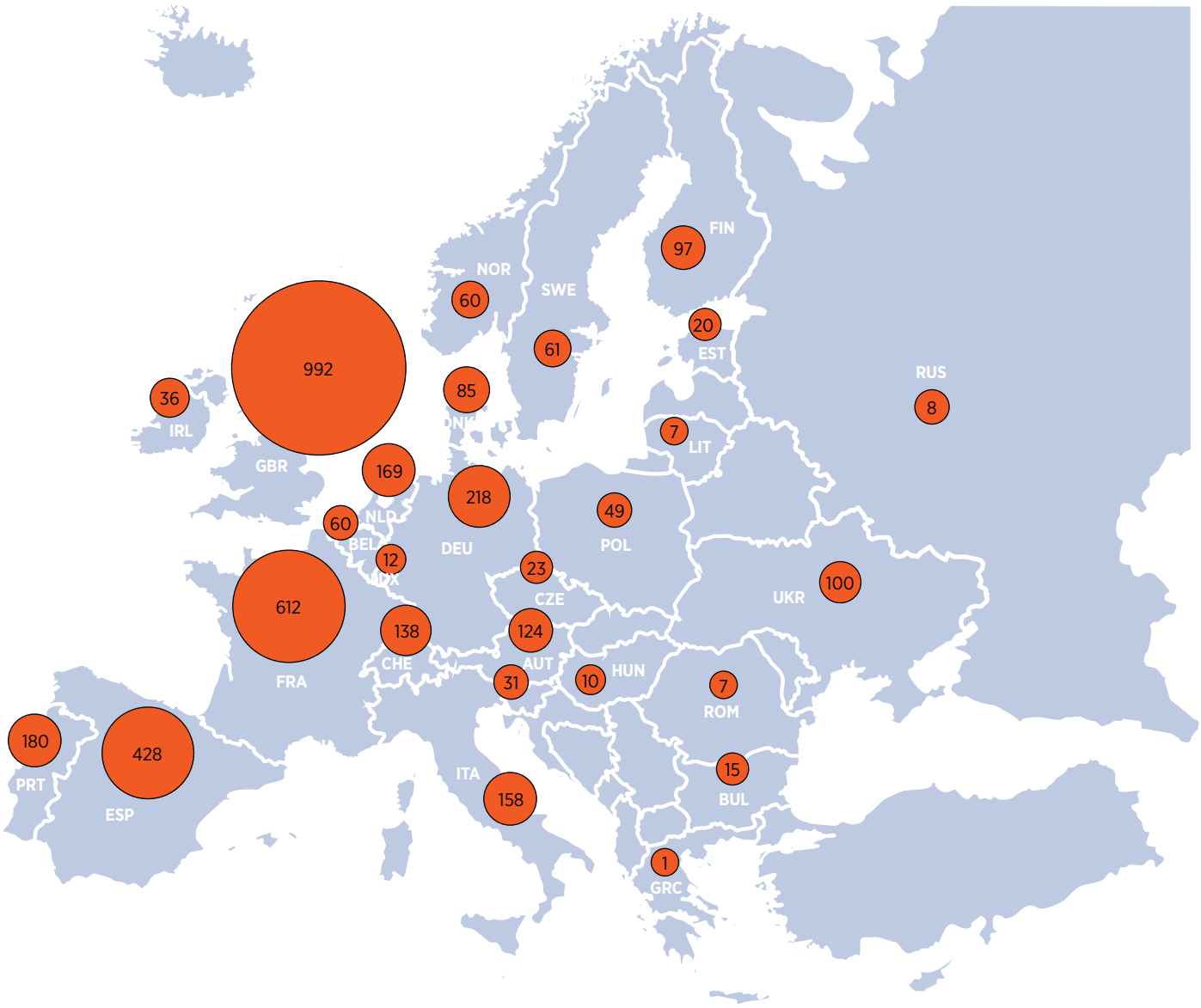
All of this data points to the conclusion that Europe has much going for it: well-educated populations; highly livable cities; democratic and (for the most part) well-governed societies; rule of law, including strong IP protection; long industrial histories; and some of the best scientific and technical institutions in the world. These qualities are in addition to European tech entrepreneurs' belief that they have important contributions to offer to the world.

At the same time, Europe does have a number of significant weaknesses. The region's grandest project, its integration under the EU umbrella, faces an uncertain future. Europe remains far from unified, whether measured in political or economic terms. In the tech space, for every leading innovator on the continent, other countries are lagging behind. The familiar north-south and west-east economic divides that historically have split European economies exist in the knowledge economy space as well.[136] Finally, like China, Japan, and South Korea, Europe also has an aging population.

For decades, the European Union has attempted to address some of Europe's biggest economic challenges through market unification, standardization of regulations, introduction of a single currency, and other measures, with mixed success, at best. In the innovation space, the EU is aggressively attempting to rectify some big flaws. The Digital Single Market is a three-year-old plan to eliminate digital economy barriers across national boundaries and institute a common set of regulations around digital commerce and digital IP. Not yet implemented, the plan speaks to one of Europe's perpetual weaknesses, involving conflicting, confusing, or inconsistent rules across national boundaries, in this case the digital space.[137] The EU's highly public spats with US digital giants, such as Google, point to a key difference between the United States and Europe. The EU's aggressive take on consumer privacy and monopolistic practices in the digital space is a direct shot at US tech firms, reflective of the seriousness with which Europeans consider the protection of the public interest.[138]

The EU is working to overcome another major structural problem, poorly coordinated and/or funded research across Europe's universities and research institutions. The EU's

FIGURE 4. Number of startups receiving investments from accelerators in 2016



Source: Gust, Accelator report, http://gust.com/accelerator_reports/2016/europe/.

Horizon 2020 program aims to send 80 billion euros over seven years (2014-20) to European universities, research institutions, and even startups, to encourage collaborative research, skills training, technology prototyping, and other endeavors. Much of this funding is funneled through the European Research Council, a public body dedicated to cross-border cooperation among scientists and researchers.[139]

Despite fostering a significant amount of entrepreneurial activity, Europe has produced very few tech giants. In stark contrast to the United States and China, none of Europe's richest companies are tech firms. The region's most valuable tech firm, the chip manufacturer SAP, has a market capitalization value of $135 billion, a far cry from America's Apple (at $873 billion, the most valuable company in the world), and China's Alibaba ($473 billion). Since 2003 Europe has produced 41 unicorns, including Trivago, Skype, Rocket Internet, Minecast, Spotify, FanDuel, and BlaBlaCar. Seven European unicorns emerged in 2017 alone.[140] None of these, however, rival the biggest US tech firms.

Explanations abound. One French investor told us that a big part of the explanation is cultural, involving ambition. European entrepreneurs, he said, simply have not set their sights high enough, preferring to sell their startups to corporations once they have scaled rather than trying to create the next Apple. An EU official had a different take, telling us that European startups that are trying to commercialize the most revolutionary technologies—the kind of technologies that created Google— face a chronic shortage of investment

EUROPE'S COMPETITIVE ADVANTAGES IN THE ENTREPRENEURIAL AGE

BY **NICOLAS COLIN**

The United States and China dominate the digital economy, with the largest tech companies as well as the most vibrant tech ecosystems. In comparison, Europe looks marginalized, having so far failed to grow tech companies that dominate at a global scale. Despite the constant deepening of the single market, it appears that linguistic, regulatory, and cultural barriers make it impossible for European entrepreneurs to rely on the continent as the domestic market that will jumpstart their global ambitions.

For many observers, this means Europe is condemned to lag behind in the age of ubiquitous computing and networks. Europe, they argue, should simply resolve to provide US and Chinese companies with the skills of its engineers and the data of its consumers.

Others, however, believe that the core issue is strategic positioning. It may be impossible for European companies to directly compete with the larger tech companies from the United States or China. Nevertheless, Europe has unique strengths that could help it to grow different companies in other industries. It is high time to reflect on what could be Europe's sustainable competitive advantages in the current Entrepreneurial Age.

The first advantage is how Europeans lead different lives than their counterparts in the United States or China. As a result, we can count on European entrepreneurs to best solve problems that are traditionally part of European living. For instance, Europeans have long lived in large, dense cities and used public transportation, whereas most Americans are still stuck in suburbs with their own cars. Thus, European entrepreneurs can address urban challenges that Americans may not even be able to see. Europeans' tech-based solutions can in turn be exported to help solve urban challenges elsewhere.

Entrepreneurs gather for conversation at The Family's offices in Paris.

The next advantage is in the welfare state. The US welfare state has always lagged behind those in Europe in terms of the risks and populations that are covered. While China's welfare state is strengthening with the rise of a more prosperous middle class, it still has a long way to go before it reaches the comprehensive breadth of social insurance programs in Europe.

This is clearly an opportunity. Most European countries have excellent public services and a wide social safety net. Strong bases such as these could serve as platforms for entrepreneurs and give rise to European tech champions in sectors such as healthcare, insurance, housing, elder care, child care, and education.

This won't happen overnight, however. European governments need a radical redesign so that policymakers can partner with startups and developers to improve and customize public services, an approach known as "government as a platform." For that to occur, new rules must be designed to make room for creating profitable business models based on government resources, notably pertaining to intellectual property, liability, and revenue-sharing.

If European governments make progress in those fields, they could pave the way for government agencies to harness the power of entrepreneurship by delegating parts of certain public services to entrepreneurs instead of clumsily trying to deploy technology themselves. This entire field, sometimes called govtech, seems an opportunity that is uniquely European.

Finally, one should not assume that European entrepreneurs are not at the cutting edge of new tech developments. Rather, Europeans can and do seize new opportunities to lead. A good example is the crypto economy, which Europeans explicitly advocate as a way to shift the Internet's infrastructure from US and Chinese tech giants toward open protocols. Because crypto protocols have the potential to redistribute power in the global economy, they provide an opportunity for Europe to better position itself.

We at The Family are starting to see exactly that happening in Berlin, where an impressive, fast-growing ecosystem of world-class developers is riding the new crypto wave. The coming years will tell whether it can all be converted into strategic power in the Entrepreneurial Age.

Nicolas Colin is a cofounder and director of The Family, an early stage investment firm located in London, Paris, and Berlin.

capital because the risk to private investors is too great. His solution was to have the EU assume some investment risk for these types of startups, based on the proposition that public institutions in the United States (the Defense Advanced Research Projects Agency (DARPA), in particular) have played exactly this role in building the US system.

Germany: Global Role Model

Germany has a long history as an innovator, extending as far back as Gutenberg's invention of the printing press in 1440. Of the world's largest economies, Germany's ($3.5 trillion GDP) rates among the very strongest innovators. The country scores high on the major innovation indices (ninth on Cornell/INSEAD/WIPO, fourth on Bloomberg, fifth on the World Economic Forum global competitiveness index's "innovation pillar"). It also ranks high in nearly every subcategory of innovation: whether R&D spending (2.9 percent of GDP, ninth globally), IP protection (fifth on the US Chamber's IP index), logistics (first globally, according to the World Bank), greentech innovation (eighth globally), English proficiency (ninth globally), or low corruption (tenth globally). Berlin, Germany's capital, is well known as a startup hub, rivaling London, Stockholm, and Paris. Germany's startup ecosystem is also vibrant in Munich and Hamburg.[141]

Beyond the numbers, if one were to pick the most innovative country across a range of technologies and economic sectors, it would be Germany. The United States may lead the world in inventing and financing new technologies, but Germany is in a class by itself in adapting technologies and injecting them into all sectors of the economy to increase productivity.

Dan Breznitz argues in *Harvard Business Review* that Germany coordinates key elements of innovation into a mutually reinforcing "virtuous circle." Germany, which emphasizes innovation to boost all sectors of the economy, has strong research and social institutions as well as perpetual education and training. Germany also employs whole-of-government strategic planning for tech innovation, coordinating its efforts across the country's federal government and among its sixteen states.[142] For all of these reasons, Germany still has a vibrant industrial sector, accounting for about 25 percent of Germany's economy and workforce. This is in large part because the sector continuously innovates; for example, Germany's auto companies are using IT software and its machine manufacturers are using computer modeling and 3D printing.

Traditional scientific and social institutions stretch back to the nineteenth century. Germany's prestigious Max Planck Society is a network of eighty-four institutes with twenty-three thousand scientists and engineers doing basic scientific research throughout the country.[143] One of the most impressive institutions, and a global exemplar, is the Fraunhofer Society, a network of seventy-two applied research institutes across Germany (and in six different countries) with some twenty-five thousand researchers. Fraunhofer is a key transmission belt to industry, including SMEs. About 70 percent of Fraunhofer's budget is from contract work for industry and government.[144]

FIGURE 5. Most cited responses for question: which European country do you think is best placed to capture this opportunity?

DEEP TECH FIELD	1	2	3
Artificial intelligence	United Kingdom	France	Germany
Crypto/blockchain	United Kingdom	Switzerland	Estonia
Cybersecurity	Germany	United Kingdom	Estonia
Autonomous vehicles	Germany	Sweden	Norway
Robotics	Germany	United Kingdom	No single country
Genomics	Germany	United Kingdom	Switzerland
Virtual reality	Germany	Finland	United Kingdom
Augmented reality	Germany	United Kingdom	Sweden
Quantum computing	Germany	United Kingdom	Switzerland
Drones	Germany	United Kingdom	Germany

Source: Atomica. https://2017.stateofeuropeantech.com/

Another important traditional institution underpinning German competitiveness is the "dual-apprenticeship" program, which provides young people entering the labor force with both vocational learning and on-the-job training.[145] Both Fraunhofer and the German apprenticeship program have received global attention. Seven Fraunhofer research centers are now open in the United States, at the invitation of state governors. In addition, during the past several years the United States has been piloting versions of apprenticeship programs from Colorado to North Carolina.

Another essential component of Germany's "virtuous circle" involves strategic planning. Berlin's "Industrie 4.0" is the current iteration of a series of action plans based on a 2006 long-term strategy. Industrie 4.0 is designed to more fully digitize German industry and create "smart" advanced manufacturing using AI/big data and the IoT. Industrie 4.0 is based on the merger of the digital with the physical, called "cyber-physical systems."[146]

Germany's desire to lead in advanced manufacturing has translated into a robust startup ecosystem around relevant technologies. This ecosystem, much of which is centered in Berlin and Munich, generated a record $4.5 billion in VC investment in 2017. It also has some 60 incubators and accelerators.[147] The German government aims to connect the dots between the digital and physical economies by creating a network of twelve tech hubs across the country, with each concentrating on specialized technologies. Berlin and Frankfurt will focus on fintech and IoT; Munich on mobility; and Hamburg on logistics.[148]

France: Confounding Stereotypes

Stereotypes die hard, and global views of France's economy are no exception. The stereotype of France as a sclerotic economy might have some merit, but France has a vibrant tech-innovation ecosystem in Paris and elsewhere around the country. France scores reasonably well on several of the biggest global innovation indexes (eleventh in the Bloomberg index, fifteenth in the Cornell/INSEAD/WIPO index, seventeenth in the World Economic Forum's Global Competitiveness Report innovation pillar) and very well on a few other indexes related to innovation (ninth in the ETH Zurich globalization index, sixth in the US Chamber's IP index, eighth in Statista's "Made In" index).

Paris is at the center of France's knowledge economy and is home to more than two thousand tech startups, over one hundred incubators and accelerators, dozens of co-working spaces, the lion's share of the country's tech financing deals, and an annual "VivaTech" conference that draws 68,000 people.[149] The recently opened Station F, the world's largest incubator, is the most powerful and visible symbol of Paris's growing stature as a global tech hub. Station F, so named because it is a refurbished railroad station, brings an entire tech ecosystem under a single roof, including investors, large firms, startups, government ministries, and others.

Although data supports the proposition that the French tech innovation ecosystem is in the top tier of European countries, perhaps the most compelling evidence comes from the ecosystem's participants themselves. To a person, interviewees said that cultural shifts have been a critical element in France's resurgence. They stressed that entrepreneurialism has grabbed the French imagination, with entrepreneurs now celebrated and the nation's best STEM students much more willing to become entrepreneurs themselves. Even more impressive is the assertiveness of the French in selling their knowledge economy, as is the case with the spectacular Station F. This embrace of the knowledge economy is evident in the government's highly visible and confident policies to advertise French innovativeness to the outside world.

France is a case study in aggressive public policies applied to the knowledge economy. The government has few qualms about creating well-funded programs to support the country's tech-innovation ecosystem. Although President Emmanuel Macron is a known advocate of French entrepreneurialism, important programs for startups and entrepreneurs date back to President François Hollande's tenure, and long before that in support of private R&D spending. Although France ranks twelfth in the world in R&D spending at 2.2 percent of GDP (halfway between Germany at 2.9 percent and UK at 1.7 percent), spending between public and private sources is imbalanced. Low private investment in R&D is due to the relatively small size of France's tech sector relative to other sectors and to large firms' historic reluctance to invest in startup technology ventures. The government has spent large sums to boost France's overall R&D share, including robust support for business R&D.[150] Tax breaks are a core tool, especially the CIR (*Crédit Impôt Recherche*), which allows a firm to deduct 30-60 percent of its R&D costs. Another is public financial support to startups. A main vehicle is BPI-France, a six-year-old public investment agency.

Cultural shifts have been a critical element in France's resurgence... Entrepreneurialism has grabbed the French imagination.

In addition, the French government has adopted several programs designed to recruit talent and advertise the French knowledge economy abroad. Assembled under the clever marketing platform called "La French Tech," these programs include a "French Tech Ticket" incubation program for foreign startups willing to relocate to France for a year or more and a tech visa program designed to attract foreign entrepreneurs to France.

In terms of investment capital, over the past six years France has ranked third in Europe, behind the United Kingdom and Germany.[151] In 2017, $3.2 billion was invested in French tech companies, a five-fold increase from 2013.[152] Owing in part to public investment, seed capital is more plentiful, but capital for scaling is scarce. One problem is that foreign investors at later stages want the startup to relocate, perhaps to London or Silicon Valley. Nevertheless, several interviewees believe that French investors are maturing and that a positive shift is under way toward the domestic retention of successful startups.

The United Kingdom: Europe's Leader?

The United Kingdom is sometimes considered the leader among Europe's big economies in tech-driven innovation. Global rankings are mixed regarding this proposition. The Cornell/INSEAD/WIPO innovation index places London fifth in the world, just behind the United States but ahead of both Germany and France. On the other hand, Bloomberg's index rates Germany much higher, at fourth, and France slightly higher, at eleventh, than the UK at seventeenth. The UK has been Europe's leader in attracting investment capital to the tech sector, with $18.7 billion invested since 2012 versus Germany's $11.4 billion and France's $9.0 billion over the

Under the marketing platform, "La French Tech," France has adopted programs to recruit talent and advertise the French knowledge economy around the world.

same time period. The United Kingdom attracts more skilled foreign tech workers than other European countries.[153] It bills itself as one of the world's most startup-friendly places and for good reason: in 2016 the country produced a hard-to-believe record 660,000 startups (a great many not in the tech field).[154]

As with France and Germany, the UK's premier tech hub is its capital, London. As with Paris and Berlin, London long has been the UK's leading financial, cultural, and population center in addition to its political one. As one of the world's greatest cities, London consistently receives high marks on global cities rankings. AT Kearney ranked London second worldwide on its Global Cities Index (which measures "current performance" in business activity, human capital, culture, and other categories) and fourth in its Global Cities Outlook (which measures "potential" across economics, innovation, and other areas).[155] Such rankings extend to London's competitiveness in the innovation space. Startup Genome ranked London third on its index of global tech hubs, estimating that the metropolitan area features between four thousand and five thousand active tech startups.[156] Much startup activity is centered in the refurbished East London.

The UK has some of the world's best universities; four of them (Oxford, Cambridge, Imperial College London, and University College London) place in the top twenty in the Times Higher Education's World University Rankings 2018 (Oxford and Cambridge ranked first and second globally).[157] Indeed, the city of Cambridge features one of the UK's most advanced tech hubs, owing to the university's creation of a science park in the 1970s, among other initiatives, and of course to the concentration of brilliant minds there.

Yet British universities struggle with tech transfer.[158] For decades, various studies have come to the conclusion that the UK's scientific excellence does not translate into commercially viable technology. A 2014 study commissioned by the Wellcome Trust, for example, uncovered some familiar problems regarding commercialization of university-based research. Among other things, it found that British academics face powerful disincentives to work on commercially viable research, are not rewarded in terms of job promotion for such research, and lack knowledge and awareness of how to commercialize their research.[159] Although a low tech commercialization rate is a common problem within European universities, it has heightened importance given the UK's relatively low R&D investment rate of 1.7 percent compared with Sweden (3.3 percent), Switzerland (3.0 percent), Germany (2.9 percent) and France (2.2 percent).[160]

Looking ahead, the country's prospects in the sweepstakes are uncertain. There is little doubt that the UK will remain a hub for tech-driven innovation. Whether it will be able to claim European leadership is a different question. Other European countries are highly competitive, including not just the continent's two largest economies (Germany and France) but a host of smaller players as well. Brexit is the biggest question mark hanging over the UK's future. Various surveys show hesitancy among investors and entrepreneurs regarding future (post-Brexit) locational and investment decisions.[161]

Small States, Big Impact

Although the world's largest countries have several distinct advantages over small ones—for example, large talent pools and significant amounts of investment capital—small countries (in both population and geographic area) have certain advantages in the sweepstakes. These countries can benefit from higher social capital brought about by a strong sense of national identity, an often faster and more efficient government, high network density, and social cohesion—as well as a heightened awareness of the outside world and the need to engage productively with it.

Of course, small size alone is no guarantee of success in the knowledge economy. Policymakers in small countries can fail to make the right policy decisions just as much as their counterparts in larger ones. Small countries also can have political divisions that inhibit their governments from taking decisive action. They can face difficult geopolitical conditions that inhibit some trade and investment patterns. Moreover, even if their leaders choose good policies, small countries can face a steep climb in attracting international capital and talent.

Historically, small countries have performed well on the global innovation stage. Three of the original four "Asian Tigers" (South Korea, Taiwan, Singapore, and Hong Kong) were small states (and in Hong Kong and Singapore's cases, cities). These economies followed similar postwar trajectories of moving up the global economic value chain.

A quick scan of the global indexes reveals the frequency with which smaller countries land in the top ten or twenty places. Switzerland, a country of 8.4 million people, is first in the 2017 Cornell/INSEAD/WIPO index of innovation, first in the World Economic Forum's Global Competitiveness Report (innovation pillar), fourth in Bloomberg's innovation index, and lands in the top ten rankings in numerous other indexes. Many other small countries routinely perform well on these rankings, including the Nordic countries, Singapore, Israel, Ireland, and New Zealand. Still others, for example, Portugal, are in the process of building robust ecosystems. Although the small European countries benefit from close physical proximity to other high-performing countries and/or membership in the European Union, they still support the proposition that smaller countries can be players at global level.

