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Rising to the Challenge

A Progressive U.S. Approach to China's Innovation and Competitiveness Policies

Kate Gordon, Susan Lyon, Ed Paisley, and Sean Pool January 2011

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Introduction and summary

When Chinese president Hu Jintao alights in Washington, D.C. next week for a summit meeting with President Obama, he will learn firsthand that China is fast becoming the touchstone against which everything wrong with the U.S. economy is measured. In the run up to last year's midterm congressional elections, candidates across the country accused one another of "sending jobs to China" instead of creating jobs at home. Members of Congress on both sides of the aisle regularly promise to seek trade sanctions against China for undervaluing its currency. The United States recently accepted a United Steelworkers petition accusing China of unfairly subsidizing its exports and hoarding raw materials essential for clean energy technology development. And U.S. companies across a range of industries are increasingly voicing their complaints about China's theft of their intellectual property and the country's forced transfer of cutting-edge U.S. technology in exchange for access to the nation's vast and fast-growing domestic market.

The overarching message coming from the United States is this: If China would just stop cheating, the U.S. economy would rebound, helping both nations and the rest of the world recover more sustainably from the Great Recession and sparking broad-based economic growth on both sides of the Pacific. Equally forcibly (though in more diplomatic language), President Barack Obama is expected to deliver that same message.

What this view assumes is that if only China would stop cheating, the U.S. economy would do what it has done best for the last hundred years or so—lead the world based on our prowess at science, technology, and innovation. After all, our universities are the best in the world, our entrepreneurialism is world-renowned, and our ability to turn new ideas into new job-creating products and services is unsurpassed. But this interpretation is not entirely accurate.

China is now investing in many of the building blocks of innovation-driven economic growth that the United States has all but abandoned over the past several

decades. Pick your sector and you'll find China will soon rival the United States in public investments in basic science and education, research and development, or R&D, infrastructure development, and workforce training. What's more, China's leaders have crafted coherent policies and programs in support of domestic manufacturing and services for export abroad and to ensure Chinese companies have the prime positions in China's rapidly growing domestic economy.

China, in short, is actively and methodically building up the basic foundations for future economic growth while also ensuring a market for its current and future products and services at home and abroad. The country's leaders understand completely the message driven home by The World Economic Forum, in its monumental *Global Competitiveness Report 2010-2011*, which underscores the importance of innovation as the basis for long-term economic growth:

> *Although substantial gains can be obtained by improving institutions, building infrastructure, reducing macroeconomic instability, or improving human capital, all these factors eventually seem to run into diminishing returns. The same is true for the efficiency of the labor, financial, and goods markets. In the long run, standards of living can be enhanced only by technological innovation. Innovation is particularly important for economies as they approach the frontiers of knowledge and the possibility of integrating and adapting exogenous, [or imported,] technologies tends to disappear.*[1]

China and the United States have very different legal, political, and economic systems, but both are bound by the same reality that to be competitive in the 21st century global economy, they have to innovate. But unlike most political leaders in the United States, China's leaders recognize that innovation is not created in a vacuum. Across the globe, developed and developing countries are realizing what economists have known for years—that technological innovation, more than any other factor, fuels long-term economic competitiveness and growth, and that innovation in turn requires a robust and well-integrated foundation of education, research, and infrastructure.[2]

The widespread recognition of these principles has sparked a global race to the top in innovation, science, and technology policy. But judging from the state of our innovation policy, the United States seems to have missed the memo. Other nations see innovation and competitiveness as two sides of the same economic coin. And not surprisingly, as John Podesta, Sarah Wartell, and Jitinder Kohli

FIGURE 1

Losing ground

The United States is in a race it doesn't fully recognize

Source: Stephen J. Enzell and Robert D. Atkinson, "The Good, The Bad, and The Ugly (and the Self-Destructive) of Innovation Policy" (Washington: The Information Techonology and Innovation Foundation, 2010), available at http://www.itif.org/files/2010-good-bad-ugly.pdf.

point out in CAP's recent report, "A Focus on Competitiveness," "…other countries organize their economic policy apparatus more explicitly around the question of how to effectively compete."[3]

China in particular does this very well. In this paper, we examine the challenges posed to current and future innovation-led economic growth in the United States by China's drive to boost innovation at home by any means available. As we will demonstrate, some of these challenges cut to the core of our nation's own global economic and scientific strengths—even though some of China's innovation policies and programs are plagued by inherent liabilities that are built into the country's approach to innovation.