This subsection briefly assesses four small-country cases: Sweden, Israel, Singapore, and the United Arab Emirates (UAE)/ Dubai. (Sweden and Israel are discussed in more detail in the Special Section.) Together, these cases demonstrate that there is no single template for small-country success in tech innovation. Sweden and Israel have very different histories involving peace and conflict (Sweden is in a peaceful neighborhood, Israel in a dangerous one). Each differs with respect to the balance between foreign and domestic talent: Israel relies heavily on its high-end domestic talent, UAE/Dubai almost exclusively on imported talent. As historic trading cities, Singapore and UAE/Dubai built their modern economies on exploiting trading linkages with the rest of the world. While Sweden and Israel have built their startup ecosystems only during the last three decades, each has relied on a long history of excellence in scientific and technological development.

All the countries in this group are acutely aware that they are not alone in the world. This is where small size is of high value. Small countries do not have the luxury of turning inward; rather, they need friends and trading partners elsewhere to find investment capital, talent, markets, and even protection in an uncertain interstate system.

Sweden: Innovation Society

Sweden, with a population of only 9.9 million, has translated its high social welfare, good government, outward orientation, social cohesion, and peaceful neighborhood into one of the world's strongest tech-innovation ecosystems. Sweden is the only country visited by Atlantic Council staff ranking in the top ten for every index listed in Box 1 (page 11). Sweden's vibrant ecosystem has produced thousands of startups and the second-largest number of unicorns in the world on a per-capita basis (after California's Bay Area).[162] Since 2012, Sweden has attracted $4.4 billion in capital investment to its tech-innovation ecosystem, placing it fourth in Europe after the three largest economies (United Kingdom, Germany, and France)—all of which are several times Sweden's size in terms of population.[163] Computer gaming, digital commerce, fintech, and health tech are well-represented sectors within Sweden's knowledge economy.[164]

Interviewees for this study agreed on several reasons for Sweden's success. One is the country's generous social welfare system. For students, this system enables Swedes to obtain good educations at relatively low individual cost, creating a youth talent pool that is not weighed down by educational debt as in the United States. For people in the tech-innovation ecosystem, the system helps de-risk entrepreneurialism and other forms of participation through inexpensive healthcare and income support mechanisms.[165] A second advantage, also unanimously expressed, is Sweden's high level of social capital and trust in institutions. As is true of all the Nordic countries, Sweden has long been committed to competent and transparent governance, thus the government can lead partnerships more easily across the public, private, academic, and nonprofit sectors. Third, as is true of most knowledge economy leaders, Sweden invests a significant amount of public money into its innovation ecosystem. Per its long history of outstanding science

UNIVERSITIES IN SWEDEN'S INNOVATION ECOSYSTEM

BY LISA ERICSSON AND DONNIE SC LYGONIS

In Europe, as well in the United States, universities play a significant and distinctive role in the innovation ecosystem. However, European universities historically have had a reputation for being less successful than their US counterparts when it comes to innovation and technology transfer. This is sometimes referred to as the academic innovation paradox: a lot of money goes into research, but very little comes out.

We will not try to fully explain this paradox across the entire European university system, but we can offer a couple of points worth noting from a Swedish perspective. First, it was not until the mid-1990s that universities were charged with delivering anything other than research and education and the so-called *third mission*—to engage with society—was introduced. Second, it has generally been considered noble to search for knowledge and solve complex problems, but less appealing to sell the solution or seek to profit from it. Third, a law called the *Professors Privilege* has played a significant part; as a researcher or PhD student at a Swedish university it is you, and not the university, who own the rights to any intellectual property created.

Owing to these three factors, Swedish universities did not secure their economic interests through IPR licensing, as they did not own any IPR. They also did not offer any professional support to the researchers who wanted to commercialize their results as the *third mission* was introduced without any additional funding.

The pros and cons of the *Professors Privilege* are constantly debated, and to bystanders it must seem odd that universities do not own the results created by their employees.

To clarify the universities' responsibilities for innovation activities, the Swedish government launched an initiative in 2008 called The Innovation Office Program to help fund innovation support units at universities. The overall aim was to strengthen the capabilities to commercialize more from both research and education.

Today KTH Innovation is proud to be recognized nationally and internationally for its highly ranked innovation support. Since the start we have supported around one thousand researchers and thirteen hundred students. More than 190 companies have been founded and our innovation support process has been copied both in Sweden and abroad. As a department we have grown organically from one to fourteen employees and moved from a peripheral and anonymous branch of university administration to becoming an integral part of the KTH brand. Marketing KTH Innovation is seen by the university management as one key to climbing in rankings and attracting top researchers and students.

We at KTH Innovation achieved this because, as the innovation support unit at Sweden's largest technical research and learning institution, we have adopted a mind-set and mission that sets us apart from many of our international counterparts.

We work hard at enabling innovation rather than controlling it and maximizing profits from it. We arrange ideation workshops and challenges to inspire innovative thinking and creative idea generation. We are open to everyone at KTH, and never turn an idea that falls within our scope away. Instead, our structured process allows the idea owners to carefully assess the merits of their ideas together with a business coach.

We are not so much technology transfer officers as early-stage business coaches. The coaching part is emphasized; we are coaches in a people business, not a technology business. Everyone at KTH Innovation has relevant business experience from different markets and technologies. We provide proof-of-concept funding and help to build great teams. We strongly believe that getting an idea is the easy part, the search for a value proposition and relevant business model is much harder and more important. Execution is everything.

We strive to create a truly innovative international environment where people from all sectors of society—students, alumni, researchers, business angels, VCs, entrepreneurs, industry partners, mentors and others—meet to tackle the really big challenges. We believe this is the route to success for universities all over the world.

Lisa Ericsson is Head of Department and Donnie SC Lygonis is Innovation Strategist and Business Coach, KTH Innovation, KTH – The Royal Institute of Technology.

Sweden's KTH Royal Institute of Technology.

JIM HUTCHISON/FLICKR

Block 71, an incubator, is the epicenter of Singapore's startup culture.

SINGAPORE GOVERNMENT

and engineering, Sweden invests 3.3 percent of its GDP into R&D, placing it fourth globally and first in Europe.[166] (For a discussion of innovation and tech transfer within Swedish research institutions, see the guest essay on page 37).

Finally, Sweden has one of the world's strongest and most desirable tech hubs. Stockholm, the nation's capital, also is the epicenter of Sweden's ecosystem. Like the country as a whole, Stockholm's small size (around 2.2 million) confers some advantages, including a high density of startup activity and commensurate network benefits, prestigious research institutions, such as KTH Royal Institute of Technology, and a very high quality of life.[167]

Sweden's success did not happen overnight. Its global corporate presence, long established, includes Ericsson, Saab, Volvo, ABB, Electrolux, and Ikea. Swedes also have a history of early tech adoption. The country's now-mature startup ecosystem began in the 1990s, the result of the dot-com boom as well as government policies to increase competition between different-sized firms and its subsidies of home computer purchases, which helped create a generation of youth with digital economy skills. The city of Stockholm also invested in a fiber-optic Internet grid, highly useful for the city's many digital startups because of its high speed and extensive coverage.[168]

Israel: Place and Flow

Israel is an outstanding example of a small country (population 8.2 million) and tech-innovation ecosystem with a strong sense of community and high global connectivity. Israel's tech-innovation ecosystem is impressive not just for its number of startups (some four thousand in 2016), but even more for its increasing importance across multiple technology sectors. The country is a serious player in cyber and IT, digital mobility solutions (for automobiles and other transportation modes), AI, health and medical technologies, fintech, blockchain, drones, IoT, greentech, and other technologies. A few startups such as Wix, the web development firm, have achieved global commercial success. In 2016, investors poured a record $4.8 billion into the country's tech sector, with foreign investors accounting for 60 percent of this figure.[169]

Israel's history and culture have stimulated innovation, experimentation, and risk-taking across society, to the tech-innovation ecosystem's clear benefit. Like Sweden, Israel's small size gives it a high density of tech workers while forcing Israelis to look abroad for individual and entrepreneurial opportunities. Israel's very high human capital—including but not limited to technical talent—is partly the result of its in-migration history, including a large influx of technical

There are no miracles... No country becomes an innovation leader unless it invests in [research and development].

talent after the collapse of the Soviet Union. Universal army service forces young Israelis of diverse backgrounds to work together under extreme circumstances, often creating bonds and skills that are carried forward into civilian life. The upshot is that Israel has a concentration of technically talented and motivated people who are interested in tackling difficult challenges through entrepreneurial activity.

As is also true of Sweden, Israel has invested in R&D at a high level for decades, reflecting a belief that scientific discovery and applied technical research are necessary for both long-term prosperity and security. ("There are no miracles," one interviewee said in referring to how no country becomes an innovation leader unless it invests in R&D.) Indeed, Israel leads the world at 4.3 percent of GDP invested in R&D.[170] Much of this is from private sources, especially foreign multinational corporations who have created three hundred fifty R&D centers in Israel to take advantage of Israeli talent.[171]

The Israeli government's support for R&D is both robust and unusual. As is true of the United States, for security reasons the military (the Israeli army, in particular) is an important tech investor, primarily in cyber and IT. However, its investments usually are for narrow applied research purposes. Israel's basic science is conducted by its universities and research centers, for example the Weizmann Institute and Tel Aviv University. The government's efforts were critical in helping to create the venture capital industry in Israel, which now pours money into R&D. In the early 1990s, the government created the now-famous Yozma venture capital firm, which gave the almost-nonexistent VC industry at the time a much-needed boost.[172] Since then, the government has also funded incubators across different tech sectors, providing startups with much-needed seed funding and other support.

Singapore: Micro Innovator

Singapore's surge as a tech innovator has largely developed over the past decade, though planning began in the 1990s. Its approach is largely an extension of the city-state's economic formula of strong institutions and policies, strategic planning, open markets, and entrepreneurialism, underpinned by a proactive government. As one Singaporean official put it in an interview, Singapore's success comes from its three "hubs": as a trading and transportation hub, a manufacturing base, and a hub for global services. Singapore builds on all three mutually reinforcing hubs to create its innovation ecosystem. Less tangible factors, such as a high quality of life and fortuitous geography (located at the crossroads of the Indo-Pacific), play a role as well.

Starting with a first rank on the World Bank's "ease of doing business" index, Singapore is in the top ten in several global rankings of innovation (ninth on the World Economic Forum's Global Competitiveness Report innovation pillar, sixth in the Bloomberg innovation index, sixth in the EF English proficiency index, eighth in the US Chamber's IP index, and first in the IMD World Digital Competitiveness Ranking). Singapore ranks seventh in the "gold standard" 2017 Cornell/INSEAD/WIPO innovation index, with high marks for R&D investment (2.2 percent, fifteenth globally), human capital, institutions (first), infrastructure (second), business and market sophistication (second and fourth), and knowledge production.[173]

Not surprisingly, Singapore shares a number of traits with other global innovators. Like Israel, another resource-poor small state that has become a leading global innovator, Singapore has a talent pool fed by immigration, plus an emphasis on science through world-class research institutions (the National University of Singapore and Nanyang Technical University rank in the top fifteen globally). Singapore's commitment to strategic planning parallels that of Sweden as well as Germany. Like Germany, Singapore shares a commitment to high-quality education, skills and vocational training, and lifelong learning.[174]

Singapore's startup ecosystem borrows some best practices from Silicon Valley, Israel, and others—now boasting some forty-two thousand startups, according to its development board. The epicenter of this startup culture is Block 71, an aggregation of some 750 startups begun as a collaboration of government agencies and nearby National University of Singapore (NUS), whose accelerators feed into it.[175] A government Early Venture Fund helped launch venture capital firms by providing matching funds. Other programs provide seed funding, not entirely unlike the US Small Business Innovation Research (SBIR) program. A magnet for investors is the Technology Incubation Scheme that puts up 85 percent of capital in a startup.[176] An array of early stage venture capital funds also has begun to develop in Singapore.[177] In 2017, Singapore attracted nearly $9 billion in foreign direct investment, $2.5 billion for one of its several unicorns, GrabTaxi.[178]

Singapore is forging ahead in robotics, AI/big data, quantum computing, biotech, and in new materials like graphene.[179] This is reflected in its five-year, $19 billion Research, Innovation and Enterprise plan, which seeks to integrate emerging synergistic technologies—robotics/automation, 3D printing, advanced materials, and digital

manufacturing—across its key current industries (chemicals, petrochemcials, plastics, electronics, biomedical sciences and banking/financial services).[180] If past is prologue, Singapore will be a leader in adapting and absorbing emerging technologies and is well-positioned for innovation breakthroughs of its own.

United Arab Emirates/Dubai: Breathtaking Ambition

Visiting the United Arab Emirates for the first time is a true shock to the senses. Everything, it seems, is bigger, taller, or more extreme: skyscrapers, highways, complexes, resorts, marinas, office parks, convention centers, even roller coasters (the world's fastest, called Formula Rossa, is in Abu Dhabi).[181] Indeed, from outward appearances there is no limit to this small country's ambition, which extends to tech-driven innovation.

The UAE is not yet at the top tier of innovators globally (its performance on the innovation indexes listed in Box 1 on page 11 is modest, with many ranking the UAE in the twenties-to-forties range), but it has clear aspirations to arrive there. Interviewees consistently mentioned that the country's political leadership is committed to such a transformation. The UAE launched a National Innovation Strategy in 2014, which states the desire to make the UAE "one of the most innovative nations in the world within seven years," i.e., 2021.[182] The UAE has spent huge sums of money to create research-supportive institutions and infrastructure from scratch. Like other Gulf Cooperation Council (GCC) countries, the UAE has partnered with foreign universities to strengthen higher education and research. Abu Dhabi's Masdar City, a massive development complex focused on renewable energy, contains the Masdar Institute of Science and Technology that is run in cooperation with the Massachusetts Institute of Technology (MIT).[183] Other aspects of the strategy include development of innovation-supportive policies, public-sector innovation, and upskilling the workforce.

Dubai is the center of the UAE's tech-innovation story. From humble beginnings as a small pearling and trading outpost, in a few short decades Dubai has transformed itself into one of the world's most spectacular and modern cities. Dubai's main strategy appears to be to woo the world to its doorstep through grand scale and incredible opulence. Dubai proves that the "build-it-and-they-will-come" idea can work. Although there is much truth to the proposition that Dubai's tech-innovation ecosystem was built more on the trader's salesmanship than on tech substance, during the past decade the ecosystem has evolved and matured rapidly. It is more accurate to say now that Dubai, and by extension the UAE, are taking the substance seriously and working hard to deepen a burgeoning ecosystem.

Dubai officials point to a core strength of their system. Their goal is to make Dubai the world's test bed for adoption and scaling of new technologies. They intend to build a prototyping process in which Dubai and tech firms pilot the use of emerging technologies on the ground. This process would enable swift policy evolution, which in turn would help build a commercial market in Dubai. Officials stress the virtues of Dubai's small size and ability to pivot the government rapidly in response to policy prototyping.

Yet Dubai and the UAE face significant challenges moving forward. One is that, unlike Sweden and Israel, and to a lesser extent Singapore, the United Arab Emirates does not invest in R&D. At 0.9 percent of GDP, the country ranks only forty-first in the world, a figure that partly explains the UAE's low performance on knowledge output rankings (according to Cornell/INSEAD/WIPO, the UAE ranks 114th globally in patent output and 106th in scientific and technical article production).[184] Another involves the talent pool, which is drawn almost exclusively from abroad. Given their tiny national populations, GCC states, including the UAE, have recruited skilled foreign workers in large numbers. This strategy has worked well in some respects, including as fuel for growth, but in one key respect it has failed: the Emiratis by and large have not been participants in their own knowledge economy.[185]

This observation leads to a third challenge, involving the UAE's increasingly difficult neighborhood. When asked about future challenges, interviewees consistently expressed fear that the conflicts around the region might find their way to the UAE—where, say, Yemeni rebels fire a rocket at Dubai as they have at Riyadh. In such a scenario, the fear is that ecosystem stakeholders, most of whom are foreigners not allowed to become citizens or set down roots, will swiftly abandon Dubai and the UAE. In this sense, the UAE/Dubai ecosystem is the opposite of Israel's, which is resilient to conflict precisely because its stakeholders have a strong attachment to place. UAE/Dubai is an example of high global flow but low attachment to place.

The Rest: A Global Sample

Much of the rest of the world consists of countries that are attempting to join the leading ranks of innovators. These nations often have a knowledge economy in place, with an engaged stakeholder community, and are crafting policies to deepen and broaden that economy. However, they also frequently have several difficult problems to overcome: small tech-innovation ecosystems relative to the national

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economy (hence lower political weight with policymakers); contradictory or even counterproductive policies at the national level; a lack of investment capital and/or high-quality research institutions, workforce skills gaps, an inexperienced entrepreneurial class, and other factors. Owing to their lower innovation profiles, they struggle to develop global reputations, harming their abilities to attract investment and talent from abroad.

At the same time, countries in this group can build world-class tech-innovation ecosystems and move into higher tiers. Quite a few of today's leading innovators—including China, South Korea, Sweden, France, and Israel, to name only several—were not known as "startup nations" just a few short decades ago. All have only recently joined the top ranks of global innovators, the result of concerted efforts by policymakers and other stakeholders in those countries.

Probably only a few national governments in the world today do not claim at least some form of national competitiveness in the global knowledge economy. That speaks volumes, pointing to a widespread understanding that tech-based innovation is a key component of wealth creation.

In this subsection, we peruse a small cross-section of these types of countries, representing both large and small economies around the world.

Stretching across the vast Eurasian landmass, **Russia** provides an outstanding example of a country that aspires to reach the first ranks of innovators while also facing several major obstacles. The country's historic overreliance on fossil fuels is a good illustration of such obstacles: oil- and gas-related revenues account for an estimated 36 percent of Russia's federal budget revenues.[186] Aging provides another: Russia's population is believed to be shrinking, the result of both low fertility and high mortality (Russian males have a life expectancy of 64 years, the result of poor diet, alcoholism, suicide, and a host of other chronic problems).[187]

Yet, as is the case in several other petro-states, the leadership in Moscow has realized that the petroleum era will not last forever. Russia has made quiet strides toward developing a more innovative economy. Moscow launched a National Technology Initiative in 2014, which is fueled by Russian Venture Capital (RVC), a fund of funds created in 2006 to lend to VC firms—28 at present—and generate a startup ecosystem.[188] It created Skolkovo Academy, a massive science park, and Generation S, an accelerator with more than 20 corporate partners and a presence around Eastern Europe. Moscow State University and the Moscow Institute of Physics and Technology, known as FIZTEKH, are leading research institutions with their own incubators; these have helped launch several dozen startups (90 percent in the ICT sector), though few have gotten beyond early-stage funding. In addition, there are several dozen shared workspaces/accelerators, mostly around Moscow and St. Petersburg (some 90 percent of VC capital is concentrated in Moscow). Accelerators and startups have cropped up in Novosibirsk and Kazan as well.[189]

The world's first fully functional 3D-printed building is located in Dubai.

iHub, a pioneering networking and co-working space for technologists and entrepreneurs in Nairobi, Kenya.

However, this activity is limited and much of it is state-driven. One VC official lamented, "Seventy percent of the economy is controlled by the state directly or indirectly."[190] Key components of innovation—institutions, business and market sophistication, IP, patents, and the efficiency ratio of inputs to outputs—are performing poorly.

Though it has a grand tradition in science and mathematics, Russia spends only 1.1 percent of GDP on R&D. The country lost roughly a million emigrants to Israel in the 1990s, many of whom had STEM skills. Regarding IP, Russia ranks twenty-third of forty-five nations in the US Chamber of Commerce 2017 IP index.[191] Regarding patents, Russia has few "triadic patents" (US, EU, Japan), meaning those of high international value. Russian industry lags far behind the United States and EU in digitization.[192]

Russia's venture capital market is small—in a typical year, VC deals garner less than $200 million. Few startups have gotten beyond the $5 million level of funding. One VC entrepreneur said in an interview that "the market here is too small, once they get much beyond $1-5 million level, startups leave for Europe or the US." This points to a big structural problem. Russia's natural market is Europe, but Russian President Vladimir Putin has defined Russia as separate from the West.

Africa has no countries at the global top of leading innovators (South Africa, its best-placed country in the 2017 Cornell/INSEAD/WIPO index, is ranked fifty-seventh in the world). Nevertheless, Africa is home to a surprising number of countries with admittedly small but robust and growing tech-innovation ecosystems. Like India, Africa has a large demographic youth bulge, with 60 percent of its population under 24 and the world's highest birth rate. This can be a dividend or a burden, depending on education and economic policies.[193] The leading edges of Africa's burgeoning knowledge economy can be found scattered across the massive continent. Besides South Africa—the continent's wealthiest economy—countries experiencing this transformation include Nigeria, Kenya, Uganda, Tanzania, Ghana, Botswana, and even Rwanda and Ethiopia. Admittedly, Africa faces enormous difficulties, including widespread poverty, underdeveloped infrastructure, and other obstacles. Yet those who study the continent's knowledge economy believe that African countries can use the continent's widespread

KEHITYS LEHTI/FLICKR

micro-entrepreneurial spirit (a large percentage of Africans work in the informal sector) and youthful tech savviness to leap ahead rapidly on the development curve.[194]

In tech circles over the past decade, **Kenya** has become known as "Silicon Savannah," a not-too-subtle moniker denoting the country's tech-innovation ambitions. Kenya fares modestly in global innovation and business rankings (eightieth in the 2017 Cornell/INSEAD/WIPO index, thirty-sixth in the innovation "pillar" under the 2016-2017 World Economic Forum Global Competitiveness Report).[195] The country also struggles with widespread corruption (ranking 145th in Transparency International's 2016 corruption index), political uncertainty, and criminality.[196] Yet, as is always the case, such numbers fail to tell the entire story, for Kenya has been building a digital tech-innovation ecosystem worthy of the "Silicon Savannah" designation. High mobile penetration is a big reason why. To take advantage of ubiquitous mobile phone use in Kenya, in 2007 the telecom provider Safaricom introduced M-Pesa, a spectacularly successful and now globally famous mobile banking app. Not long after and for the same reason, Kenyan entrepreneurs created Ushahidi, a crowd-sourced mapping app that quickly found markets beyond Kenya and Africa, and M-Farm, founded by women to give small farmers real-time access to market data.[197] Support infrastructure for this burgeoning entrepreneurial scene has been developing rapidly, including within sixteen "hubs" (the World Bank's term for organizations that facilitate digital entrepreneurialism through provision of office space, networking opportunities, mentoring, and more). The most famous of these is Nairobi's iHub, a networking and co-working space that has inspired copycats around Africa.[198] The government has made some good decisions as well, including investments in broadband infrastructure and formation of an ICT Authority.[199]

On the other side of the continent is **Nigeria**, Africa's most populous country (187 million people). One might assume that Nigeria would have little if any presence in the knowledge economy space, given its unfavorable global reputation for corruption, inequality, poverty, and violent separatist movements. Indeed, on global indexes, Nigeria fares poorly: 119th on the 2017 Cornell/INSEAD/WIPO innovation index, 169th on the World' Bank's 2017 Doing Business Index, 118th on the 2017 ETH-Zurich globalization index, and so on.[200] But as with Kenya, closer examination reveals a different story. Driven in part by Nigerian entrepreneurs who were educated abroad and have returned, in part by home-grown talent, Nigeria's tech economy is booming. Much of this is in the digital space, owing to Africa's high mobile penetration rates and the ease of startup formation in this field. Centered in Lagos's Yaba district (sometimes called "Silicon Lagoon"), startups can tap into a pool of workers eager to upgrade their tech skills. A startup called Andela teaches Nigerians coding and then employs them to write code for foreign companies looking for relatively cheap talent. Over the past few years, several high-profile events have focused a spotlight on Nigeria, for example in 2016 the country produced Africa's first tech unicorn, the Africa Internet Group.[201]

Like Africa, the **Latin America and Caribbean (LAC)** region features none of the world's leading knowledge economies. The region's top-ranked countries on the Cornell/INSEAD/WIPO index are Chile, at forty-sixth, Costa Rica at fifty-third, and Mexico at fifty-eighth. Brazil, LAC's largest country (210 million people) and economy ($1.8 trillion), ranks sixty-ninth out of 127 countries. Although it is always dangerous to generalize about a large and multifaceted region, LAC countries face a few core obstacles that have prevented the emergence of first-rank ecosystems. One is a systematic underinvestment in R&D: in four of LAC's major economies (Brazil, Mexico, Chile, and Argentina), only Brazil at 1.2 percent cracks the top 50 countries worldwide (thirty-second).[202] This underinvestment is combined with a historically poor rate of successful tech transfer out of the region's universities.

A second obstacle, in particular for South American economies, is an overreliance on commodity exports such as copper to generate foreign earnings. Although a (generally) strong global commodity market has been of much benefit to the region during the past couple decades—helping to lift millions out of poverty—the economic benefits have not translated into more competitive knowledge economies. A third factor is demography: although the region is still relatively youthful, it is aging fast, and the "demographic window" (the period in which a country has a high percentage of workers compared to dependents) is closing. By the early 2040s, the window will be closed for most of the region, with a much larger percentage of retirees.[203] Like Africa, however, the region also has enormous potential for improvement: it has vibrant cities, well-functioning consumer markets, no transboundary warfare, and a host of entrepreneurial tech hubs in various locations.

In global innovation and business rankings, **Chile** is consistently at or near the top of countries within the LAC

African countries can use the continent's widespread micro-entrepreneurial spirit … and youthful tech savviness to leap ahead rapidly on the development curve.

region. As a high-income country ($23,460 per capita GDP), Chile possesses the economic resources to produce a first-tier knowledge economy. Santiago, the capital and center of Chile's innovation ecosystem, is prospering as a tech hub. Startup Genome, a firm that assesses local tech-innovation ecosystems, estimates that Santiago has five hundred to seven hundred active tech startups and enumerates several important international events in Santiago, including the annual Seedstars World competition for startups and the Meet LatAm conference, focusing on entrepreneurs.[204] Besides offering a high quality of life, Santiago is known for its high density of entrepreneurs and other innovation stakeholders. The city features some eighteen accelerators and incubators, numerous coworking spaces, and 45 VC and private equity funds. Santiago's tech startups work in fintech, biotech, and greentech, the latter two categories in large part to support Chile's critically important copper mining industry.[205] In 2011, the Chilean Economic Development Agency (CORFO) launched Startup Chile, a now globally famous platform focused on entrepreneurs. Explicitly international in design, the platform offers grants for entrepreneurs from all over the world to settle in Chile. CORFO has created initiatives to boost Chile's small pool of investment capital, with programs focusing on VC and angel funds, and has partnered with foreign R&D institutions, such as Germany's Fraunhofer Society, to improve upon the country's anemic R&D investment rate (in 2017, just 0.4 percent).[206]

As one of LAC region's two biggest economies, **Mexico,** like Brazil, offers a mixed tech-innovation picture. (For a longer review, see the Mexico case study in the Special Section, by Katherine Pereira.) On the one hand, Mexico is one of the world's bigger economies ($1.1 trillion GDP) with an upper-middle-income status ($17,534 per capita GDP). It has a free-trade agreement with one of the world's two biggest economies (the United States), giving it access to an enormous and prosperous market just across its border. Mexico boasts a still-youthful population; a number of Mexican youths are interested in growing the country's small but dynamic startup scene (the Cornell/INSEAD/WIPO index ranks Mexico nineteenth in the world for share of graduates in science and engineering).[207] Mexico's massive and vibrant capital, Mexico City, offers a rich cultural experience for both Mexican and foreign entrepreneurs, who can service a growing Mexican (and regional) e-commerce and mobile digital economy.

Mexico City offers a rich cultural experience for both Mexican and foreign entrepreneurs, who can service a growing Mexican (and regional) e-commerce and mobile digital economy.

On the other hand, Mexico faces some difficult challenges, starting with drug smuggling and corruption. It is caught between Central America and anti-immigrant hostility in the United States. Consistent with the rest of the LAC region, Mexico invests a tiny percentage of its GDP in R&D (0.6 percent). Despite producing a large number of science and engineering graduates, a high percentage of Mexicans do not attend universities. Perhaps most problematic are the chronic problems of corruption, weak rule of law, inequality, and organized crime and violence. These obstacles are both domestic governance challenges as well as global image problems that reduce Mexico's ability to attract investment and talent.

The vast **Asia-Pacific** region contains both leading innovation economies, including China, South Korea, Japan, New Zealand, Singapore, and Australia (as well as the gigantic but mixed story that is India), and countries that fall either somewhat short of leading-edge status or far short of it. The former group includes large countries such as Indonesia or Malaysia, as well as smaller countries such as Vietnam or Thailand.

Indonesia might be the world's fourth most populous nation (261 million people), but it is nowhere near the leading global innovators. It spends a paltry 0.1 percent on R&D (105th in the world), and often ranks in the middle or worse on global innovation indexes (e.g., 87th on the 2017 Cornell/INSEAD/WIPO index) and digital economy indexes (e.g., 115th on ITU's 2016 ICT Development Index). It also has a dysfunctional education system that results in a large skills gap.[208] The country is beset by tech protectionism—it requires 30 percent local content on 4G phones and demands local data storage for financial and other firms' data, both of which are significant impediments to investment. Nevertheless, Indonesia has several important assets, one of which is the size of its domestic market ($941 billion GDP, $11,000 per capita). Owing to its large population with consumer purchasing power, Indonesia has the potential to be a successful absorber/adapter of emerging consumer technologies. In the digital space, its mobile market is already at 70 million mobile device users. Indonesia's app development culture (e.g., ride-sharing and e-payments apps) has produced at least one unicorn in the digital space.[209]

Thailand has been one of the Asia-Pacific region's development success stories, like Singapore or South

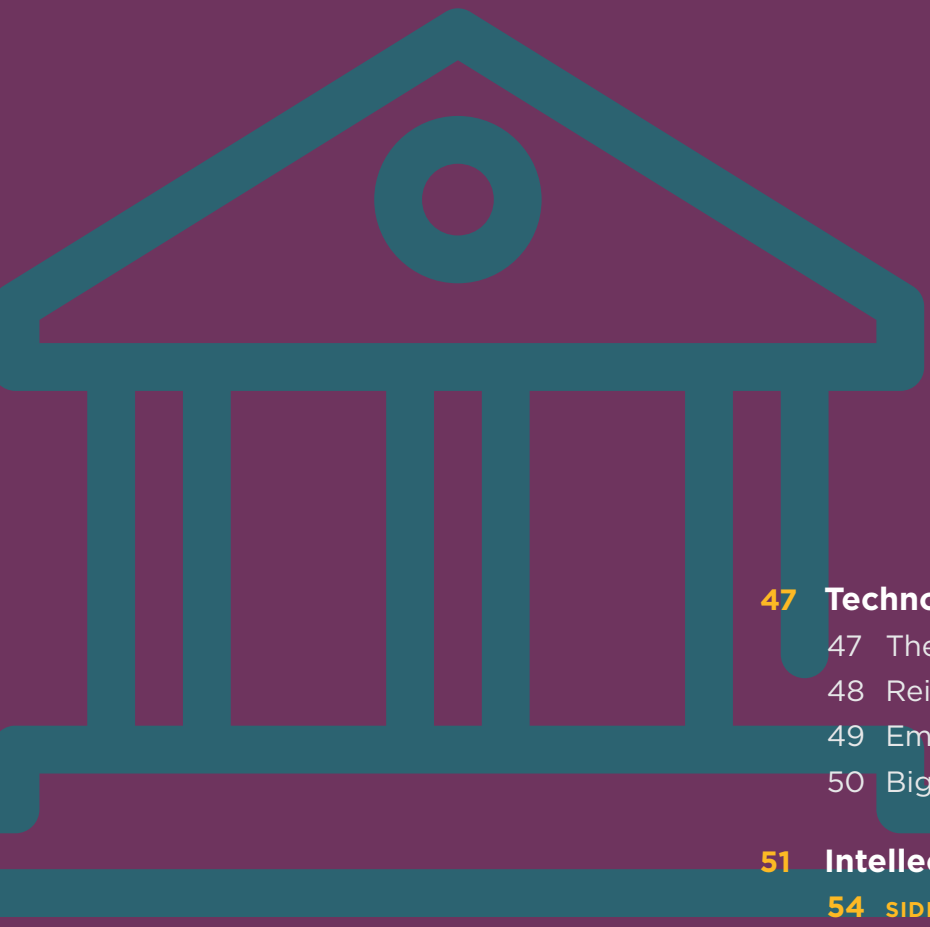
Startup Weekend in Monterrey, Mexico.

EDITH VALLE/CEDIM NEWS/FLICKR

Korea, taking only a generation to rise from low-income to higher-income status (in Thailand's case, GDP per capita is $16,097, giving it upper-middle income status). Thailand built a modern export-oriented manufacturing economy in areas such as computers and electronics, in part around strong performance in universal education.[210] However, unlike Singapore and South Korea, Thailand has been less successful in transitioning to a knowledge economy, ranking fifty-first in the 2017 Cornell/INSEAD/WIPO index, fifty-fourth in the "innovation pillar" of the 2017 World Economic Forum's Global Competitiveness Report, and forty-fourth of fifty countries ranked in Bloomberg's 2017 innovation index. A big part of the explanation, common to other members of ASEAN (Association of Southeast Asian Nations), is historically low investment in R&D. At 0.6 percent in 2017, Thailand fares poorly against the Asia-Pacific region's tech-innovation leaders South Korea (4.2 percent), Japan (3.5 percent), Singapore (2.2 percent), and China (2.1 percent). Recognizing a need to upgrade R&D, the government has introduced consecutive ten-year S&T master plans to strengthen collaboration across the entire ecosystem, from skills training and education to university-industry collaboration, to government policy and financial support.[211] There is a large and growing consumer base in Thailand, with high rates of mobile and smartphone penetration (49 percent in 2016) as well as an enthusiastic population of social media consumers and producers.[212] Besides e-commerce and related fields, observers point to fintech, medtech, biotech, and e-commerce as current or potential growth areas for Thai entrepreneurs.[213]

Taiwan is one of the most important manufacturers of consumer electronics (computer chips, screens, and other components) and other goods in the world. Today, Taiwan spends nearly 3 percent of GDP on R&D and has a competitive technological and scientific infrastructure.[214] Its rich base of STEM graduates has attracted Google, Microsoft, and Amazon to open AI research labs.[215] Several of Taiwan's firms are ramping up spending on aspects of AI/Big data, such as facial recognition. Yet Taiwan still largely lacks a startup-friendly ecosystem. Only in the last three years has the government begun to generate VC activity, and startup spaces with the government investing $83 million in startup accelerators.[216]

The Policy Environment



The technologies discussed in this report are racing ahead of standards, rules, and regulations to govern them, and at a troubling rate. Moreover, the means of keeping new technologies cybersecure from hacking intrusions are obviously still inadequate. One need look no further than cybersecurity, where thousands of hacks, disruptions, and cyberthefts occur each day.

The exponential pace of change poses extraordinary conundrums: what are the regulatory, ethical, and governance challenges posed by a world dominated by a handful of US and Chinese tech giants? One where synthetic biology and gene editing (another example of the digital and physical worlds merging) allows humans to "play God"? Where digital commerce will soon be more than 25 percent of all trade, yet comprehensive trade rules to govern it are nonexistent?

A pressing nexus of issues demands governance attention. These range from fears about AI/robotics imperiling humans, to security concerns surrounding drones, to ethical norms regarding genomics. Virtual currencies like Bitcoin and the intriguing potential of blockchain technology in regard to fintech and cybersecurity merit separate treatment. The rules surrounding IP production and protection are a major policy domain. The future of the Internet itself—which is by no means guaranteed as a stable or secure platform—is also in question. Finally, the technology revolution is having dramatic economic and social impacts, including on the future of work.

Many of these are open-ended questions and topics for future inquiry. A comprehensive discussion of all these governance challenges is beyond the scope of this report. At the same time, the absence of a sense of urgency to find global consensus in many of these areas is disturbing and not without risk. In this section the authors of this report highlight a few of the key current questions and point to means of addressing them.

Technology Outpacing Governance

This subsection examines how some emerging technologies and established technological sectors have outpaced their governance. It does not attempt to be exhaustive, rather it explores a few important examples of the phenomenon.

The Digital Economy

The digital economy, now a mature technological sector, is a prime example of how even established technologies can get ahead of governance. By some estimates, the global data flows grew forty-five times from 2005 to 2014, exponentially faster than flows in trade or finance.[217] The US Department of Commerce found that in 2014, more than half of US trade in services was digitally delivered; meanwhile, a Japanese METI report assesses that 50-56 percent of all trade in services is ICT-enabled.[218] Digital commerce already accounts for roughly 20 percent of global trade and is projected to increase to 25 percent by 2025.[219] This percentage is not the end point, but more likely the beginning of a substantial increase. Consider the explosion of e-payments, the billions of devices to be connected by the IoT, or the impact of 3D printing, where computer designs will be widely downloaded and actual products will be printed (made) by consumers.[220]

Yet the world lacks a comprehensive international framework of trade rules governing digital commerce. World Trade Organization (WTO) agreements covering services (financial, legal, etc.) and various remedies on IP rights (e.g., trademarks, copyrights, legal protections and remedies in the digital environment) offer only a partial framework.[221] There are numerous gaps in digital governance, as well as new challenges from evolving technologies, such as the growth of the cloud and cloud-based AI services. At the same time, digital protectionism (e.g. localization of data requirements) is rising while the Internet is becoming Balkanized, with nations blocking out apps or websites (e.g., *New York Times*) that they object to, ostensibly on moral or national security grounds.[222]

A nexus of issues demands governance attention, such as Bitcoin and the potential of blockchain technology.

MARCO VERCH/FLICKR

In the case of China, its "Great Firewall" is getting higher, imposing web censorship within the country and restricting the web presence of US tech firms—Google and Facebook, among them. Such treatment has meant that Amazon has only 1.3 percent of China's e-commerce and is unable to appeal to Chinese consumers and compete with the dominant Alibaba and JD.com.[223] China has long imposed forced technology transfer conditions on foreign firms as the price of access to its alluring market. Recently, Beijing has restricted foreign direct investment (FDI) in priority technologies.[224]

In its National Trade Estimate, the US Trade Representative (USTR) highlights some of China's barriers to digital trade, citing data localization requirements (forcing firms to keep data in the country of operations) and local computer facilities requirements, restrictions on the use of secure lines and networks, restrictions on FDI in cloud computing services, and "extensive blocking" of Internet content. Nevertheless, China is not alone. USTR cites data localization requirements and Internet content restrictions in multiple other countries.[225] US firms are concerned about the impact of EU privacy laws, particularly the EU's General Data Protection Regulation (GDPR), which takes effect in May 2018 and seeks to give citizens control over their data. In addition, consumers and many in the US Congress are concerned that the US abandonment of "net neutrality," which the EU has embraced, may shift control to Internet service providers.

One antidote is in the digital commerce section of the Trans-Pacific Partnership (TPP), the first effort at a comprehensive set of rules and norms. When the TPP enters into force (expected by the end of 2018), it will establish nondiscriminatory treatment as the default norm. It will reduce all manner of barriers and prohibitions on digital commerce, for instance the prohibition of customs duties for electronic transmissions, and it will require that states proactively create consumer data protections and endorse equal Internet access (net neutrality).[226] Such provisions—some of which have been suspended in hope of US re-entry—are a precedent for regional and global standards that the North American Free Trade Agreement (NAFTA), Korea-US Free Trade Agreement, and the WTO could build on.

An urgent need exists for the major economic actors to find consensus if an open, rules-based order is to underpin the technological revolution.

The TPP notwithstanding, an urgent need exists for the major economic actors to find consensus if an open, rules-based order is to underpin the technological revolution. One obvious starting point is for the United States and the European Union, which together comprise roughly 44 percent of the world's economy, to find a common approach. Such a step would go a long way toward creating global norms. Together with Japan, South Korea, Australia, and other Organization of Economic Cooperation and Development (OECD) states, a coalition effort in the WTO and G20 could force China to alter its predatory, mercantilist behavior.

However, the US and the EU differ over many tech issues, such as the EU's disciplining of big tech. Two reports that explore how to bridge the digital gap are instructive (see endnote).[227] The EU's GDPR creates a single set of rules for data protection. The United States, on the other hand, has no comprehensive national framework, but rather a mix of national and state laws and regulations. Two agreements—the Privacy Shield, under which US firms are obliged to protect the personal data of EU citizens, and a US-EU Umbrella Agreement on exchange of information for law enforcement—reflect a partial, but still uncertain framework.[228]

Privacy rights are subject to different interpretations. EU copyright laws are a work in progress, in the process of being modernized in line with the single digital market initiative. Two related means could facilitate steps toward harmonizing US-EU digital rules, norms, and principles. One would be an ongoing US-EU Digital Council, proposed by an Atlantic Council Task Force, which could report to the US-EU summit.[229] This could feed into efforts to finalize Transatlantic Trade and Investment Partnership (TTIP) negotiations, with a digital chapter building on TPP digital commerce provisions.

Reinventing the Internet?

The digital economy obviously is closely related to the underlying technology itself, the Internet. The future of this fundamental technology—actually, a collection of many technologies—has become an issue of debate. Key concerns include concerns over net neutrality; the exponentially growing volume of data crowding the network; cybersecurity; and the billions of additional devices that the IoT will connect. Experts are proposing various ways to reinvent the Internet: for example, adapting peer-to-peer network protocols, where use would be between two entities rather than through the entire worldwide web.[230] In addition, data localization, which is threatening to create a fragmented Internet, is leading to efforts to preserve the original purpose of the Internet: end-to-end communications.

The fast-approaching next-generation of mobile services will catalyze an explosion of connectivity.

Although there is no single dominant idea among those seeking to reinvent the Internet, numerous potential mechanisms are available to address the Internet's numerous problems. Each may develop in experimental fashion. One governance idea is a certification board of experts to set minimum standards for connecting devices to the Internet. Engineering more resilience and redundancy into IoT devices is important and a governance issue requiring public sector cooperation with the private sector, where the bulk of expertise resides. A similar concept could be the creation of a US/EU standing cyber-commission to periodically review the state of play with respect to Internet governance. Such a commission could be developed under other auspices as well, for example, via the UN and International Telecommunications Union (ITU), which oversees a public/private process for the 5G world (see below). Yet another idea, as one report suggests, is to create "many, special purpose Internets, which can provide differing levels of secure infrastructure to discrete sectors of the Digital Economy."[231]

All these ideas are attempts at solving a long-term set of Internet governance problems, which loom as potential obstacles to innovation. There are no obvious resolutions, but the problems discussed above underscore the urgency of closely coordinated regional and global public and private efforts to begin what will almost certainly be a complicated and arduous process.

Emerging Technologies

The digital economy and Internet are just tips of the proverbial iceberg. The Internet as a technological system, and the digital economy based upon it, are familiar. Emerging technologies present a qualitatively different challenge: the governance question is about how best to shape the anticipated impacts of such technologies. Below are two examples: 5G wireless systems and artificial intelligence.

A 5G (Fifth-Generation) World: This fast-approaching next-generation of mobile service will catalyze an explosion of connectivity, the IoT, whose impact McKinsey forecasts will add $3.9-11.1 trillion in value per year by 2025.[232] Several service providers are experimenting with early versions of 5G, based on existing 4G technology, which does not deliver the 20 gigabit/sec speed that the new technology will eventually obtain. The International Telecommunications Union (ITU), the UN agency responsible for governing 5G, is

developing technical and engineering standards by working closely with a private-sector-led group, the Third Generation Partnership Projects, composed of major telecom associations. The EU has also formed a 5G infrastructure public/private partnership.

Unlike previous mobile systems, 5G will use extremely high-frequency bands of the spectrum, called "millimeter bands." This requires substantial infrastructure investment in hundreds of thousands of cellular radio antennas.[233] The risks include fragmented markets and conflicting standards. Efforts to avoid/minimize such outcomes should be led by the private sector, as is now the case. An open innovation approach is needed to explore various solutions for different markets before reaching new standards, with the hope of harmonizing or at least achieving compatible standards. At this point, the most appropriate role for government is only as a facilitator, making available bandwidth on the spectrum, and creating public/private partnerships at national and local levels to address infrastructure issues. One big, unanswered question is cybersecurity. With IoT, new layers are being added on top of an already vulnerable Internet. The private sector will most likely mitigate the problem, but in a public/private partnership with, and probably incentivized by, government.

Artificial Intelligence: If AI only pertained to technologies such as Siri, Alexa, personal assistants, machine-language translation or even driverless cars, the policy questions might be more easily manageable. AI is only now moving beyond pattern recognition to deductive cognition: it is a new platform, think "Internet 2.0." Although AI has yet to become a mature technology, it opens a Pandora's Box of huge, existential issues from the future of work to whether self-reproducing robots will have any use for human beings.