Some Chinese R&D spending, for example, ends up fueling academic fraud, a huge problem in China, where local scientists often try to lay claim to new discoveries that are bogus. But the spending levels are still impressive, as is the fact that China has taken pains to invest across the entire innovation chain from basic science, to R&D, to market creation for new technologies, to production and deployment of these technologies. This is paying innovation dividends in hybrid electric vehicles, advanced batteries, high-speed rail, and solar power systems, to name a few.[4]

Indeed, one of China's other innovation "assets" is its growing direct investment in basic research and development. In 2008, China's gross national expenditure on research and development stood at roughly $66 billion, or about 1.5 percent of China's gross domestic product.[5] This is the highest investment level among

developing economies as a percent of their domestic economy and ranks China fourth in the world in overall R&D spending behind the United States, Japan, and Germany.[6]

Similarly, China's massive domestic investments in global market-scale industries such as clean technology products, transportation, mobile telecommunications and aerospace are now enabling Chinese companies in these sectors to compete for business abroad and dominate their home market. Again, there are liabilities built into this strategy: Economists can point to costly misplaced investments in some of the infrastructure needed to get these industries off the ground—misinvestments that saddle the Chinese state-owned banking system with an entire new raft of non-performing loans and resulting in way too many empty science parks and regional industrial zones that are no more than property speculation gone awry.[7]

This same strategy—key directed investments in science and innovation to spur rapid economic growth no matter the cost—is even evident in the Chinese government's planning processes. China's famous communist-era "five-year plans," which often bore little relation to reality, are now precise blueprints for strategic market-oriented, innovation-led economic growth to spur job creation at home and exports abroad. Then as now, however, local political and business leaders in China's provinces and cities, counties and townships continually go their own way in interpreting these plans and then spending the cash, often resulting in misleading statistical data flowing back to Beijing "proving" the metrics of the blueprint are being met while in fact the funds are being spent on a variety of other activities, including local property development and speculation.[8]

But these liabilities do not mean that U.S. policymakers can afford to be complacent. China's so called "import/assimilate/re-innovate" model of technology development, for example, actively drives foreign companies to share their technologies with Chinese joint venture partners in exchange for access to the cheap Chinese workforce and burgeoning domestic marketplace. This strategy poses a direct challenge to U.S. competitiveness because it enables Chinese (often state-owned) companies to gain access to cutting-edge technologies but also build upon them incrementally to create a Chinese innovation ecosystem. Never mind that economists recognize that the downside to this model of economic development is that it delivers diminishing returns without genuine domestic innovation delivering world-class breakthroughs.[9]

In the pages that follow we will examine China's innovation assets and liabilities as the country races to build a globally competitive innovation-led economy, and then consider how the United States should react to these challenges. We then offer our recommendations to U.S. policymakers on steps our own government can take to ensure our nation rises to meet the challenges posed by China. Briefly, though, we will argue that the U.S. government needs to give our nation's innovation engine a tuneup by:

- Modernizing our basic infrastructure to allow businesses to more effectively collaborate and compete in domestic and international markets
- Investing more in science and math education and workforce development to ensure we have workers able to participate in the technology-driven economy of the present and future
- Crafting finance policies to make more public and private capital available to innovators and bolster our culture of entrepreneurship by rewarding risk-taking and competitiveness
- Promoting international trade policies that ensure access to foreign markets, and the free flow of goods, services, knowledge, and capital across borders
- Honing our research and development policies so that we invest not just in basic research but also the full innovation lifecycle from invention, to development, to production and commercialization

These are progressive proposals that would boost our national competitiveness and jobs growth in the short run and ensure our once-dominant position in science and technology, innovation and entrepreneurship, and job creation is not eclipsed by China in the 21st century. On the eve of Chinese president Hu Jintao's visit to Washington, these are progressive proposals that Congress and the Obama administration dearly need to take to heart.

China's innovation assets and liabilities

The days of China as the low-cost, low-tech manufacturer of the rest of the world's high-tech innovations may soon be coming to a close. China now leads in the production of not just low-end manufactured consumer goods, but also some high-tech devices, many of which were developed in the United States. From high-speed trains to next-generation mobile phones to advanced clean-technology products, Chinese products now boast top-flight technologies that they can sell competitively abroad and that dominate their domestic market.