Industrial robots from the Johannes Kepler University's Institute for Robotics.

VANESSA GRAF/ARS ELECTRONICA/FLICKR

The public's darkest fears of AI are put forward by the late physicist Stephen Hawking, who exclaimed that "the development of full artificial intelligence could spell the end of the human race."

Yet AI is still in its early stages and pretty much under control. Deep learning is based on neural networks, and scientists still do not completely understand how the human brain works. AI can learn to recognize a monkey, but it does not yet know how to think like a monkey. A more sanguine school of thought is reflected by robotics innovator Rodney Brooks (of iRobot fame), who told *Technology Review* that fears of being overrun by AI superintelligence are "comparable to seeing more efficient internal combustion engines and jumping to the conclusion that warp drives are just around the corner."[234] Other leading neuroscientists are also skeptical that AI can duplicate human intelligence because emotions, memories, and culture are a part of human intelligence that machines cannot replicate.[235] Even if fears of AI are justified—and that remains a matter of debate—AI is certainly decades away from attaining such a capacity.

Nonetheless, at present, AI raises more than its share of substantial ethical, social, and economic governance questions. How do governments regulate AI/robotics? Driverless vehicles are experimentally on the streets of several cities, despite safety and liability issues (who is responsible when a robot car errs?). The controversy over robots and jobs also looms—what will happen to truckers, taxi/Uber drivers, etc., when vehicles drive themselves? AI applies to all jobs involving repetitive behavior, as well as to legal, financial, and medical services. Even so, AI potentially raises even more profound questions. For example, should algorithms replace judges or evaluate job applicants?[236]

To address this welter of questions, some variation of what science fiction writer Isaac Asimov's "three laws of robotics" might be needed: a robot may not allow a human to be harmed through action or inaction; a robot must obey orders from humans, except when they conflict with the first law; and a robot must protect itself, as long as that protection does not conflict with the other two laws. In addition, the principle of augmentation may be a useful guideline: AI/robots will augment many human jobs; algorithms may offer useful data analysis on finance, medical diagnostics, and legal issues; but at the end of the day human judgment should prevail.

Big Tech: Echoes of Standard Oil?

Casting a large shadow over global innovation is big tech, which is dominated by a handful of US (Alphabet/Apple, Google, Amazon, Facebook, Microsoft, IBM) and Chinese (Alibaba, Baidu, Tencent, and JD.com) firms. These are overwhelmingly digitally based companies such as Alibaba,

computer manufacturers such as Apple, and software developers such as Microsoft. Google accounts for an estimated 87 percent of global online searches. Google and Alibaba have been quick to gobble up promising startups from Silicon Valley to Shenzen. Big tech dominance impacts advertising, media, and e-commerce interests. Google and Facebook account for some 80 percent of referrals of news articles, and in 2017 together garnered about 80 percent of new online ad revenues in the United States, while Amazon dominates about 40 percent of US online commerce.[237]

Yet recent controversies over matters such as privacy and Russian interference in US democracy, combined with traditional structural questions pertaining to monopoly practices, have created a backlash against big tech.

One question that will most likely become more pronounced in the years to come is whether and how governments should regulate big tech companies, up to and including using antitrust laws to break the biggest firms. Data is a major issue, at once a privacy and monopoly issue. Data is obtained via "free" services offered by Google or Facebook and is then sold or used for proprietary purposes. Concern about monopolistic practices by big tech is growing in the United States after the European Commission levied a $2.7 billion fine on Google in 2017 for favoring its own services over competitors.[238] Facebook has been under pressure in Germany and France as well as the United States over social media issues. In the US, now facing heavy public and Congressional scrutiny, big tech firms are attempting to self-regulate some of these issues. Facebook is more carefully screening its advertising, while Twitter is rejecting bot pseudo-accounts. In the future, Congress may more fully legislate privacy issues as well as restore net neutrality.[239]

In a number of US states, attorneys general have begun probes into Google. The US federal antitrust case against Microsoft in the 1990s (over the firm favoring its own search browser) began when states launched probes. In fact, it could be argued that if Microsoft had not been sued, the then-fledgling Google might have been quashed. Some see more parallels with earlier Standard Oil and AT&T antitrust cases than is often considered.[240] The paramount concern in traditional US antitrust laws is the impact on consumers. Because some big-tech sites are free (Google and Facebook) and others are very consumer-friendly (Amazon), it may be difficult to apply such criteria.

Big tech is having a major impact on competition and innovation. In theory, the digital world allows a startup offering an innovative algorithm, product, or service access to both local and global e-commerce markets. However, if large search engines like Google find that a startup conflicts with their own service—or inspires them to create a competing one—they bury the startup at the bottom of search results. Both *Yelp* and *Foundem*, two search apps, suffered from this problem—Google searches buried both apps down the list of results, so few people saw them. In 2017, the EU levied Google with a record $2.7 billion fine for such behavior.[241] Acquisitions of potential competitors—Google/YouTube, Facebook/WhatsApp—also raise questions. Efforts to control big tech could take various forms, such as competition of divestiture (e.g., Amazon, spinning off Amazon web services), closer scrutiny of the impact of acquisitions on competition (e.g., Amazon buying Whole Foods), and closer monitoring of search results that disadvantage small businesses.

European Commissioner for Competition Margrethe Vestager addresses EU officials.

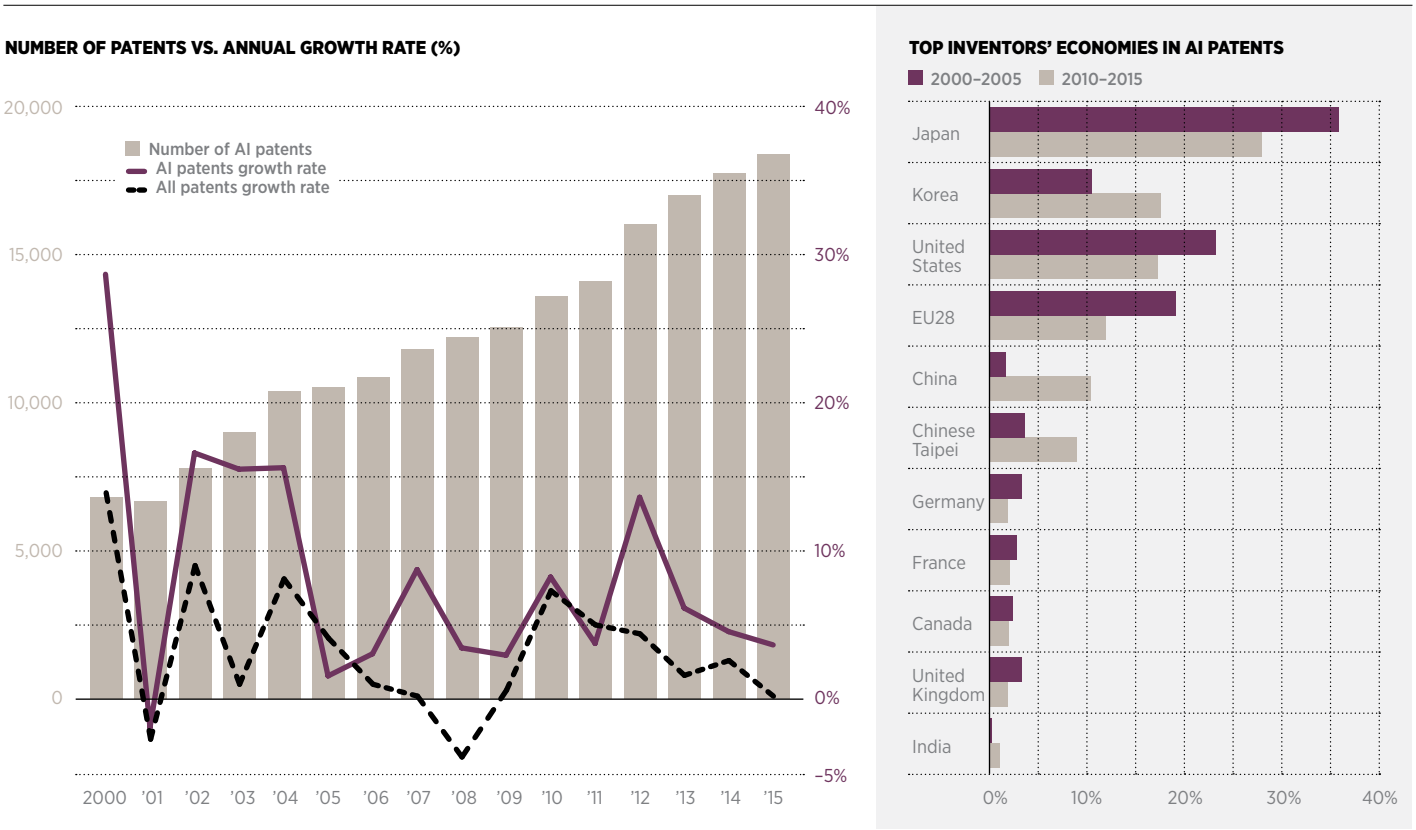
EUROPEAN CONSERVATIVES AND REFORMISTS GROUP/FLICKR

Intellectual Property

Almost by definition, the production and dissemination of ideas—intellectual property—is the central characteristic of the knowledge economy and therefore of innovation. Like the concept of innovation, IP is an idea that is both easily grasped and yet exceedingly complicated in its practicalities. The concept itself, which has almost limitless permutations, is wrapped in a complex legal infrastructure.

Although there are many definitions of IP, the World Intellectual Property Organization (WIPO) offers a straightforward one: IP consists of "creations of the mind: inventions; literary and artistic works; and symbols, names, and images

FIGURE 6. Patents in artificial intelligence technologies, 2000–2015



Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, June 2017. http://www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017_9789264268821-en#.WmpN62dy4uQ#page1

used in commerce."[242] The most familiar IP category is the patent, which is an exclusive right granted to an inventor by a legal entity (usually a patent office at the national level) for a set period of time, normally twenty years. Other important IP categories include trademarks, copyrights (for creative work by artists, authors, etc.), industrial designs, geographic locations (e.g., Champagne), and trade secrets. All these are protected categories under national, regional (e.g., European Union), and global IP law. Collectively, these protections are known as IP rights (IPR), which WIPO defines as "rights like any other property right, allowing creators or owners of IP to benefit from work, investment, or creation."[243]

At the global level, the two principal agreements regulating the production and protection of IP are the Patent Cooperation Treaty (PCT), administered by WIPO, and the Trade-Related Aspects of Intellectual Property Rights (TRIPS), administered by the World Trade Organization

Created in 1970, the PCT is an enabling mechanism, allowing for a smoother and more globally operative patenting system. Under the PCT, WIPO accepts and reviews inventors' patent applications and issues and publishes expert opinions on each application. However, despite the use of the word "application," this process does not result in a globally valid patent. WIPO grants no patents under the PCT; the only legally binding patents are granted by national and a very few regional offices (such as the European Patent Office). As a result, patent protection remains geographically based, within countries that recognize the validity of a patent issued by a specific national or regional patent system. Nevertheless, the PCT assists inventors through assessing the complex global patent landscape for them and by providing them with some important filing rights at national level.[244]

WIPO and PCT have enormous value for national and regional patent-issuing systems around the world. As the PCT provides expert review of patent applications, it removes burdensome search and examination work that otherwise would have to be done by patenting offices. Those offices often issue patents based on the PCT review, given their acceptance of the common form and procedure underpinning the patent application.[245] WIPO itself contributes significantly in other ways, for example, it helps design and develop national IP plans, facilitating standardization and familiarity across national systems. An example is a program called the Patent Prosecution Highway—WIPO-encouraged

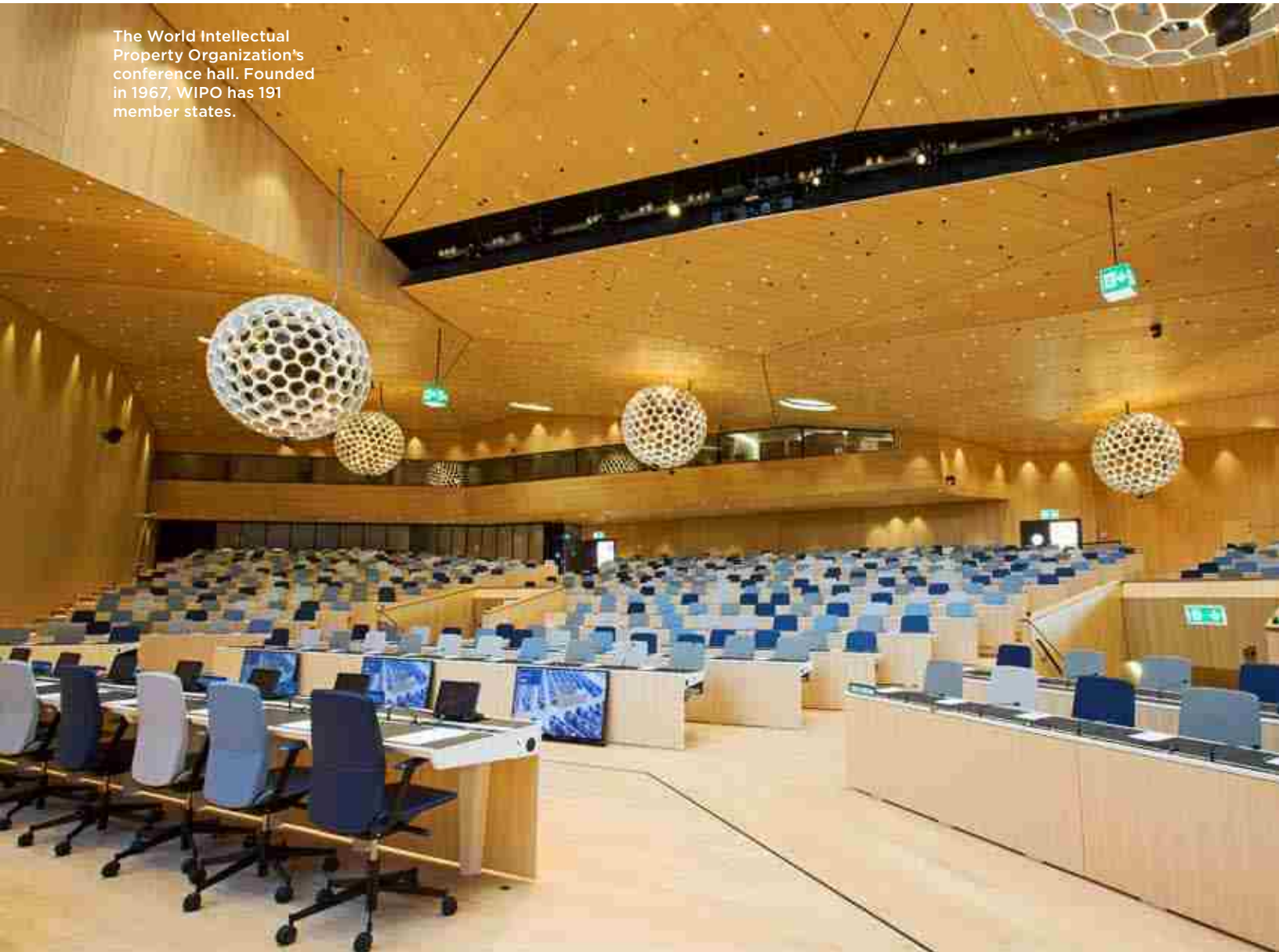
OPPOSITE PAGE: EMMANUEL BERROD/WIPO/FLICKR

bilateral agreements to facilitate patent examination between national patent offices. A pilot effort between Brazil and the United States began in 2016.[246]

The younger TRIPS agreement (1995) is an IPR treaty: it defines minimum protection standards for IP, covers enforcement and remedies for IP infringement, and provides dispute settlement procedures. The agreement is comprehensive in that it covers much of the IP landscape, from patents to copyrights, to trade secrets. The agreement requires member states to enforce IPR, including patents, without discrimination against the inventor. TRIPS provides waivers from some rules, for example, Article 27 permits patenting exceptions for "diagnostic, therapeutic, and surgical methods for the treatment of humans or animals."[247] In the context of medical technologies especially, clauses such as this one have proven contentious within multilateral diplomacy. A 2016 UN Secretary-General high-level panel report on access to medicines explicitly called on patenting authorities to interpret such clauses in Article 27 in the broadest possible manner "in the best interests of public health," i.e., because its authors believed that new medicines and medical technologies were not created and diffused rapidly enough around the world.[248]

Patent protection remains geographically based, within countries that recognize the validity of a patent issued by a specific national or regional patent system.

The biggest and longest-running global diplomatic divide over IP concerns its role in the development of poor countries. For decades, the multilateral, interstate conversation over IP/IPR has been dominated by a split between developing and developed countries. Speaking generally, developed countries maintain that strong IPR underpins both the creation of IP and its rapid diffusion around the world. They claim that if inventors and owners of IP believe they will be protected under the law, they will have more confidence in



The World Intellectual Property Organization's conference hall. Founded in 1967, WIPO has 191 member states.

INNOVATION AND INTELLECTUAL PROPERTY IN EMERGING COUNTRIES

BY **JENNIFER BRANT**

Innovation is a recognized driver of economic growth in countries at all levels of development. Across sectors and technology fields, innovators rely on IP tools such as patents, trade secrets, and copyrights to rationalize their investments in R&D and move ideas to market. IP rights can be used to prevent others from making or selling an invention in the marketplace during a specific time period.

Enforceable, quality IP rights provide legal certainty and an incentive to engage in R&D. These exclusive rights are instrumental in collaborative or "open" innovation because they enable innovators to share what they know with partners without losing their competitive edge. Especially for SMEs, which tend to collaborate with more experienced actors to bring ideas to market, IP rights are important tools. Innovators—whether private companies, individuals, or public research institutes—require specialized knowledge in order to effectively use IP tools, through sound "IP management."

For many years, mature markets have been home to robust IP systems and high levels of expertise with IP management. This is rapidly becoming the case in emerging nations as well. In recent years, these countries have been enacting legislative and institutional changes to improve their IP systems.

This development has much to do with innovative activity moving toward these countries as they begin to develop critical technologies and other innovations. In China, recent legislative amendments and administrative and judicial decisions have made it easier to protect cutting-edge software as well as business-method and biotechnical inventions. Although its patent laws are only about thirty years old, in 2016 China enacted its fourth amendment, increasing statutory damages for patent infringements five-fold and expanding enforcement provisions. Brazil, too, has taken steps to improve its IP system, in particular to address the country's longstanding, significant, and growing patent backlog problem (patents were taking up to eleven years to get issued). In 2015, Brazil hired more examiners and concluded a pilot work-sharing agreement with the United States, providing for collaboration between national patent offices. Across Latin America, nine patent offices are cooperating under the Regional Cooperation System on Industrial Property (PROSUR) integration initiative (signed in 2012 by nine South American countries to cooperate on IP promotion) to improve the timely delivery of quality IP assets.

In addition to the importance of a predictable, efficient IP system, emerging economy governments are recognizing the value of IP management skills, which support the commercialization process and help ensure that inventors benefit from their own ingenuity. In Colombia, Colciencias, the Ministry of Science, Technology,

Students learn computer skills in Antioquia, Colombia.

CHARLOTTE KESL/WORLD BANK/FLICKR

Start-up space in Johannesburg, South Africa.

and Industry, works with research institutes to manage their IP, and with SMEs to encourage the use of IP tools. The often high cost of using formal approaches to protect ideas may be a barrier for smaller companies in particular.

IP rights such as patents may be used to transfer publicly funded research to other actors. Developed countries have long had relevant frameworks in place, for instance the 1980 Bayh-Dole Act in the United States.

Emerging countries are now following suit. South Africa, for instance, continues to refine its national tech transfer system for converting public research into commercial offerings. Forthcoming new research by the author of this essay, together with McLean Sibanda of the Innovation Hub in Pretoria, assesses the country's longstanding efforts to set up this framework, which is bearing fruit.

Since its transition to democracy in 1994, South Africa has prioritized the establishment of an inclusive innovation system. Starting with the 1996 White Paper on Science and Technology, the government identified IP management and the commercialization of IP, whether publicly or privately financed, as an important development objective. It established the Innovation Fund, with an in-house IP function, to support entrepreneurial projects aimed at commercializing R&D. It launched sector-specific innovation strategies, targeting six critical sectors including ICT, biotechnology, and advanced manufacturing. Moreover, the Department of Science and Technology (DST) published an IPR Framework Policy recommending how publicly funded IP should be managed.

These developments set the stage for adoption of South Africa's Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act) in 2008 and the National Intellectual Property Management Office in 2010. The IPR Act constituted a major step forward, establishing a formal, unified national framework for the commercialization of public research outputs. It included mandatory compliance mechanisms and a strong government commitment to provide financial support for IP management and tech transfer office training. Previously, tech transfer capacity had differed sharply across institutions.

Since the implementation of the aforementioned measures, IP awareness and technology transfer capacity have grown across public research organizations (PROs) in South Africa. Gradually, the South African research community has embraced the use of IP tools. The growth in the filing of patent applications by PROs, especially by universities, has resulted not only from the IPR Act and activities surrounding it but also from an increased awareness of IP in general. Although a lot remains to be done to ensure all PROs can manage IP well, today there is more identification and protection of publicly funded IP and, critically, higher and growing rates of IP conversion—or transformation of promising ideas into solutions. Ultimately, the goal of such efforts—which must be complemented by other actions to improve the business environment for innovation as well as the domestic skills base—is to ensure that public IP is converted into commercially viable solutions that can improve the South African economy and people's lives.

Jennifer Brant is Director of Innovation Insights.

ER STRATEGIC DESIGN/FLICKR

The twenty-first session of WIPO's Committee on Development and Intellectual Property.

WIPO/EMMANUEL BERROD/FLICKR

investing the resources required to produce IP and—most important—they will be more willing to enter into partnerships with others to share it. Developing countries have taken the opposite position: they claim that IPR is a form of monopoly that slows knowledge diffusion, providing a barrier to poor countries' development due to high costs and inaccessibility. Although the empirical evidence about knowledge production and diffusion largely supports the position of the developed world, this split is the most common divide within multilateral diplomatic forums such as TRIPS.

The developing countries' position, which has been supported by a number of prominent nongovernmental organizations (NGOs), has been shaped by a searing debate over the production and protection of medicines and (especially) their high cost to poor people and countries.[249] Access to affordable medicines and other health-related technologies has been a major point of debate in multilateral IP diplomacy since at least the 1990s. Before the TRIPS agreement, many developing countries manufactured and sold generic and much cheaper versions of patented medicines because these countries were not subject to patents. After TRIPS, however, WTO member states became obliged to provide IPR protection for such medicines. An enormous controversy over the high price of patented medicines erupted. To assuage the interests of both patent holders and developing countries, in 2001 the WTO reached an agreement that incorporated many their concerns. The Doha Declaration enshrined the principle of affordable access to medicine and affirmed that states should take advantage of the TRIPS agreement's waiver mechanisms. One such TRIPS mechanism is "compulsory licensing," wherein a government authority can break a patent holder's patent and indigenously produce the drug or product itself (or by license), even without consent of the patent holder.[250] A state's threat to issue a compulsory license can bring a patent holder to the bargaining table.

Yet, despite the stickiness of the diplomatic divide within multilateral contexts and the fierce battles over medicines, the IPR landscape is shifting in the direction of the developed world position for two principal reasons. First, as more emerging economies are joining the IP-producing club, more countries are interested in both protecting their own inventors' IPR and attracting IP-centric investment and partnerships from foreign companies. This trend is reflective of shifts in the global economy toward emerging markets in Asia (China, especially) and elsewhere. During the 1990s and 2000s, for example, rapid Chinese economic growth, combined with the country's rise up the value-added ladder, drove global growth in R&D spending and in patenting.[251]

The [intellectual property rights] landscape is shifting in the direction of the developed world position.

The second reason for the shifting IPR landscape involves the changing nature of knowledge production, which is evolving toward greater cooperation across international boundaries. Open innovation, facilitated by digital communications and easy global mobility of researchers, is the name of the game, as firms and research institutions seek partnerships around the world in order to leverage others' expertise and resources. Cooperation has increased horizontally and vertically: horizontally between firms; vertically between firms and upstream research institutions such as universities and downstream customers. Multinational firms are opening more research centers in more places around the world to take advantage of local research talent (an important example is provided in the Israel case study in the Special Section). Stronger IPR systems facilitate open innovation as they increase "legal certainty and predictability," giving entrepreneurs, universities, individual researchers, and large firms confidence to enter into cooperative agreements.[252]

Observers concede that for both these reasons, multilateral forums now favor the development of strong IPR. A 2015 European Commission survey of non-European IPR systems provides a glimpse into such shifts within a selection of emerging economies. China, it asserts, has updated its IP legislation on patents and trademarks; created several new IPR courts; and taken other public measures, including a high-profile National IP Strategy, in support of achieving its long-range ambition of knowledge economy leadership. The survey also tracks progress in a host of other emerging economies, including India, Brazil, Malaysia, Indonesia, Mexico, Thailand, and other countries. In most if not all cases, the commission observed progress in one or more IPR dimensions. It credited India with upgrading some aspects of enforcement and patent examination processes, for example, and Brazil with taking stronger anti-counterfeiting measures. The commission also pointed to remaining challenges across emerging economies, including slow and unpredictable judicial systems, long patent processing times, inconsistent and geographically uneven IPR enforcement, inadequate remedies and damages for IPR infringement, and widespread counterfeiting and digital piracy markets nearly everywhere.[253]

The existence of these challenges underscores how a national IPR regime's strength is a function of both law and practice, of both formal legal rights well as law enforcement and administrative capabilities. As the European Commission's survey and other studies consistently point out, the administrative component is critical. Many economies—primarily emerging economies but also advanced ones—can fare poorly on the administrative side, with problems ranging from geographic fragmentation, to weak enforcement, to insufficient financial and legal remedies.[254] (For a discussion of changing IP management systems within emerging economies, see the guest essay by Jennifer Brant.)

Given this scale and speed of change, why does the diplomatic divide remain, with emerging-economy, IP-producing states continuing to support the weak IPR perspective? One possible answer is that a gap exists between the multilateral positions taken by countries—which are mostly public expressions and often involve multiple diplomatic considerations—and their practical in-country behavior. The IPR debate today, compared with twenty years ago, is more public. At the multilateral level, NGOs were not as engaged then as they are now, and those that were engaged favored strong IP. Today, however, more NGOs are on the opposite side. The media landscape has changed, too, allowing an intense focus on highly visible and sometimes explosive aspects of IPR agreements, representing only a small share of an otherwise technical and highly complicated topic. Another possible answer is that it takes considerable time to change policy within large multilateral forums compared with individual national policies, thus the former is lagging well behind the latter.

FIGURE 7. 2016 Patent Applications Worldwide

1,338,503
CHINA

605,571
UNITED STATES

318,721
JAPAN

Source: WIPO. http://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2017.pdf.

CONCLUSION

Five Big Questions for the Future (and some Recommendations)

In this concluding section, the authors offer their answers to the biggest questions that flow from this study. These questions are enormous, for individual societies, groups within those societies, and the world at large. All are so consequential that it is hard to overstate their importance. Each question begs additional questions and additional work. Where appropriate, the authors provide recommendations for policymakers and others.

1. Is there a "secret sauce" to innovation?

During the past two years, the authors' tours of tech-innovation ecosystems have yielded many insights regarding what gives certain countries a leg up in the innovation sweepstakes. On the one hand, there are common metrics of success, which are offered in the following paragraphs. On the other hand, the more that the authors researched individual ecosystems, the more it became apparent that each offers something unique, and each has a different story to tell. Therefore, while there is a cookbook from which to draw, there are many specific recipes. There is not one "secret sauce," but many.

Leaders in the most forward-leaning ecosystems understand that they should not to try to copy Silicon Valley, which has its own unique (and to some extent non-replicable) history, culture, and national context. Rather, they understand that they need to draw upon their own strengths and histories in order to forge new and innovative technologies that will appeal to the rest of the world.

This observation speaks to a key insight: most vibrant tech-innovation ecosystems **score high on both place and flow.** As emphasized in the Israeli case, the best ecosystems are those that nurture a strong sense of place—people like to live and work in such ecosystems and develop a strong attachment to them. In addition, such ecosystems have high exposure to global flows of money, ideas, and talent. These places have both local and global identities: they are local because they offer talented individuals a unique and desirable place to put down roots and invest in the life of the community; they are global in that they have extensive, sophisticated, and highly developed networks with the rest of the world.

Developing an **innovative culture** therefore is at the top of the authors' list of secret sauces. Culture is not easily quantifiable and therefore is easily dismissed in a world that mostly values hard data. Nevertheless, based on the research conducted for this study, the authors conclude that culture and social cohesion are among the most important strengths of first-tier ecosystems. The attitudes that people have toward risk, entrepreneurship, work, mentoring, horizon-setting, and community are key drivers of ecosystem performance.

Bike-share bicycles line the streets in Beijing.

For example, a French investor interviewed for this study believes that one of the primary reasons why France has not created the biggest tech companies on Earth (e.g., Apple and Google) is because its entrepreneurs have had limited ambitions. French entrepreneurs sell their startups to big, established corporations once their startups become valuable, rather than investing the additional time and energy to turn them into giants. For this investor, the question is less about complex policy questions, access to finance, and the like. Rather, it is a function of how entrepreneurs think, hence act—both of which are cultural phenomena.

At the same time, government policies, investments, and practices matter a great deal. These work in synergy with culture. Leading tech-innovation ecosystems are found in countries that have **governments that make enlightened decisions** on issues ranging from investment priorities, to educational policies, to infrastructure spending, to supporting intellectual property rights. The authors of this study believe that any debate that places the size of government at the center of this conversation is misplaced. Rather, the debate should be about purpose—how governments best support, enhance, and facilitate innovative activity, not about big-versus-small government. The big-versus-small debate is the central frame for the American political experience, which is unfortunate in the authors' view because it misses

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Engineers working on new drone technology. Leading innovators are those who make sure to invest in research and development.

the point entirely. How governments provide incentives, partner with actors from other sectors, and invest in their own innovation ecosystems (R&D, education, training, infrastructure, etc.) are key determinants of success or failure. Governments need to craft a vision around tech-driven innovation, realize what needs to be done over the long term to achieve that goal, and then execute a plan.

RECOMMENDATIONS

- **Strategic planning:** Most of the world's leading innovators engaged in some form of long-range, "whole-of-government" strategic planning to get to where they are now. While there are many different variations, strategic planning and long-range foresight processes to identify and assess economic and technology trends have been prominent in Sweden, China, Singapore, and Germany. These countries prioritize government policies and public/private-sector collaboration to become tech leaders. The United States followed this template after World War II, with the US government developing an aggressive tech-focused plan to become the dominant creator of technologies in the world. That plan has worked for the last seven decades (see the authors' 2017 report, *Keeping America's Innovative Edge*, for a discussion), but it is eroding.

- **R&D:** "There are no miracles," one prominent Israeli scientist said during an interview for this study. He meant that no society can be in the top tier of tech-focused innovation—or remain there for long—if it does not invest in R&D. The leading innovators are also at the top of the list of R&D investment: Israel, South Korea, Germany, Sweden, Japan, China, and the United States, for example. Although it can be painful to invest scarce public funds in research that may never pay off economically, it is imperative that states do so. Over many iterations, such research does pay off.

- **Tech transfer:** There is a difference between discovery and innovation. The former is about lab-based science, the latter about transferring scientific knowledge into practical and commercially viable technologies. As discussed at some length in this report and its predecessor (and by guest authors Lisa Ericsson and Donnie Lygonis in these pages), universities need to establish strong tech transfer offices (TTOs) and other innovation-centric offices that encourage and train students and faculty in entrepreneurship. Although controversial, universities also have to figure out how to deal with academic culture, which historically discourages commercially applicable research by faculty, staff, and students.

- **Intellectual property:** States should recognize that strong IP protection will lead to more prosperity over the long run. As discussed in the IP subsection above, this is a controversial proposition in much of the world: many developing countries see IP protection as a form of monopoly, which keeps prices artificially high, in particular for critical products such as pharmaceuticals. Yet, despite this longstanding position, the global trends suggest movement in the strong-IP direction. The devil lies in the details. Crafting strong IPR systems is not just a legal question, involving clear IP rights and obligations specified under the law, as well as clear remedies for parties found in violation of the law—it also involves effective management, where governments have invested in the capacity to run their IP systems well. Such governments invest the money and people required to process patent applications in a timely manner. In addition, they police IPR, so that counterfeiting, piracy, and so forth are diminished. They take enforcement seriously, providing adequate legal remedies in a high percentage of cases. None of these things are simple or easy. They involve tackling major problems such as public sector corruption. Like R&D spending, they involve spending scarce funds on systems that may not have an obvious return in the eyes of the public.

- **Immigration:** It is a trope to say that openness to immigration, in particular structuring it to attract entrepreneurial and technical talent, is key. Indeed, in nearly every leading case examined in these pages, immigration has been a major factor contributing to success. Other countries have adopted the US template, which is to be open to talented foreigners, including students, investors, entrepreneurs, and skilled workers. Countries need to see themselves as competitors in a fierce global competition for talent. An underappreciated aspect of this story is that countries need to be open to far more than hosting talented and well-paid guest workers. People need to feel welcomed if they are to stay and invest their talents in a given country's innovation ecosystem over the long run. Countries should offer paths to citizenship for talented people who have settled in an ecosystem for a period of time and have demonstrated a commitment to its success.

- **City planning:** Housing, transport, livability, amenities, environment, and lifestyle were frequent topics of discussion among the interviewees. Social cohesion is also a common characteristic of successful innovation ecosystems. As the authors of this study asserted in the 2017 report about the United States, city planning issues are not trivial. In fact, good city planning is fundamental to the entire tech-innovation equation. This is an important frame for national policymakers, who tend to focus on policy levers abstracted from the practicalities of how real, specific places function. Yet their policy decisions have massive repercussions at the city level. The most obvious example is infrastructure. Policymakers should assume that having twenty-first century infrastructure makes cities more competitive in the global innovation race. Governments need to make the necessary investments in areas ranging from world-class airports and passenger railway connections to high-speed broadband connectivity.

2. Will some people be left behind by tech-driven change?

This question has two dimensions:

- ***Enlarging the circle of people involved in creating new technologies or innovating around existing ones.*** Unfortunately, women, lower-income groups, and some ethnic and religious minorities are consistently underrepresented in the world's tech ecosystems.
- ***Dealing with the downsides of innovation, specifically how new technologies and tech-based innovations threaten employment and earnings prospects***, at least for some percentage of the world's workers, particularly, the least skilled.

Neither dimension has been fully addressed, let alone solved, by anyone. Indeed, a full examination of both dimensions is beyond the scope of this report. However, there are two intertwined issues that can be addressed here: inequality and the future of work.

Unequal participation in the tech sector was a constant theme raised by the interviewees. Almost without exception, interviewees expressed concern about inequality and uneven access. Their common theme was that while the tech sector delivers riches to some people, the majority have little hope of participating in the tech-innovation sector. Whether in the United States, France, or Israel, interviewees said that their country's economic and social elites tend to be the dominant players in innovation. Most of these players are males who are drawn from upper socioeconomic strata. For whatever reasons, women, some minorities, and lower-income people are systematically underrepresented. The biggest concern is the emergence of a **dual economy** in which a relatively small share of a society participates in the high-reward tech sector, while the largest share does not. Unable to gain access to that sector, those in the latter group fall well behind. The result is a **two-tiered society**, with significant social and political consequences.

Meanwhile, the **nature of work** is changing fast. Already roughly one-third of the US workforce is engaged in irregular or freelance employment (the proverbial "gig economy"), representing a trend in advanced industrial economies.[255]

A co-working space. Roughly one-third of the US workforce is engaged in irregular or freelance employment.

Although several factors account for this trend, the biggest factor is that **technologies are altering entire industries and workplaces**. Uber, to provide a famous example, is an app-based tech company that has upended one of the oldest and most common professions of the industrial era (taxi driving). Looking ahead, estimates of job losses from AI, robotics, and automation to 2030 range from 7 to 38 percent (although some expect augmentation of employment from these technologies).[256] A 2017 McKinsey study projected that between 3 and 14 percent of workers globally will need to switch jobs by 2030 due to technology.[257]

Available evidence is contradictory. A recent survey of various estimates shows the broad range of possible futures, revealing the depth of uncertainty.[258] On the one hand, unemployment rates in the most advanced and most automated industrial nations (United States, Germany, and Japan) are near historic lows. On the other hand, there is a high and often unmet demand for highly skilled workers, at least in the United States. Unemployment numbers are deceptive: the United States is at the lowest rate in decades in terms of the percentage of labor actually in in the workforce (63 percent compared to a high of 67.3 percent in 2000).[259] These facts speak to an urgent need to close gaps between high-tech employment and education and training.

Adapting to the future demands on a twenty-first century workforce involves more than just matching skills to jobs, however. It requires a **rethinking of the social contract,** in some nations more than others, and a consideration of **policies of redistribution.** The authors of this study do not pretend to have the answers, but some notional ideas would probably need to be part of any solution.

One trendy idea is a **guaranteed annual income**. The concept is that because the new economy provides inconsistent employment opportunities—unlike the high industrial economy, which at its peak offered well-paying, lifetime employment—people need to be given an income floor. This idea is problematic in a number of respects and at best premature, as it is only in experimental stages in a few places around the world. Yet another approach is a **job guarantee,** wherein the government is an employer of last resort. A tried-and-true prescription during tough times (think of America's Civilian Conservation Corps during the Great Depression), a more permanent version might be a kind of public/private partnership, involving hiring incentives for businesses with government paying some portion of wages and benefits.

Such options would need to part of a larger package of healthcare and retirement benefits that people would have throughout their lives. The Europeans generally, and the Swedes in particular, believe that their strong social safety net is a real strength and one that gives them a leg up in both mitigating risk and attracting talent.

All these safety net solutions create problems, not the least of which are fairness and equity considerations (how should wealthy people be treated?). One cosmic issue is how to finance what would prove to be a massive increase in any government's social spending. One part of the answer could be some form of rents from big tech firms, based on their use of data collected from the public, which is their lifeblood.

RECOMMENDATIONS

- **Inclusivity:** Governments need to acknowledge that even high-functioning tech ecosystems are exclusionary. Such ecosystems tend to reward certain groups—especially males drawn from society's upper strata—over others. To correct this form of inequality and improve national economic performance, governments should encourage participation in tech innovation by women and girls, ethnic and religious minorities, and lower-income groups. Female-supportive policies, for example, might aim to identify and recruit girls in primary and secondary school for higher education in STEM-related fields; support the expansion of female-specific professional networks, in particular those that target young women in the early stages of their careers; provide incentives to firms to recruit women into their workforces; and statistically track women's progress in the tech sector.

- **Human capital:** Governments should acknowledge that in the knowledge economy, human capital is their greatest single asset, the primary source of national wealth and power. To become and remain competitive at the global level, governments need to ensure the constant upgrading of their entire workforces, not just a small share of them. For obvious reasons, STEM graduate rates track closely with innovative economies (to be accurate, knowledge economies need more than just technically trained people;

RECONDOIL/FLICKR

more broadly, they need creative, well-educated people who possess critical thinking skills). The United States has compensated for its shortage of STEM graduates with foreign students, many of whom stay in the country after graduation. Nevertheless, the United States has failed its citizenry in other ways, including in providing low-cost higher education and in worker skills training and retraining programs. Germany's apprenticeship program—now more than a century old, remains a template for training young workers—with a focus on those who never plan to attend university. More generally, all governments need to emphasize lifelong education and skills training.

- **Social safety net:** Now is not the time to dismantle social safety nets. Rather, these should be strengthened and adjusted to fit the realities of the twenty-first century economy. The worst policy mistake would be for governments to do nothing, which would provide a recipe for more, rather than less, contentious societies in the future. Experimentation will be the name of the game, as there is no obvious single-bullet solution to the social gaps created by the swift-moving gig economy. Minimum and supplemental income schemes, job guarantees, portability of benefits, and so on all need to be tested in real-world conditions, with lessons learned and shared across borders.

3. Can technology be governed?

This might be the most pressing and difficult question in this list. Although there is no obvious answer, as the question is to some extent a philosophical one, **governments must seek to shape technology's production and impact**. Experts may not know how new technologies will affect societies, the global economy, security, and geopolitics when such technologies arrive on the scene, but new technologies will no doubt have an impact. Some of those impacts will be profound. A few will be existential.

While scientific knowledge is universal, transcending international boundaries, the governance of scientific outputs—the legal authority and administrative capacity that is needed to address the consequences of technological development—is by and large a national responsibility. Thus even if some states want to shape the development of an emerging technology for ethical or security reasons—say, AI or genetic engineering—nothing prevents other states from moving ahead with research in such areas.

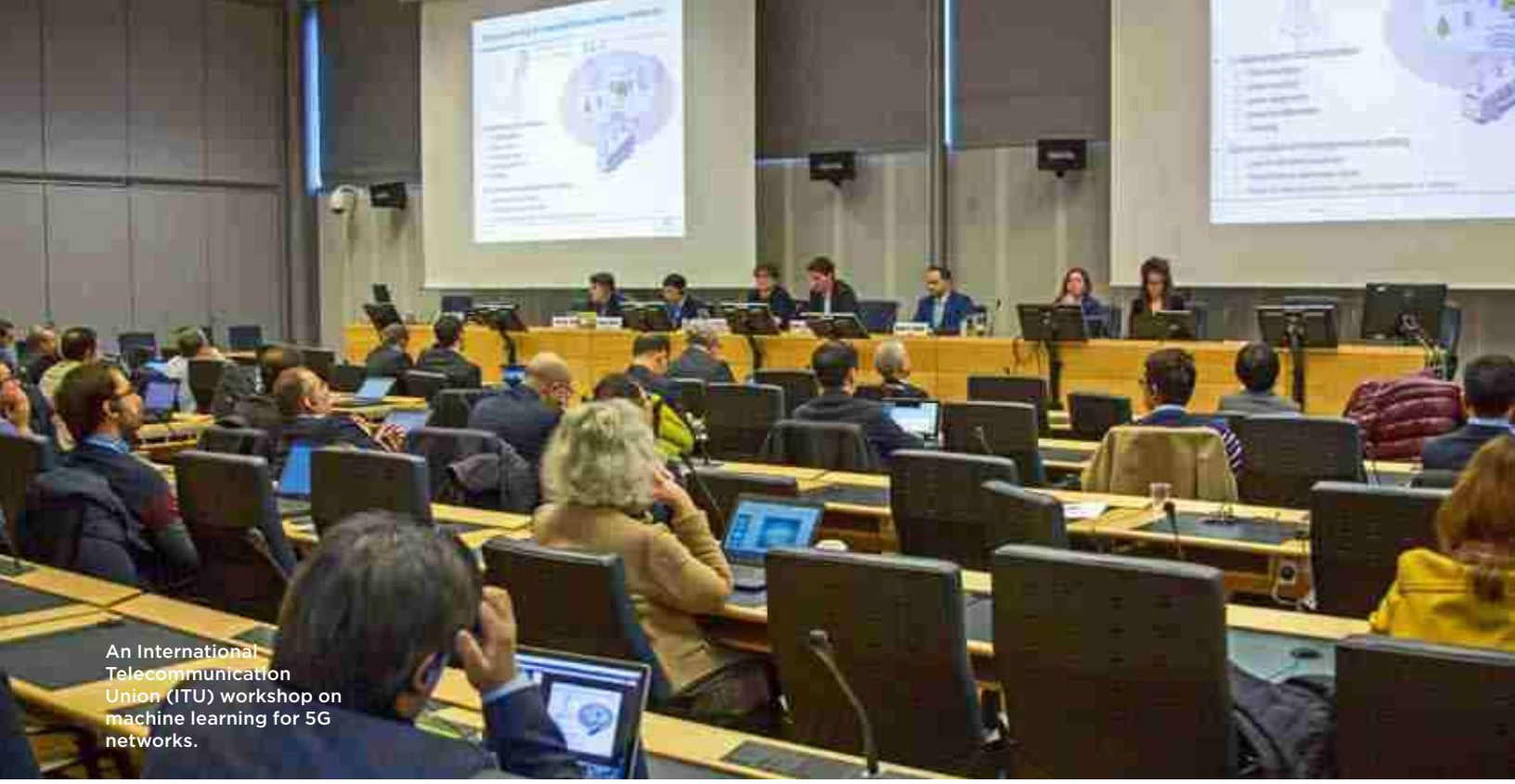
Nearly all of the incentives, in fact, align in the opposite direction. To a great extent, **all states have powerful incentives to develop technologies as swiftly as possible, consequences be damned**. The reasons are clear. The money to be made from developing breakthrough commercial technologies is in some cases almost unimaginable, reaching

CONSUMER DIGITAL BILL OF RIGHTS

This recommendation is that such rights be codified in congressional legislation.