Several innovation assets directly and indirectly help drive China's shift from sweatshop to cutting-edge innovator. Among them are:

- The size of the country's economy and the potential for much more consumer spending
- The scale of its public investments and the benefits that derive from these investments
- The wage competitiveness of its labor force across all industries and services
- The aggressive, innovation-oriented national action plans and fiscal policy that help accelerate the development of China's science and technological innovation capacity

These assets have allowed China to adopt an "import/assimilate/re-innovate" model of economic growth that is working to fuel its incredible growth rate.

On the liability side of the ledger, however, stand some serious impediments to China's innovation and competitiveness strategies. The major problem with China's approach to innovation is that incremental innovation works well to play catch up with more developed countries, but it does not necessarily lead to true technological leadership. The Chinese economy effectively relies on purchased or forcibly transferred foreign technology to drive efficiency gains and growth.

But China's nascent science and innovation systems have yet to show that they are capable of producing truly game-changing new technologies on their own. Incremental improvements in manufacturing allow China to produce goods and services based on foreign technologies that are more efficient, but truly significant technological developments—think of the Internet, the automobile, or penicillin—rarely originate in China. At the same time, rising wage pressures and a coming demographic shift as the country ages means the nation can't capitalize on its cheap workforce for much longer.

So let's examine China's assets and liabilities in turn to see where, on balance, they pose the most significant challenges to the U.S. economy and U.S. science and technology leadership.

China's assets

Market scale

China's booming export-based economy, currently growing at 10 percent per year,[10] benefits the country's innovation system in several ways. Chinese domestic markets have experienced explosive growth in recent years; China is now poised to overtake Japan as the world's second largest consumer market in the next decade.[11] This surge in demand for certain products and services, such as domestic appliances[12] and automobiles, passenger jets and high speed trains, enables the Chinese government and companies to extract foreign technologies from foreign companies that want to access this market.[13]

Similarly, China's ability to point to products and services that might experience eventual rapid demand growth enables its government to persuade other foreign companies to set up research labs and joint ventures in China on the promise of future access, especially for demand driven by government contracts. Consequently, software and telecommunications companies, advanced materials companies, and pharmaceutical and biotechnology companies alike are helping to train an entire new generation of Chinese scientists and researchers.[14]

The high rate of savings in China contributes to this market-scale asset. These funds, sitting in state-owned banks, enable the government to channel domestic capital toward infrastructure investments and other public investments to help build the country's long-term innovation capacity. This capability enables the

Chinese government to demand technology transfers in exchange for company participation in these investment programs, providing natural fodder for a strong innovation environment.[15]

China's future economic development plans point to even larger spending in China, as the government encourages Chinese consumers to save a bit less and spend a bit more. The current leadership is eager to develop a domestic marketplace that depends more on consumer spending. To that end, China is now trying to improve its public health system so that consumers will have more money to spend elsewhere,[16] and is actively working to build a modern consumer finance marketplace to enable ordinary Chinese to save and borrow, invest and spend in more efficient ways.[17] This, too, enables China to draw in foreign expertise in sectors as different as financial services and health care.

Directed investment in innovation

Anticipated consumer demand and a growing private-investment environment combined with massive public investments have enabled China to achieve enormous economic gains. China is using public dollars not just to build the equipment and infrastructure it needs to meet the needs of its economy today, but also to make longer-term commitments to science and technology that will help it to build the innovation economy of tomorrow.

In 2008, the last year when complete data are available, China's gross national expenditure on research and development had grown to roughly $66 billion, or 1.5 percent of GDP—higher than most developing economies. Moreover, China has gone further to invest across the innovation chain from basic science, to R&D, to market creation for new technologies, to production and deployment of these technologies. Here's one of many cases in point: While many businesses in the United States and Europe have responded to the current economic downturn by slashing R&D funding and subsequently reducing the number of patent applications they filed, Chinese patent applications jumped 18.2 percent in 2008 and 8.5 percent in 2009.[18]

In addition, the country is continuing its tradition of focusing resources on science and math education, as well as more targeted workforce training in growth sectors such as clean energy.[19] For instance, China offers strong incentives for its educated émigrés to come back home and lead research institutions, start busi-

nesses, or help grow them. In 1994, China began a program called "100 Talents" intended to bring scholars back to the country. As of 2009, over 1,300 scientists had returned. [20]