- **PERSONAL CONTROL:** Consumers have the right to control the personal data companies obtain from them. Consumers have the "right to be forgotten" (the right to limit or withdraw consent for the use of their data). Data should not be stored indefinitely.
- **TRANSPARENCY:** Consumers have a right to easily accessible and understandable information about companies' privacy and security practices. Companies should explain in clear language what data is required from consumers, why it is necessary, how it will be used, if and when it is deleted or shared with third parties.
- **CONTEXT:** Companies should limit the collection, use, and disclosure of personal data consistent with the specific and explicit context and purpose for which it was provided. Personal data requested should be limited to what is necessary for the transaction.
- **MINIMALISM:** Personal data requested by companies should be limited to what is necessary for the transaction or relationship.
- **SECURITY:** Consumers have a right to secure, responsible, and accountable management of their data. Companies should make all reasonable efforts to minimize risks and protect against unlawful use, loss, or damage to data. Consumers have a right to timely information regarding any security breaches involving their data.
- **ACCOUNTABILITY:** Companies controlling personal data should be legally accountable for abiding by this bill of rights. Companies are under enforceable contractual obligations for data shared with third parties.

This list is drawn from a Consumer Privacy Bill of Rights drafted under the Obama administration (https://obamawhitehouse.archives.gov/the-press-office/2012/02/23/fact-sheet-plan-protect-privacy-internet-age-adopting-consumer-privacy-b) and the EU GDPR (https://advisera.com/eugdpracademy/gdpr/).



An International Telecommunication Union (ITU) workshop on machine learning for 5G networks.

into the trillions of dollars for tech-sector dominance. The national security reasons are even more powerful. Ceding technological primacy to one's rivals is a sure-fire way to end up on the losing side of any future war. Such fears drive the world's great powers to develop shock-and-awe technologies, in the hope that doing so will provide security and power in an insecure world. Although Silicon Valley today is treated as a private-sector-led enterprise, its history is far more complicated. Silicon Valley exists largely because decades ago, the US government decided it had to win its superpower showdown with the Soviet Union. It invested heavily in science and technical research, sending billions of dollars and myriad forms of other support to places like the Valley.

The antidote, of course, rests with diplomacy. What can be built can be managed. The task is to modify existing agreements to fit new circumstances and, when necessary, create new structures entirely. Multilateral forums like the G20 could be useful, for example, by adding a Future of Work subgroup. A few complex issues that need to be addressed have been highlighted in Section III above. Although the list below is not exhaustive, it covers some pressing global governance questions.

RECOMMENDATIONS

- **WTO:** The WTO should launch sector-specific, comprehensive global trade rules on digital commerce, building on previous tech agreements and on TPP rules. Restarting negotiations for a US-EU TTIP accord that adopted similar digital commerce provisions would be a big step toward setting global rules. In addition, the WTO should oversee G20 efforts to identify emerging technologies (e.g., AI, synthetic biology) requiring rules and form working groups to shape prospective sector-specific agreements.

- **5G:** Compatible global standards for 5G broadband will be critical to realizing the benefits of IoT. As discussed above, the ITU public/private working groups should be brought into a G20 dialogue if they fail to reach an outcome in harmonizing standards.

- **Trans-Atlantic/Pacific cooperation:** The European Union, United States, Japan, South Korea, and Australia should cooperate on acceptable minimal standards on a host of issues, e.g., privacy standards. They should push back on discriminatory Chinese trade and industrial practices, while encouraging reciprocity on tech investments and cross-border acquisitions. Parallel US-China and EU-China bilateral investment treaties could provide a framework for reciprocity.

- **Monopoly practices**: These include remedies to control the growing power of big tech (and consequent growing potential for monopolistic behavior), using some combination of antitrust and/or utilities-like regulation. A key public-interest arena concerns rules for the use of personal data. With GDPR (discussed above) and penalties inflicted on big tech monopoly practices, the EU has provided a benchmark. A cabinet-level US-EU-Japan-South Korea dialogue aimed at reaching consensus policies should be

ITU/D. WOLDU/FLICKR

considered. The United States, in consultation with the European Union, should conceive a consumer digital bill of rights, compatible with GDPR (see box on page 63 for notional list).

- **New standards and norms**: Developing standards, limits, and norms for AI/robotics and synthetic biology/genomics would be beneficial. Such an effort would probably be best started with a working group composed of the five major players—United States, Germany, China, South Korea, and Japan—perhaps under the auspices of the G20.

- **Intellectual property**: Given stalemates in multilateral forums, governments should focus on creating more bilateral and regional agreements that are consistent with strong IP norms. When such agreements are between developed and developing countries, they should contain provisions for IPR capacity-building and assistance (cross-training, expert advice, and so forth) in the developing countries. Multilateral institutions such as WIPO will continue to have a critical role to play in the global IP system, through administration of the Patent Cooperation Treaty, the collection and rigorous analysis of global IP data, programs to strengthen national IPR systems, and of course providing multilateral forums for IP diplomacy—as contentious as such forums can be. All of these functions are indispensable to the smooth functioning of global innovation and should not only be maintained, but enhanced.

4. What are the foreign and security policy implications of tech innovation?

The security dilemma is the central problem in international relations: as states exist in a (more or less) anarchical global system, they have every incentive to ensure their own survival through preparation for warfare. Such preparation includes developing, or at least having access to, cutting-edge warfighting technologies. A race to create the latest military technologies therefore is built into the global system's DNA.

The exact implications of tech-driven innovation are open and continuously evolving. The Chinese concept of Comprehensive National Strength is a fair place to start. According to this concept, national power is the sum of economic, technological, political, and military strength. Given that new and emerging technologies are primarily dual-use, they are an outsized metric in that equation. Russian President Vladimir Putin's comment on AI, that "whoever becomes the leader in this sphere will rule the world," is almost certainly an overstatement. Any advantage will most likely be temporary. Technological capabilities are not zero-sum (China's advances do not necessarily mean US losses). Nevertheless, new technologies do have profound national security implications, a few of which can be listed here:

- Digital commerce, particularly the growing capabilities and utility of 3D printing, which localizes production, and the growth of more efficient, renewable energy—which is leading to a post-petroleum era—will change the patterns, if not the nature of globalization and/or de-globalization during the coming two decades. Supply chains are likely to become more localized. This could impact how nations calculate their national interests and result in economic dislocation and disarray. For example, ASEAN economies thrive on a global supply chain.[260]
- Probably the most dramatic impact of technology is on the future of warfare, from weapons to logistics, to the battlefield itself: 3D printing parts, even weapons, nano-manufacturing weapons, drones, body armor, use of cyber, nonkinetic weapons, use of electromagnetic spectrum, (e.g. electric lasers, space capabilities), and more precise real-time battlefield command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR).
- To the degree that the United States or China operationalizes military application first, either country might have a strategic advantage in a conflict scenario. Obvious examples include swarms of smart drones, disabling C4ISR capabilities, and autonomous weapons making real-time decisions to changing conditions.
- The pace of tech-driven events will complicate national security decision-making.

As mentioned under question three, diplomacy is a means for addressing the security implications of emerging technologies. Indeed, states have created diplomatic agreements that attempt to keep novel weapons systems—the product of tech development—at bay. Perhaps the best examples are the agreements prohibiting the use of chemical and biological weapons, dating to the 1925 Geneva Protocol. Although states have not always followed their prohibitions, these agreements have created important legal and ethical norms around the use of such weapons.[261]

Yet at the same time, diplomatic agreements limiting the possession or use of the world's most dangerous weapons are rare. Moreover, they are imperfect instruments, with states finding ways to cheat or avoid altogether the agreements' constraints. Perhaps worst of all, they frequently come into existence only after the weapons have been invented and used in warfare. It took the horrific use of chemical weapons during World War I to create the first international attempts to constrain them. It took the invention and use of the first atomic bombs during World War II, plus the frightening near-death experience that was the

Cuban Missile Crisis of 1962, to create enough consensus for the nuclear test ban and non-proliferation treaties.

For this century's challenges, a key question should be whether binding international agreements concerning similarly novel and dangerous weapons can be created before they have the chance to be used.

This should be a "Sputnik moment," and to many in the national security field, it has been.

RECOMMENDATIONS

- **UN:** The UN system is the logical focus for multilateral diplomacy around the invention, possession, and use of novel and dangerous weapons. The UN has dual roles here: first, to help set an agenda for interstate negotiations; second, to be the forum within which states can arrive at binding agreements. One such area concerns the rules for future conflicts regarding AI/robotics and drones. Unfortunately, such rules are nonexistent. Under the Convention on Certain Conventional Weapons, which entered into force in December 1983, the UN has begun an expert dialogue on autonomous weapons.[262] Although supporting such UN-directed efforts appears to work against the interests of military powers, history shows the opposite to be true. In the twentieth century, states found that they had to put the novel-and-dangerous-weapon genie back in the bottle, after an ugly first use that in retrospect made the world less safe. States, including the largest military powers, should support UN-directed agendas that explore preemptive solutions to emerging-tech weapons.
- **Bilateral strategic dialogues:** As is true across other foreign policy spheres, multilateral institutions are only one piece of the puzzle. States, in particular the greatest military powers (the United States and China), should engage in strategic dialogues that address novel and dangerous weapons systems.

5. Will the United States keep its innovative edge?

This study confirms the urgency of recommendations made in the authors' 2017 report regarding the risks to the United States' technological edge.[263] The authors' views echo numerous alarms in National Science Foundation (NSF) and American Association for the Advancement of Science (AAAS) reports for more than a decade.[264] All the warning signs are even more lucid now than one year ago. This should be a "Sputnik moment," and to many in the national security field, it has been. For example, the Pentagon's "Third Offset" strategy was a direct response to the need to accelerate development and deployment of emerging technologies. However, perhaps because of the absence of a single, shocking dramatic event—like the 1957 Soviet Sputnik launch—that crystallizes the challenge, perhaps due to the incremental and diffuse nature of the problem in an era of information overload, the present situation clearly has not been the catalyst for the development of a targeted US strategy.

The USSR's launch of Sputnik 1 in 1957 spurred the United States to create the Advanced Research Projects Agency (ARPA, later DARPA), which became key to the United States' astonishing run of tech-innovation success. Congress also enacted the 1958 National Defense Education Act, which provided low-interest loans for college tuition to students majoring in math and science. Additionally, federal financial help was extended to foreign language scholars and area studies centers to help grow experts for later employment in national security agencies. The US government also provided financial assistance—primarily through the National Defense Student Loan program—for thousands of students who would be among the growing numbers enrolling at colleges and universities in the 1960s.

In recent years, discussions of another Sputnik moment have reentered the US policy arena. In his 2011 State of the Union address, President Barack Obama "appealed for the Republicans to co-operate to 'win the future' and said the present generation faces its 'Sputnik moment,' requiring government investment in research, infrastructure and education."[265] Then Secretary of State John Kerry talked about the US facing another Sputnik moment in relation to green energy.

More recently, President Donald Trump's National Security Strategy (NSS) stressed that the United States needs to take the lead again on innovation: "To maintain our competitive advantage, the United States will prioritize emerging technologies critical to economic growth and security, such as data science, encryption, autonomous technologies, gene-editing, new materials, nanotechnology, advanced computing technologies, and artificial intelligence."[266]

Yet despite this mention in the NSS, many are concerned that the current administration does not understand the urgency of the situation and may have an anti-science bias. Treasury Secretary Steven Mnuchin has cavalierly dismissed concerns that automation will displace US workers. The White House's Office of Science and Technology Policy has been decimated—now, nearly a year-and-a-half into the administration—and there is no office director. The White House log concerning possible hiring of a new director was recently released, showing desultory interest at best for identifying a successor to former director John Holdren.[267]

The administration has sought to cut many civilian agencies undertaking R&D, particularly on any energy- and climate-related topics. The most recent FY 2019 budget proposal, if enacted, would hit the Environmental Protection Agency (EPA), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA) and US Geological Survey (USGS) hard. Defense programs, such as DARPA, have been spared and would probably benefit from the increased defense spending agreed to between the administration and congressional leaders. Congress also intervened this past year to restore some of the cuts to the civilian agencies.

A more alarming trend is that federal funding of basic research has been cut by many administrations. Historically, the federal government has provided the bulk of the nation's spending on fundamental science (basic R&D), defined as studies undertaken without "specific applications towards processes or products in mind."[268] In recent years, however, the share of basic research funding provided by the federal government has been slipping, from roughly 70 percent in the 1960s and 1970s to an estimated 44 percent in 2015.[269] Economists such as Mariana Mazzucato contend that risk-taking and entrepreneurship by the United States in past decades has had a big economic payoff. Apple would not have achieved its huge commercial success without DARPA and other federally funded programs providing it with such critical technologies for the smartphone as the Internet, GPS, touch-screen display, and Siri.[270]

As discussed above, there are some hopeful signs that the current administration is beginning to grasp the situation, particularly about AI. In his FY 2019 budget request, President Trump cited AI as an R&D priority. At the recent AI summit, the White House established an inter-agency committee to coordinate and mobilize government efforts and oversight.[271] At a March 2018 G-7 Innovation Ministerial, the US negotiated a statement to enhance adoption of AI technologies and collaborate with allies on research, best practices, and standards.[272]

But, the degree to which such US intentions will be translated into sustained action remains highly uncertain and there is no guarantee that the United States will remain at the top of the tech-innovation world. This report makes it clear that there are fierce and capable contenders for global leadership, China first among them. For the United States, finding the right policy mixes will not be the biggest challenge. Rather, the biggest challenge is about willingness. To retain its prominence, the US needs to take a good hard look at itself. The question is whether it is capable of doing so.

The recommendations contained in the authors' 2017 report on US innovation are, if anything, more relevant today than one year ago. These recommendations are updated below.

RECOMMENDATIONS

- **Inclusion:** The United States might still have the most robust tech-innovation system in the world, but it does a poor job of ensuring that the bulk of its citizens can participate in that system. Federal, state, and local policies need to be crafted or revised to enable more people to prosper within an economy that is increasingly driven by technological changes. To do so, the authors recommend:
  - reversing trends in higher education funding, which increasingly have burdened students and their families;
  - incentivizing STEM training, from primary through higher education, alongside critical thinking skills;
  - creating a technology adjustment strategy, defined as a comprehensive skills and social safety net package, wherein workers displaced by technological disruption can find the tools and resources needed to upskill themselves and reenter the workforce;
  - revisiting postwar social protection programs, which are based on lifetime employment rather than today's gig-economy realities; and
  - per the recommendations listed under question two above, crafting policies and programs to attract and retain groups of people who are underrepresented in the tech sector, including women, minorities, and lower-income groups.

- **Geography**: The United States has a highly uneven economic geography, with some places doing well but many others falling behind. This imbalance applies to the tech

The Saturn V rocket was used by NASA between 1967 and 1973 to launch US astronauts to the moon.

STUART RANKIN/FLICKR

Everyone has foosball — so to speak. Other countries have figured out the formula to attract and grow an entrepreneurial class.

sector as well, as the 2017 report details, with a raft of undesirable consequences. To avoid a worsening of this geographic imbalance, federal, state, and local governments should provide high-quality infrastructure, appropriate to the needs of the twenty-first century economy, and otherwise ensure that more places around the country are attractive destinations for talented workers, investors, and entrepreneurs.

- **Everyone has foosball**: The authors' on-the-ground research around the world yielded many important insights; one of the more visceral is that *everyone has foosball*. When the authors walked into startups in just about every country visited, the feel was exactly the same as in Silicon Valley: open floorplans, free-food kitchens, cool lighting, and fun games—ping pong and foosball tables. Although this example might seem a bit superfluous, the underlying lesson is important. Other countries have figured out the formula to attract and grow an entrepreneurial class. US policymakers have to recognize that the world's best entrepreneurs can locate just about anywhere they wish, not just in the United States. Other countries are seen as highly attractive destinations for talented people, a point that entrepreneurs around the world often mentioned. To remain a competitive destination for entrepreneurs, US policymakers need to craft supporting environments for them. Besides quality-of-life considerations, measures include linking entrepreneurs with scientific and research institutions; ensuring the ready availability of intermediary institutions such as accelerators, incubators, and co-working spaces; fully funding R&D programs that assist startups with promising but not-yet commercially viable technologies; and strengthening or creating programs that help startups access investment capital.

- **Tech transfer**: Everywhere in the world, it seems, transferring technologies from universities and research institutions into the commercial bloodstream is a real challenge. Although US universities tend to perform well relative to other countries' research institutions, they are far from perfect vessels. To improve their performance, universities need to sponsor intermediate institutions—incubators, accelerators, research parks, innovation offices, and the like—that collectively assist the tech transfer process; encourage entrepreneurialism among faculty, staff, and students; and constantly benchmark against global tech transfer best practices.

- **The feds**: Last but certainly not least, the US government has a critical role to play in retaining the United States' innovative edge. Only the federal government has the power or resources to do certain things, for example, funding the bulk of the nation's public R&D (including much of its pure science). The authors' 2017 report recommended the creation of standing expert commissions and interagency committees to monitor the US innovation system and make recommendations on how to improve it. It recommended that the United States continue to robustly fund R&D, which provides the fuel for the nation's tech-innovation system. It called for linking R&D funding to other elements of that system, for example, linking it to university tech transfer improvements. However, these recommendation pale in comparison to the most important point: while the federal government has been instrumental in building the most formidable tech-innovation ecosystem in the history of the world, the system is now backsliding for fiscal or ideological reasons. All US competitors have zero qualms about giving their national governments starring roles in building their ecosystems. The federal government is an irreplaceable cog in a magnificent innovation machine. The United States would be wise not to eviscerate it.

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SPECIAL SECTION

GLOBAL INNOVATION PROFILES

China: Up Close and Personal
BY SAMUEL KLEIN

While in Shanghai, I walked into a Coco, a popular bubble tea store in China, and scanned the menu on a TV screen, finding my favorite drink at the top: Zhenzhu naicha (珍珠奶茶). I reached for seven renminbi in my wallet, but I noticed the other customers pointing their cell phones at a QR barcode on the TV screen (circled in yellow below). This was China's mobile payments revolution playing out in real time. I had heard of China's leadership position in mobile payments, (in 2016, China had $790 billion in mobile payments, nearly eleven times more than the United States[273]), but seeing it up close was still a shock. Customers simply walked in, opened an app in WeChat, placed their order, and paid. They could even do so from nearly thirty feet away at the back of the line, which at a place like Coco is always out the door. When witnessing the ease and speed of mobile payments in action, whether it was renting a bike or ordering food from a street vendor, I could not help but be amazed. This ability barely existed the last time I visited China, four years ago.

Seeing such transformation raises a few questions: Is China finally shedding its "copycat" reputation and becoming a global front-runner in technological innovation? Could China leapfrog the United States and other technology leaders in other areas, like it did with mobile payments? Or is this example just indicative of "innovation with Chinese characteristics," where Chinese companies make small refinements to existing technologies for the local market, rather than inventing something truly new and cutting-edge? To answer these questions and gain a broader perspective of Chinese innovation informed by on-the-ground reporting, the Atlantic Council sent a research delegation to Beijing and Shanghai in the fall of 2017 to meet with policymakers, academic researchers, entrepreneurs, business leaders, venture capitalists, and startup incubators.

From these meetings, it became clear that China understands the fundamental building blocks needed to spur innovation and is taking concrete steps to encourage their development. Public and private investment in R&D continues to rise; more students are graduating with degrees in science, technology, engineering, and math; and the number of scientific papers published and patents filed is increasing. Additionally, the country is acutely aware of the key areas in which it lags, an important point for ensuring successful strategic planning. While many interviewees still view the United States as the preeminent example of tech innovation and as a guide for what China needs to do, at the same time, the Chinese are going their own way, adopting novel approaches and practices that are tailor-made for the political, economic, and social realities present in China.

While in Beijing, Atlantic Council researchers met with several science and technology policy researchers at **Tsinghua University**, one of China's most prestigious research universities. Though several different university rankings exist, Tsinghua is often ranked comparatively with the Massachusetts Institute of Technology in the United States.[274] Tsinghua has twenty schools across a variety of disciplines but is most well-known for its science, engineering, and mathematics programs. Approximately fifty thousand students attend. As one of China's leading

Bubble tea store in Shanghai. The yellow circle shows a QR barcode used for mobile payments.

research universities, it also focuses on basic and applied research. Other comparative universities in China include Peking University in Beijing and Fudan University in Shanghai.

When asked to assess China's innovation ecosystem, the Tsinghua researchers answered by using the United States as a foil, describing how the country still dominates China in several key areas. They pointed to the United States' world-class universities; an open and collaborative environment conducive to the spread of ideas and the commercialization of technology; and a historically consistent commitment to investing in R&D (though recent trends may suggest otherwise). These experts were not fearful of the United States' preeminence nor deterred from the possibility that China would become a world innovator itself. Rather, their observations about US strengths left the impression that they were closely studying and rapidly integrating the ingredients necessary to foster innovation. After all, they did mention that China is a fast learner.

[China] recognizes that a global competition is under way and is rapidly taking steps to gain a first-mover advantage.

Underscoring this awareness, several Chinese individuals—not just at Tsinghua, but during other meetings as well—repeatedly referred to how the number of Japanese Nobel laurates far outweighs the number of Chinese winners. The country recognizes that a global competition is under way and is rapidly taking steps to gain a first-mover advantage.

To see this in action, one only has to walk fifteen minutes across Tsinghua's campus to **X-Lab**, a university-affiliated incubator—or educational platform as the Chinese prefer to call it. The lab, which works with students, alumni, and faculty across Tsinghua's twenty schools, takes on a more educational mission than typical startup incubators. The staff focus on teaching students about entrepreneurship and cultivating their talents, rather than simply investing in potentially lucrative business ventures to turn a profit. In fact, they are a nonprofit and do not take equity in the start-ups; they aim to give those with science and engineering backgrounds the business knowledge and skills they need to have an entrepreneurial mindset.

The projects at X-Lab span a wide range of industries, from healthcare, energy, and the environment to media, hardware, and education. Some specific examples include startups working on robots that carry heavy loads in factories, biodegradable plastics made from seawater, and smart homes and remote connectivity. Based on X-Lab's facts and figures, the incubator has worked with over 1,133 teams and incorporated over 464 startups since its launch in April 2013. To date, 152 X-Lab startups have raised over $293 million (1.93 billion RMB) combined.

X-lab offers a Silicon Valley-esque work space; support for intellectual property and marketing; and a variety of special events, demo days, and training programs. The incubator also works closely with many industry partners from around the world, helping students to get practical advice and business experience. These partners seem to believe in the value of working with X-Lab and its startups, as they provide just over 50 percent of X-Lab's funding.

Of course, the fact that X-Lab looks and feels like Silicon Valley does not mean China is suddenly the world's leading innovator. However, it does show that spaces exist in China for entrepreneurs to cross-pollinate and take risks—two key ingredients necessary for innovation. X-Lab's roster of startups is impressive, its network of private industry partners spans the globe, and its focus on educating the next generation of entrepreneurs is oriented for the long term. These are important developments to consider when assessing China's innovation ecosystem. Notably, X-Lab is but one of dozens of organizations like this dotting China's eastern seaboard. Though unique in its focus on education, many other incubators have risen in cities like Beijing, Shanghai, and Shenzhen.

Beyond the growth of accelerators and incubators, to get a feel for just how excited and optimistic people are about the future innovative capacity of China, look no further than the venture capital industry. Between 2006 and 2016, early- and later-stage venture capital investment in China increased by 3,000 percent, from $1.1 billion to $34.1 billion dollars.[275] The majority of that growth occurred from 2013 to 2016 alone, (from 2006 to 2013, venture capital investment only averaged $4.3 billion, before shooting up to $34.1 billion).

A few venture capital firms at the center of this activity include **Qiming Ventures** and **Baidu Ventures.** Qiming, with locations in Shanghai, Beijing, Hong Kong, and Suzhou, invests in companies across China in industries including healthcare, information technology, and clean tech. They also have recently opened offices in Cambridge, Massachusetts; Palo Alto, California; and Seattle, Washington

OPPOSITE PAGE: SAMUEL KLEIN

Chinaccelerator, a Shanghai-based startup accelerator.

to invest in US-based healthcare companies, reflecting growing Chinese investment in the United States—a major emerging trend. Baidu Ventures is loosely affiliated with the Chinese technology giant Baidu, mostly relying on that company for funds but making investment decisions independently. Baidu Ventures is more of a connector organization, helping to provide emerging startups with Baidu's foundational technology, plus capital, to tackle new challenges. One implication of this is that Baidu can spread its ecosystem of foundational technology solutions across China through the startups that Baidu Ventures invests in.

When China's venture capital scene first started in the late 1990s, it consisted of a few firms, nearly all of which were multinational (rather than Chinese-owned and -operated) and managing US dollar-dominated funds. Fast forward to today, and the landscape has changed substantially. Interviewees estimate that over one thousand venture capital firms are active in China, with the portion of RMB-denominated funds becoming a dominate force in the market.[276] Funding from state-owned enterprises and government "guidance funds" has helped fuel this explosion of venture capital. Most important, these state-backed funds can strategically direct their investments toward key emerging technologies that China hopes to gain an advantage in, such as AI.[277] While bureaucracy and corruption associated with government-backed funds may slow down returns on investment to a point, the massive amounts of money being invested probably makes this a moot point.

Taking high-speed rail—a self-described Chinese innovation, (more on that below)—to Shanghai, approximately 660 miles to the southeast of Beijing, the authors of this report had an opportunity to further explore China's startup ecosystem by speaking with a few Chinese entrepreneurs who are growing their startups at the incubator **Chinaccelerator**. We spoke with representatives of three companies, one that uses AI to help Chinese students living abroad find jobs, another that helps overseas companies build online-to-offline distribution channels for its products in China, and a third that uses AI science and data analytics to support sports marketing firms. Each of the companies' CEOs were optimistic about China's future success as a global tech innovator, saying that is "only a matter of time." They

SAMUEL KLEIN

pointed to the availability of capital and the government's willingness to invest as two key reasons for their optimism.

At the same time, these entrepreneurs pointed to several challenges they feared could derail the country's recent success. The exchange of knowledge and best practices remains an obstacle in China, which continues to place restrictions on information flows. Whereas innovation hubs like Silicon Valley champion the importance of openness and helping one another, such a culture has yet to take hold and sprout in China. Beijing is less friendly toward start-ups founded by foreigners trying to establish a foothold in the country. It is much harder for such startups to receive government grants, for instance. These young entrepreneurs echoed many of the same worries about China's innovation ecosystem as those brought up by the researchers at Tsinghua—namely that China only has a few world-class universities compared with other tech hubs and that fostering collaborative environments remains difficult.

Speaking with these young entrepreneurs also provided a window into the human capital and talent pool available in China's innovation ecosystem. However, the trends here are mixed. On the one hand, some experts were very enthusiastic about the Chinese talent pool, pointing to the millions of STEM graduates that universities churn out every year as well as the uptick in Chinese scientists and researchers returning from abroad. These experts further explained that the younger generation of Chinese are very early adopters of new technologies and are eager to experiment—critical characteristics for the creation and spread of new technologies.

On the other hand, others pointed out that large quantities of STEM graduates do not necessarily compensate for their poor skills, noting that China is still behind other countries in terms of the number of prestigious universities in the country. These experts also explained that many Chinese technology companies will only hire graduates from a few top-level schools, such as Tsinghua or Fudan, which then causes a shortage of talent—despite the large number of graduates across the country. Societal pressure to attend top schools rather than a vocational or community college also exists in China, further exacerbating the talent gaps—a trend that also exists in the United States. Researchers at Tsinghua are considering how China can encourage the growth of community colleges that produce employable graduates to fill gaps in the talent pool. They see the United States as a model.

There is no doubt that innovation in China is taking hold and becoming a strong and robust engine leading to the creation of new technologies. However, at times it appeared the Chinese may have slightly different definitions of what innovation is and looks like when compared with how it is viewed in the United States and elsewhere around the world. A few interviewees used the word "innovation" to describe the adaptation of existing technologies for the Chinese market. For example, China's success in building high-speed trains, (it now has the world's largest amount of high-speed rail lines),[278] was often cited as an example of its innovation prowess. However, the breakthrough technology behind these trains' success was primarily developed by the French and Japanese. While improving on an existing product is certainly one form of innovation, it is not necessarily indicative of a capacity for truly cutting-edge, revolutionary innovation on the level of the development of the Internet or GPS, for example. However, AI may prove to be an area in which China leads in actual cutting-edge technology, as the country aligns significant monetary resources and human capital behind the research and development of this emerging technology.

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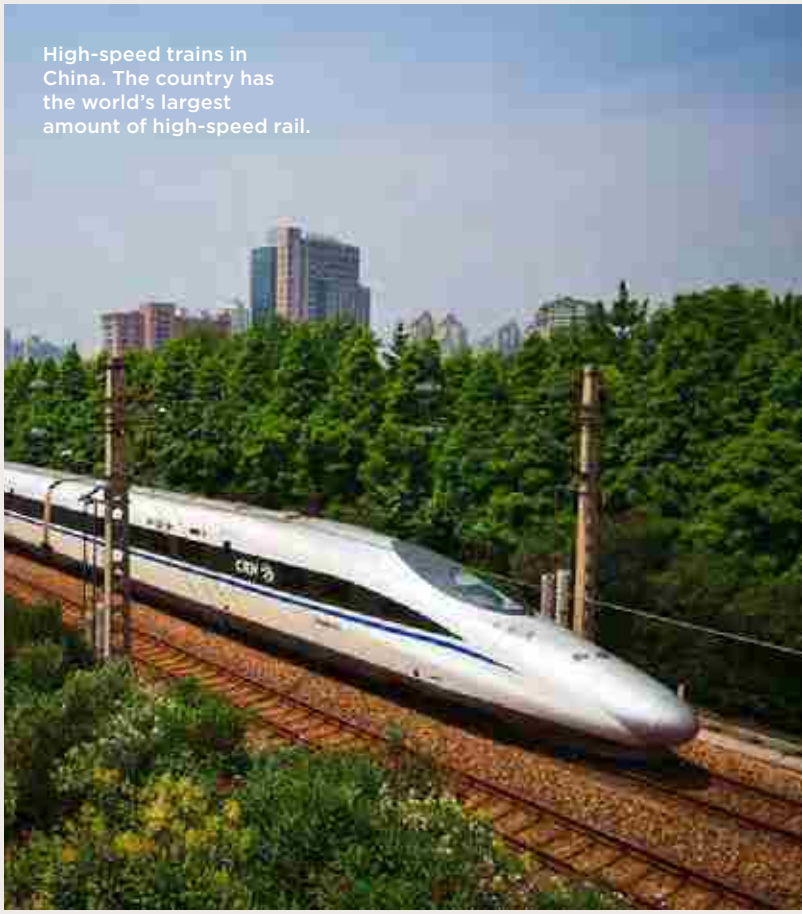

High-speed trains in China. The country has the world's largest amount of high-speed rail.

MR THINKTANK/FLICKR

France: Confounding Stereotypes

Stereotypes die hard, and global perceptions of France's economy are no exception. France has a reputation for having a short work week, high taxes, and unimaginative business practices. This stereotype might be deserved in some respects, but in others it could not be less true. France has a robust tech-innovation ecosystem that is growing in global significance. Paris, at the forefront of this effort, is forging a reputation as one of the world's most vibrant tech hubs.

Innovation indexes show that France is both competitive in the world's knowledge economy but not yet at the global pinnacle. The World Economic Forum's 2017 Global Competitiveness Index is a case in point. It ranks France twenty-first out of 138 nations across twelve categories, knocking the country for its restrictive labor market, "inefficient" bureaucracy, and high taxes. However, the index gives France a stronger seventeenth place for innovation, reflecting an upward trend in innovative capacity, quality of research institutions, R&D spending, and patent applications.[279]

France employs aggressive public policies to boost entrepreneurial activity, including R&D investment, startup investment, tax breaks, and other support. The country suffers from low private investment in R&D, owing to the relatively small size of its tech sector and large firms'

Station F, the world's largest incubator, located in Paris.

SHARON VANDERKAAY/FLICKR

reluctance to invest in tech development. A 2017 government survey of large companies, for example, found overwhelming support for tech startup acquisition but very little actual investment (among surveyed firms, only 0.1 percent of purchasing budgets went to startups).[280]

For years, the government has been injecting funding to boost France's overall R&D share.[281] In 2016, France placed third among OECD countries in central government support for business R&D.[282] BPI-France, formed in 2012 as a one-stop shop for public startup funds, has funded some 40,000 companies (many are not tech startups) through 48 regional offices. Tax breaks are another core tool. The most important is the CIR (*Crédit Impôt Recherche*), which allows a firm to deduct 30 percent of its R&D costs up to 100 million euros. If a firm collaborates with a public university, this tax break is doubled. While the CIR dates to 1983, the limits recently were increased significantly. This incentive is far more generous than elsewhere in Europe and is important for attracting R&D investment.

In 2017, Station F, the world's largest incubator, opened in Paris.

Startup financing is robust in France. In 2017, French tech companies attracted $3.2 billion in investment—a nearly 50 percent growth over 2016 and a five-fold increase from 2013.[283] France ranks third in Europe, behind the United Kingdom and Germany.[284] Thanks in part to public investment, seed capital is more plentiful but capital for scaling is scarce. One problem—often heard elsewhere—is that foreign investors at later stages want the startup to relocate, perhaps to London or Silicon Valley. But interviewees describe investor maturation in France and believe that a positive shift is under way toward the domestic retention of successful startups.

France boasts outstanding science, but poor tech transfer, specifically from universities that discourage commercially applied research. Tech transfer tends to be initiated more by France's public research labs, which have crafted joint research efforts with private industry. As an example, CNRS (the National Center for Scientific Research) under the French education ministry operates some 126 joint research labs around the country.[285] Here, public/private research teams work together in common labs—often located at a university—on common projects.

Regarding France's geography of innovation, Paris is the most important French city by almost every measure. The greater Paris region boasts a huge R&D complex on the Paris-Saclay "cluster," which is responsible for 15 percent of France's industrial R&D and generates some 35,000 tech jobs.[286] In 2017, nearly half (46 percent) of France's 743 tech financing deals went to Paris-based tech companies; the next city on the list, Lyon, had 26.[287] As the largest city and national capital, Paris has always had an outsized role in the French economy. At the national level, however, this dominance leads to similar problems as Silicon Valley's dominance does in the United States: Paris's tech-innovation ecosystem is so well developed that investors have little incentive to consider other French cities.

Paris is home to well over two thousand tech startups, over one hundred incubators and accelerators, and scores of co-working spaces. An annual "VivaTech" conference draws some 68,000 entrepreneurs, students, academics, investors, and executives to Paris.[288] The city's government does its part, managing its own tech incubators, awarding innovation prizes, and encouraging tech solutions for the city's public challenges in, say, transport or carbon emissions. For these reasons and more, Paris rates well on global cities rankings. Startup Genome places Paris as eleventh in its 2017 *Global Startup Ecosystem Report*, while A.T. Kearney ranks Paris third in both of its global cities rankings.[289]

In 2017, Station F, the world's largest incubator, opened in Paris (the building is a refurbished railroad station). Funded by tech entrepreneur Xavier Niel, Station F brings entrepreneurs and startups, multinational corporations, tech investors, and government ministries together under a single and very impressive roof. Synergies abound. For example, Inria (France's public math and computer science agency) works closely with startups at the station, providing research support as well as its own IP, when appropriate, in exchange for a small percentage of equity.

Cultural shifts are an important part of France's burgeoning tech-innovation ecosystem. Interviewees consistently pointed to how entrepreneurialism is taking hold among workers, researchers, and students in addition to elites. Previously, entrepreneurs were not celebrated, whereas now they are. In years past, top engineering graduates at prestigious universities wanted to work for large corporations, whereas now many are willing to join a startup or create one themselves.

These shifts are also evident in the government's confident policies to advertise French innovation to the world and thereby overcome global stereotypes. France recently created a tech visa program to attract foreign entrepreneurs and a "French tech ticket" incubation program for foreign

French president Emmanuel Macron.

EUROPEAN PARLIAMENT/FLICKR

startups. The latter provides grant money, access to master classes, mentoring, and recruitment into a French incubator for one year. These and other efforts are organized under "La French Tech," a massive five-year-old public marketing program designed to both animate the French tech diaspora and raise the profile of French innovation abroad. La French Tech hosts side events at major global conferences (for example, Helsinki's Slush and Austin's SXSW). Domestically, it also awards French cities with a "French tech" label, with applicant cities going through extensive review processes.

For these reasons and others, interviewees were hopeful about the future. The 2017 election of Emmanuel Macron to the French presidency accounts for some of this optimism, as Macron is an innovation enthusiast who has proposed innovation-friendly policies such as a ten billion euro technology fund (Francois Hollande previously instituted several key reforms).[290] Data showing the strength of France's ecosystem keeps building, with some indicators showing the nation catching the continent's leader, the United Kingdom.[291]

Yet interviewees also had reason for caution. Attitudes toward failure are changing, but French business culture is still based upon pride and the view that failing is shameful. Some argued that France's passion for high technology development results in too much public focus on new tech development and too little on encouraging startups to solve practical problems using existing technologies. (Recall that Uber, one of the world's most disruptive startups-turned-unicorns, built itself upon existing digital technologies.)

Regarding Paris's future as a tech hub, interviewees were as bullish. Nevertheless, they also frequently listed city planning, brick-and-mortar worries: housing, transportation, and the high cost of living. Their concerns echoed those heard in almost every tech hub visited by the Atlantic Council over a two-year research period in the United States and around the world. Paris is not yet London in terms of the high cost of living. Yet all fear that as Paris's tech sector matures, the cost of living will only increase. The city already is more expensive than Berlin—Paris's tech-hub competitor—without commensurate salary differentials.[292]

Israel: Place and Flow

Israel is perhaps the best example of a tech-innovation ecosystem having both a strong sense of community (place) alongside a high degree of global connectivity (flow). This place-flow dynamic is rare and is provided by Israel's unique history and small size. Israelis who work in the tech sector possess an unusually high commitment to their ecosystem's success. This commitment is partly due to a strong national identity, partly to individuals' strong connections to one another (the small physical size of the ecosystem produces very high density), and partly to bonds forged during shared military service. When combined with Israel's many other strengths, these ties give the Israeli ecosystem an important competitive advantage.

The basic facts are impressive, especially given Israel's small size (population 8.2 million). In 2016, there were 7,435 high-tech companies in Israel, including 3,962 startups. About 309,000 people were employed in the former and twenty-two thousand in the latter.[293] Israelis create more than one thousand new tech startups every year, with the rate increasing. In 2016, Israeli tech companies raised a record $4.8 billion in investment capital, spread over 659 deals, mostly to companies in the software, communications, Internet, and life sciences sectors. This startup ecosystem is maturing, producing both large numbers of new startups and growing some into large companies such as Mobileye and Wix. Between 2012 and 2016, more money ($3.4 billion of the total $4.8 billion) went to mid- and late-stage startups than ever before, while seed funding—although still robust in absolute dollar terms ($172 million)—shrank to its smallest share of investment capital since 2012. Foreign investors have taken notice, pouring ever-larger sums of money into Israel's ecosystem. In 2012, foreign investors accounted for 31 percent of new capital invested in Israeli startups; in 2016, that figure was 60 percent.[294]

This tech-innovation success story is a product of Israeli culture. Contrary to what one might expect, Israel's fraught history has stimulated innovation, with adversity encouraging experimentation and risk-taking in addition to building resilience. From youth onward, Israelis are encouraged to be improvisational, inventive, and pragmatic. These features in turn mean that adult Israelis are impatient, driven, and "expect to fail," which is considered a positive as it breeds both proactive entrepreneurs and investors who are willing to lend to people despite previous failures. Time and again, interviewees offered this explanation for the country's success.

Israeli culture generates numerous strengths for the tech ecosystem. These include a shared sense of purpose, as indicated. The army is universally acknowledged as a critical factor here, bringing Israelis of diverse backgrounds together under often-extreme conditions. The bonds that are forged in the military last for years afterward, providing a networking service while acting as a social leveler. The army also gives young people access to high technology and the training needed to use it. Israel's human capital has been augmented by several immigrant waves, including a large influx of talented scientists during the 1990s after the collapse of the Soviet Union. Finally, Israel's strengths include its small size, which provides close physical proximity and a high density of tech workers (people in the ecosystem call it "two degrees of separation," meaning that everyone in the ecosystem is connected through a mutual acquaintance). Small size contributes to a strong identification with place and yet also forces Israelis to look outward—owing to the small size of the domestic consumer market, Israelis have to engage with the outside world and find markets abroad.

All of this adds up to a vibrant tech-innovation ecosystem that produces both quantity and quality. Israel not only produces a large number of startups, it also is increasingly important across multiple tech sectors, including cyber and IT, automobiles and transportation, AI, health and medical technologies, fintech, blockchain, drones, IoT, greentech (including agriculture and water technologies), and other areas. Israel's strong performance across so many fields is partly due its collection of talent in the digital economy. Israeli entrepreneurs are outstanding at using digital tools to tackle problems in nondigital sectors such as transport, health, and food.

There is a deeper explanation for Israel's tech innovation success as well. As one interviewee put it, Israelis long have fretted over the country's "hard problems," as in agriculture and water. Ensuring food and water security in a harsh desert environment forced the new country to become a global leader in "agri-tech" and water-related technologies. ("High tech in Israel began with agriculture," argue Dan Senor and Saul Singer in *Startup Nation*, their book about Israeli innovation.)[295] Yet history and ecology are only partial guides. Israel's leadership in auto-related technologies has no clear historical antecedent, rather it provides an example of a sector where talented Israeli entrepreneurs and engineers have identified various transport needs around the world and worked on finding digital solutions to them.

Today, Israel is home to dozens of "auto-tech" startups that have attracted some of the world's biggest carmakers to set up R&D centers in Israel and invest in Israeli companies. Israel has exceedingly talented people who are interested in tackling the world's most difficult challenges.

Israel's ecosystem benefits from decades of R&D investment. "There are no miracles," one interviewee said, by which he meant that no country can long be at the cutting edge of innovation without high R&D spending. In percentage terms, Israel is first in the world at 4.3 percent of GDP invested in R&D, with South Korea second at 4.2 percent.[296] The primary difference between the two countries is that Israel invests a larger share from private sources. Foreign investors, especially multinational corporations (MNCs), have discovered Israeli technology and talent and have become the dominant investors.[297] Besides investing directly in high-tech companies, MNCs have created 350 R&D centers in Israel. US and European companies are preponderant, but Asian countries—China, Japan, and South Korea in particular—are increasingly present as well.

This private- sector-led, pragmatic investment focus is by design. Decades ago, the Israeli government created a Chief Scientist office (now the Israel Innovation Authority, or IIA) to prioritize tech company funding. Among other programs, it created Yozma venture capital in the early 1990s, a now-legendary move that jumpstarted the VC industry.[298] The IIA has also funded incubators across different tech sectors, providing seed funding and other support to startups in fields such as healthcare.[299] The army is an important tech investor as well, primarily in cyber and IT, usually for very narrow applied research purposes.

Tel Aviv, Israel.

TWIGA_SWALA/FLICKR

Although universities conduct the bulk of Israel's basic science, on a relative basis they are starved of R&D capital. As in most countries, Israeli universities struggle with an internal cultural divide, a split between basic science and commercially applicable R&D. Israeli institutions own the IP of their employees and students, but individuals receive a share of any royalties. None of the major scientific research institutions in Israel—the Weizmann Institute, Technion, and Tel Aviv University—encourage entrepreneurial activity among their faculty, because they believe faculty should be producing basic science and (in the words of one interviewee) that "scientists don't make good entrepreneurs." University tech transfer strategies revolve around preparing university IP for the market and finding experienced entrepreneurs to assist in that process. Ramot, Tel Aviv University's tech transfer office, is staffed by entrepreneurs brought in from outside the university.[300] Israel pays a price, however. Some technologies simply take longer to mature—those in biotech, for example—and need more gestation inside Israel's research institutions, which are under-funded.

As for the future, the tech community is cautiously optimistic. All believe that the ecosystem's trajectory is straight up, but there are grounds for concern. One is a growing talent shortage at the high end, which is driving up labor costs and already forcing some Israeli tech firms to outsource some functions to other countries, in Eastern Europe in particular. In this case, Israel's small size works against it because the country simply produces too few engineers and scientists. Another is the dual economy problem, in particular the increasing wage gap between the tech and non-tech sectors. In Tel Aviv, the epicenter of Israel's tech ecosystem, most workers are not employed in technology.[301] As in California's Bay Area, the tech-generated higher cost of living is forcing many people out, including the celebrated "creative class," threatening to undermine Tel Aviv's vibrancy. Interviewees believed that this challenge is manageable, provided that the country can include more Orthodox Jews, women, and Israeli Arabs—all groups that are underrepresented in the tech sector.

Yet when asked to contemplate worst-case scenarios, interviewees' typical response was to say that Israelis don't think in such terms because if they were to do so, they'd never live in Israel in the first place. Yet many exceptionally talented people choose to put down roots in Israel, which speaks directly to their high resilience, strong sense of place, and attachment to their community.

Mexico: Hopeful Challenger
BY KATHERINE PEREIRA

Mexico used to be a country of monopolies, where big business colluded to force out competitors. Previous generations of business people had a low tolerance for failure and a tendency toward risk-aversion. Today, Mexico's pool of young professionals (over half the population is under twenty-nine) see failure as the first step toward success and refer to the phenomena as "the Silicon Valley effect extending into Mexico."[302] Political, economic, and social transformations are fundamentally reshaping Mexico and positioning it as one of the region's most innovative countries. In the last decade, venture capital investments, tech-savvy workers, and an ideal location—between the United States, one of the biggest markets in the world, and a rising Latin America with a growing middle class—has created the perfect environment for the startup scene to explode. Mexico now has some 160 fintech companies, 222 incubators, and 1,235 startups.[303]

Mexico boasts some impressive knowledge economy credentials. The World Economic Forum's Global Competitiveness Report ranked Mexico fifty-first globally in overall competitiveness (eleventh for its market size), and fifty-fifth globally in terms of innovation.[304] The World Bank ranked Mexico as the number one country in Latin America for an entrepreneur to start a business in, highlighting the regulatory environment's conduciveness to starting and operating small firms.[305] It estimated that it takes 8.5 days on average to create a company.[306] (In 2016, the government created the Sociedad Anónima Simplificada [SAS], which allows small businesses to establish themselves in a single day free of charge, requiring only an electronic signature and company name.[307]) Mexico has become a top producer of raw engineering talent, with prestigious universities graduating 130,000 engineers per year, more than Canada, Brazil, or even Germany.[308]

The large pool of qualified tech and finance professionals, combined with a large consumer base, has enabled e-commerce to take off in Mexico. In 2017, the International Institute for Management Development (IMD) World Digital Competitiveness Ranking ranked Mexico forty-ninth globally, but second in Latin America, providing a measure of the country's ability to use digital technologies to transform government practices, business models, and society. According to the ITU, the use of mobile phones in Mexico (85.8 percent) has now surpassed Internet use (43.5 percent).[309] On average, 21 percent of mobile phone users in Mexico pay for purchases via mobile phones with a forecast growth of up to 50 percent of the country's total number of mobile telephone users.[310] Linio, the biggest e-commerce platform in Latin America with a presence in eight countries, is just one large digital company that has taken advantage of the region's digital economy.

As the capital and largest city, Mexico City is at the center of Mexico's knowledge economy. Mexico City's modern infrastructure, access to investment capital, presence of accelerators and incubators, skilled workforce, and engaged local government have solidified this status. With attractive immigration laws for skilled foreign workers, companies easily recruit top talent to Mexico City. The metropolitan area's 24.4 million people provides a huge consumer base for innovators to pilot products and develop creative solutions to urban sprawl that can then be replicated around the world. Companies like Carrot, an electric car-sharing company, have boomed because they provide a solution to mobility crises in mega-cities through a more effective and efficient twenty-first-century transportation system.

Institutions are a critical part of this story. Public and private universities contribute scientific research and instill innovation into their curricula, helping students develop business plans, attract investors, and place them with incubators. The Consejo Nacional de Ciencia y Tecnologia (CONACYT), a federal government agency based in Mexico City in charge of promoting science and technology, provides scholarships for post-graduate studies. In the past forty-five years, CONACYT has granted 328,000 scholarships and has pledged to grant 200 more this year.[311]

Another federal government agency, the Instituto Nacional del Emprendedor (INADEM), focuses on promoting high-impact entrepreneurship by financing new business ventures and solidifying capital investments up to 50 million pesos by providing co-investment capital with a capped return. The Mexican government distributed $658 million in 2014 to an estimated 620,000 entrepreneurs, resulting in six thousand new companies and 73,000 new jobs, according to government statistics.[312]

Mexico now has some 160 fintech companies, 222 incubators, and 1,235 startups.

Mexican president Enrique Peña Nieto meets with employees of INADEM, a government agency focused on promoting entrepreneurship.

Startup Mexico (SUM), a private program that does not take any ownership stake in its incubated companies, has created over 130 companies.[313] Startup Mexico encourages collaboration in pursuit of high-impact startups that can reach international markets. Backed by both federal and local governments and initially funded by INADEM, SUM is the first entrepreneurship campus in Mexico. Entrepreneurs can acquire products or services helpful to their startup, take advantage of the co-working space, and attend events and courses. SUM has been expanded beyond Mexico City to Mérida, León, and Querétaro.

Regarding IP protection, Mexico's legal framework is mature, with a modern patent system that works fast and is considered transparent (Mexico ranks twentieth out of forty-five countries on the US Chamber's IP index).[314] Yet interviewees for this study mentioned a few IP enforcement issues. Patents have a jurisdictional (territorial) base, meaning patent laws are only to be enforced in a specific territory (state) rather than nationwide. The vast majority of patents created in the country are by foreign firms that patent their own IP in Mexico, signaling that Mexican firms see little value in getting a patent because of weak enforcement. While companies can get patents, officials who investigate cases can be bribed (bad actors often go unpunished).

The signing of NAFTA twenty-three years ago forced Mexico to align its intellectual property laws with its North American partners. Current renegotiations over NAFTA create an opportunity to modernize IP laws. A NAFTA modernization could include benchmarks against corruption and tariff reductions if patent laws are enforced, thus creating incentives to carry out the law.

If Mexico is to become a global knowledge economy leader, it will have to overcome several important challenges. One involves talent. The country attracts talent from abroad and manages to retain much of its own skilled workforce. However, after having proved their concept or gained the necessary experience, some entrepreneurs choose to move to Europe or the United States to pursue their ambitions. Part of the talent problem involves wages, which even for highly skilled workers are not yet competitive at a global level. Another challenge involves the "pay-it-forward" culture of collaboration among entrepreneurs, which is still new in Mexico and needs to deepen if entrepreneurial momentum is to continue. Still another involves inclusiveness. Although the country has made progress in education, only a small percentage of the Mexican population has a college degree in science, technology, and applied fields. More opportunities need to be created for low-income individuals, women, and the indigenous population in particular if the knowledge economy's benefits are to be more broadly shared.

Finally, Mexico's chronic problems, including corruption and weak rule of law, remain significant obstacles. Lack of transparency by the government and lack of enforcement of rule-breaking by bad actors are disincentives for firms to invest and grow in the country. Yeti, Urbvan, Reserbus, Skyalert and XM Radio were all startups that saw their growth potential vanish due to corruption and impunity. Innovation-friendly programs need to be made permanent and independent of political cycles in order to give greater certainty to tech investors. The government needs to create a legal framework for entrepreneurship, one that is more flexible and helps protect investors. The Sociedad Anónima Promotora de Inversión (SAPI) is one such step, designed to accommodate private equity investments and serve as a transition from a closely held corporation into a publicly traded company.

Despite these challenges, this is the best moment for entrepreneurs in Mexico. Millennials are willing to take risks and are looking for creative ways to solve problems. Universities, industry, and the government are generating new institutional and social formats for the production, transfer, and application of knowledge to address some of the world's toughest problems.

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PRESIDENCIA DE LA REPÚBLICA MEXICANA/FLICKR

South Korea: From Chaebol to Gangnam Style

If South Korea finds niches of cutting-edge technology in the unfolding transformation, it will be Seoul's S&T institutions like its Electronic Technology Research Institute (ETRI) that catalyze consumer electronics heavyweights like Samsung and LG as well as future startups and small- and medium-sized enterprises (SMEs). South Korea's global electronics prowess and embrace of the digital economy—the country is Asia's third largest e-commerce market—has positioned it well for the mobile economy. South Korea is the most wired nation in the world with 19 million households representing 99.2 percent of the population having access to the Internet, most with broadband.[315] The country is also ranked fourth globally on the World Bank's "Ease of Doing Business index.[316]

The energy and dynamism of this Internet culture is one of the intangibles, which, combined with the other ingredients of innovation—robust R&D, strong IP, adequate venture capital, a skilled labor force—has helped propel large-scale government efforts to boost SMEs and moves to foster a sustainable innovation ecosystem. In contrast to Japan, South Korea's efforts to accelerate innovation by moving from chaebol-driven to SME-driven growth are not directly government-run; rather, they are an effort of government support to foster something akin to a Korean mini-version of Silicon Valley.

South Korea's endeavor to foster a new growth dynamic has been under way primarily since the 2008-09 financial crisis. The previous government, under President Park Geun-hye, launched a three-year "creative economy" initiative. In partnership with seventeen *chaebols*, the government opened seventeen "innovation centers" around the country backed by more than $3 billion in investment funds for early (seed funding) and mid-stage startups, angel investor matching funds, subsidies, loans, guarantees, tax deductions, and other incentives. This program included incubators and public money for failing startups.[317] These efforts stimulated the venture capital industry, which grew by some $2 billion in the subsequent two years, with capital flowing less toward traditional industries and more toward startups.[318] Park's program supported 1,713 SMEs and startups.[319] The vast majority of startups have been in the ICT sector, gaming, social media, e-commerce, and food delivery with a handful of mature firms such as search engine NAVER and social media giant KAKAO and several unicorn startups—COUPANG, Yellow Mobil, and Ticket Monster.

After President Park's impeachment in late 2016, the South Korean government push was rebranded and enlarged by her successor, the government of President Moon Jae-in. Moon has promoted a South Korean campaign under the banner of joining the Fourth Industrial Revolution, creating a commission so named to create a blueprint to realize his goal. He has reconfigured agencies while injecting $9 billion in new investment funds to be created by 2020 in partnership with the private sector, $2.45 billion of which is designated for startups beginning in 2018. In addition, state-controlled financial lenders will make available up to $1.7 billion in loans available for startups.[320] Moon also rechristened a Ministry, that of SMEs adding "and Startups" to it, and announcing that it would select forty-eight venture capital firms to manage a $1.2 billion fund to finance fourth industrial revolution startups.[321]

All this lavish spending notwithstanding, South Korea's still-nascent startup ecosystem remains a work in progress. It has fostered more impetus for entrepreneurship among the upcoming generation. Nevertheless, the jury is still out regarding whether SMEs and startups will become the driver of the country's economy. At least 61 percent

EAST4 Parking Cowork Studio. Co-working facilities are increasingly popular in South Korea as spaces for innovative thought and design.

KANGHEE RHEE/FLICKR

Gangnam, Seoul.

of Korean tech startups and 81 percent of the country's venture capital are in Seoul's trendy Gangnam district (39 percent) – including Google's first Asian campus (Apple and Tesla also have offices there), and Seoul's satellite, Seongnam city (22 percent).[322] Due to their rapid proliferation and transient nature, exact numbers are difficult to ascertain, but there are some 30,000 SMEs and startups, somewhere between five hundred and seventeen hundred tech startups, the vast majority in the ICT sector. In addition, South Korea has some forty to fifty incubators and accelerators of varying sizes and quality (e.g., mentoring, funding access, etc).[323]

Questions abound regarding the quality and scale of Korean startups. The easy access to seed money/early stage investment has lowered the bar for entry. Although there are more than 120 VC firms, most are worth $200 million or under, as is the case with the small, but growing number of foreign VCs (e.g., YCombinator, Sequoia Capital) in South Korea. Many Korean startups face a "valley-of-death" problem. Several interviewees in the Korean startup community said that they fear that President Moon sees support for startups mainly as a jobs program—that Seoul cares more about whether they are a source of jobs than whether they make profits and scale up. In any case, South Korea's market size and difficulty competing globally with US, Chinese, and other startups have limited the abilities of South Korean startups to expand globally. Large-scale access to global venture capital is another limiting factor. "We need one big success, a global brand like Skype or Spotify to get attention and attract global VC," an accomplished tech entrepreneur in Seoul told the authors.

Ideally, the startup ecosystem is viewed by its advocates as a bridge to big companies. And as in Japan, many big firms see startups as an adjunct to their own R&D efforts. According to a McKinsey study, startups account for about 6.9 percent of GDP; that percentage could grow to 10.9 percent and provide 160,000 jobs by 2020 if a sustainable Korean startup ecosystem matures and is able to nurture later- stage startups.[324]

Certainly, building on its first-generation ICT success, South Korea is likely to be a major player in the next wave, an innovator in some tech areas (5G/ IoT is a likely area), and certainly adapting/absorbing innovation competitively. Samsung is making a big push into AI, even hosting an AI Summit in Silicon Valley in 2018. Similarly, South Korea's largest telecom firm, KT, is focusing on 5G, AI, and blockchain technologies.[325] To what degree Seoul succeeds in shifting its growth model away from the *chaebols*, or creates a hybrid growth model with a larger role for startups in combination with big firms, remains an open question.

DCONVERTINI/FLICKR

Sweden: Innovation Society

Sweden, like Israel, is an example of how a country's small size (9.9 million people) can be an advantage. Sweden's many strengths include a peaceful neighborhood, competent government, well-educated population, quality research institutions, a global outlook, a strong social safety net that enables risk-taking, and a well-developed startup scene. For these reasons and more, Sweden is the only country highlighted in this study to rank in the top ten on every index listed in Box 1 (page 11)—which Swedish officials point to with considerable pride. The country's tech-innovation ecosystem is globally competitive, churning out thousands of startups and the second-largest number of unicorns in the world on a per-capita basis (after only Silicon Valley). In 2017, these included Spotify, Skype, King, Evolution Gaming, Mojang, and Klarna.[326]

Sweden's robust performance stems from its history. The country's traditional excellence in engineering helped it build major corporations such as Ericsson, Saab, Volvo, ABB, Electrolux, and Ikea. Sweden's small internal market historically forced the country to build strong linkages with the rest of the world. Interviewees often compared Sweden to Norway, which has been less outwardly oriented. They contend that the Swedish government avoids protectionist thinking, steering public conversation toward future challenges. Swedes also have a history of early tech adoption that attracts global corporations that test consumer reactions to their technologies. Swedes, for example, own more smart devices than people living anywhere else in Europe, making Sweden a testbed for smart device-based consumer technologies (e.g., fintech apps).[327]

Following an early-1990s recession, the Swedish government enacted policies to increase competition between the country's largest corporations and its smallest firms, through anti-merger legislation, tax code reform, and other mechanisms. The government subsidized home computer purchases, helping to hook a generation of youth on computers and coding, giving them digital economy skills. At the same time, Stockholm invested in a fiber-optic Internet grid, a boon to digital startups for its high speed and extensive coverage. (This decision was similar to Chattanooga's investment in "The Gig," its own citywide high-speed Internet service.) This happened around the dot-com boom, which created a first generation of digital startups.[328]

Sweden, like Israel, is an example of how a country's small size (9.9 million people) can be an advantage.

This history created Sweden's current tech-innovation ecosystem, home to thousands of startups. Since 2012, Sweden has attracted $4.4 billion in capital investment, fourth in Europe after the largest economies (UK, Germany, and France).[329] Computer gaming, digital commerce, fintech, and health tech are well represented.[330] Stockholm, the epicenter of Sweden's ecosystem, has a small geographic size but high density of startup activity, prestigious educational and research institutions, and scores well on global city rankings.[331]

Sweden's startup ecosystem is mature, having gone through early formative periods, starting in the 1990s, that birthed successful entrepreneur cohorts. These entrepreneurs helped establish a global reputation for Sweden and now invest their own money into the ecosystem. They also helped change attitudes toward failure and entrepreneurialism, adding to a Swedish culture that is informal and team-oriented. These features compare favorably to Silicon Valley.

Swedes believe they have a few distinct advantages over the United States. One is a high level of social capital and trust in institutions. The public sector enjoys a deserved reputation for competence, necessary for galvanizing cross-sectoral efforts among government, universities, firms, and others. Swedes also believe that their social welfare system, which is far more generous than its US counterpart, boosts innovation. It provides Swedes with good educations at low individual cost (thus preventing university graduates from acquiring crushing debt) and helps de-risk entrepreneurialism through inexpensive healthcare and income support mechanisms.[332] Interviewees unanimously pointed to this system as one of Sweden's biggest advantages.

Sweden invests 3.3 percent of its GDP into R&D, ranking it fourth in the world and first in Europe (Switzerland is second at 2.9 percent).[333] However, as elsewhere, Swedish research institutions face difficulties in translating science into commercial technologies. Within its universities,

Stockholm, Sweden.

academics own their IP but resist commercialization. To change this dynamic, Swedish universities have been strengthening tech transfer offices and facilitating cultural shifts around innovation. For over a decade, KTH Royal Institute of Technology (a flagship university) has been operating KTH Innovation, designed to commercialize university IP and build support processes for entrepreneurialism.[334] It helps students and staff at the very beginning of research commercialization ("pre-incubator training," as the Swedes call it), offering free support ranging from understanding IP rights, finding investment capital, managing a startup, and accessing Sweden's larger tech ecosystem. The office's staff, many pulled from the entrepreneurial community, believe that their efforts have contributed to KTH's growing reputation among prospective students as an entrepreneurial training ground.

An intriguing part of this story involves Sweden's attempt to organize R&D around "societal challenges." Starting roughly ten years ago, the Swedes helped refine this concept, which attempts to organize a country's research apparatus around major problems. The argument is that doing so will open more doors to innovation while focusing the tech-innovation ecosystem on important issues that matter to all of society. The Swedish government defines three such challenges: digital transformation, life sciences, and climate change. It has set up a National Innovation Council, an advisory body under Prime Minister Stefan Löfven, to gauge stakeholder interest, craft proposals, and oversee policy transitions across these three areas.[335]

A major 2016 OECD report gave Sweden credit for boosting the societal challenges idea within the European Union (back in 2009).[336] At the same time, it criticized the government's implementation for failing to articulate a long-range plan for transforming Sweden's ecosystem. Besides noting that funding falls well short of the scale needed, the OECD said that the program funds "niche solutions to very broad societal challenges."[337]

The OECD report also pointed to how the Swedish government is not set up to tackle interagency and "horizontal" problems like societal challenges. As is true of governments the world over, Sweden's vertically organized ministries struggle with horizontal problems. Vinnova, the national agency charged with facilitating innovation in Sweden, funds exciting projects to deal with these challenges, yet it consistently runs into policy barriers. Different ministries at the national and local levels have regulations that hinder implementation of novel technologies. Vinnova therefore is pushing "system" innovation, focusing on experimentation in policy and practice. It is starting to focus on "policy labs" to encourage the adaptation, uptake, and scaling of novel technologies in the real world. Officials point to Denmark's *Mind Lab* (run by the Danish government) as a model.[338]

When asked about Sweden's tech-innovation future, nearly every interviewee cited the country's strong performance on international indexes. Indeed, where Sweden ranks matters greatly to the country's politicians. Nonetheless, interviewees suggested two problems. One, a minor point, is that the indexes are too abstract to diagnose the system's true strengths and weaknesses. The second, more significant, point is the risk of complacency, in the sense that high rankings will seduce the country's leaders into thinking that all is well. The tech-innovation ecosystem, they maintain, has many strengths, but the basic model will need constant development in order to improve. Their fear is that Swedes, who live good and comfortable lives, will start to believe their own rhetoric and fail to maintain their competitive edge.

Besides this concern about resting on one's laurels, interviewees listed several other pitfalls. One, heard almost everywhere else, is a familiar refrain about the high cost of housing, which threatens to undermine the attractiveness of Stockholm for foreign talent. Higher costs might contribute to a scaling problem, wherein successful startups will begin leaving for cheaper cities such as Berlin, with larger pools of skilled labor. A last concern involves inclusiveness: interviewees expressed unease about who participates in the tech-innovation ecosystem. As is true nearly everywhere in the world, women are underrepresented in the country's tech sector. Sweden's immigrant population is underrepresented as well, although the government welcomes skilled immigrants with open arms.

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Glossary

3D printing any various processes in which material is joined or solidified under computer control to create a three-dimensional object. (pcmag.com)

artificial intelligence the capacity of a computer to perform operations analogous to learning and decision-making in humans, as by an expert system, a program for CAD (computer-assisted design) or CAM (computer-aided manufacturing), or a program for the perception and recognition of shapes in computer vision system. (thesaurus.com)

big data data sets, typically consisting of billions or trillions of records that are so vast and complex that they require new and powerful computational resources to process; supercomputers can analyze big data to create models of global climate change. (dictionary.com)

biotechnology the exploitation of biological processes for industrial and other purposes, especially the genetic manipulation of microorganisms for the production of antibiotics, hormones, etc. (google.com/dictionary)

blockchain a user-verified ledger consisting of "blocks" that are linked to one another and secured through cryptography (digitaltrends.com)

computer-aided design CAD, or computer-aided design and drafting (CADD), is a technology for design and technical documentation, which replaces manual drafting with an automated process. (Autodesk.com)

fintech a portmanteau of financial technology that describes an emerging financial services sector in the 21st century. Originally, the term applied to technology applied to the back-end of established consumer and trade financial institution. (Investopedia.com./terms/f/fintech.asp)

fifth generation (5G) wireless systems, abbreviated 5G, are improved wireless network technologies deploying in 2018 and later. (pcmag.com)

greentech technology that is considered environmentally friendly based on its production process or supply chain; a means of energy production that is less harmful to the environment than more traditional ways of generating energy, such as burning fossil fuels. (Investopedia.com/terms/g/green_tech.asp)

healthtech the application of organized knowledge and skills in the form of devices, medicines, vaccines, and systems developed to solve a health problem and improve the quality of people's lives. (who.int)

Internet of Things (IoT) sensors that can collect and transmit data through the Internet. (dictionary.com)

memory chip an integrated circuit made out of millions of capacitors and transistors that carry and store data or can be used to process code. (techopedia.com)

nanoengineering the practice of engineering in the nanoscale. (nano.gov)

nanomanufacturing the production of nanoscale materials, which can be powders or fluids, and the manufacturing of parts "bottom up" from nanoscale materials or "top down" in small steps for high precision, used in several technologies such as laser ablation, etching and others. (nano.gov)

net neutrality generally, refers to the requirement that Internet service providers enable equal access to the web, without favorable treatment. (Authors)

quantum computer a computer that makes use of the quantum states of electrons or other particles to store and process information as quantum bits. (dictionary.com)

technology incubator a means to assist technology-oriented entrepreneurs in the start-up and early stages of development of their firms by providing workspace (on preferential and flexible terms), shared facilities, and a range of business support services. (OECD.org)

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