These "sea turtles," as they are called in China, are bringing with them their talents for innovation picked up in the United States, Europe, Australia, and Southeast Asia. The National Institute for Biological Sciences, for example, attracted 23 American-educated Chinese scientists back home by offering incentives including a $300,000 annual budget and a top-class lab.[21] Generous "welcome home" bonuses are offered to especially talented scientists, experts, and academics.[22]

China's workforce policies also include a focus on imported talent. Last year the Chinese Academy of Sciences began a program to attract 1,500 foreign scholars, promising them more research funding and better facilities than they were getting in their own countries.[23]A high-profile example of the success of this action is the case of Applied Materials Inc., one of the world's leaders in semiconductor and flat panel display materials, whose Chief Technology Officer Mark Pinto relocated to Beijing to help run the firm's major new research facility in Xi'an.[24]

At the same time, China has worked hard to formalize its relationships with foreign universities. The U.S. government recently announced a joint clean energy project worth $150 million, intended to spur clean energy technology development in both countries.[25] This joint collaboration with U.S. universities, West Virginia University and their Chinese counterparts have yet to be announced, but work has already begun to advance the project's goals.[26]

Cheap labor force

China has seemingly possessed an endless supply of cheap labor for decades. The export-driven Chinese economy, which has largely been built on inexpensive labor for the past 30 years, has benefitted from the resource of a vast and relatively well educated population. The Economist notes,

"At the bottom of the heap, a "floating population" of about 130 million migrants work in China's boomtowns, taking home 1,348 yuan a month on average last year. That is a mere $197, little more than one-twentieth of the average monthly wage in America. But it is 17 percent more than the year before."[27]

Even as wages rise, and despite recent strikes and labor unrest, as well as the labor trends considered below, labor is still a far cheaper alternative.

With China's historically abundant cheap labor and bursting economy, it is no wonder it has been the go-to location for cheap low-skill manufacturing labor. Perhaps less intuitively, it has also attracted cheap educated labor, such as software developers who are also being outsourced to Asia by their U.S. employers. Not only do foreign companies flock to China for cheap labor, but they also transfer technology there in order to gain access to this cheap labor force. [28]

Far-sighted national action planning

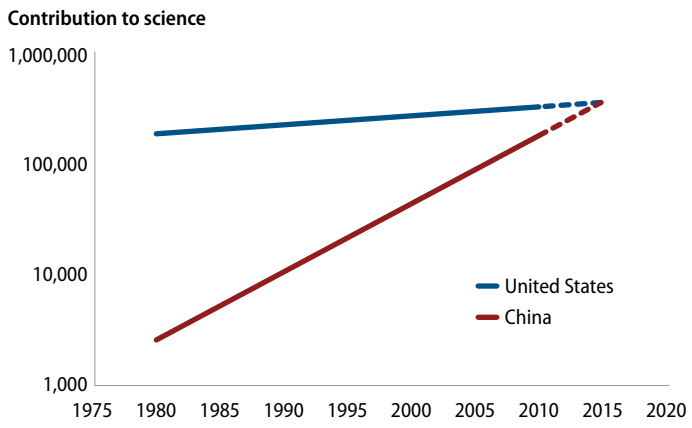
Because of the nature of the Chinese political decision-making process, which is done through central command rather than through a democratic election process, the Chinese Communist Party has no problem setting aggressive goals and launching sweeping national action plans to guide its innovation strategies. China's Medium-to-Long-Term Science and Technology National Plan, implemented in 2006, established quantitative benchmarks such as achieving global top-five rankings in patents generated, and required that "the country's reliance on foreign technology will decline to 30 percent or below" by 2020. [29] The Chinese Communist Party's twelfth five-year plan, which is slated for approval in early 2011, is even more heavily focused on these goals.[30]

China's strategic planning and far-sighted investments in the building blocks of innovation have yielded some impressive results. The number of Chinese patent applications and journal articles in all scientific fields has recently exploded.[31] In the early 1980s, Chinese scholars were responsible for only 0.4 percent of all published scholarly articles, but by 2009, the country had increased its share to 11 percent. In that same period, U.S. articles went from 40 percent down to 28 percent.[32] In terms of quantity of published articles, Chinese scientists have surpassed those of Japan, Germany, and Great Britain, and now stand at second place in the world, just behind the United States and up from 14th just 15 years ago.[33] (see graph)

FIGURE 2

Publish or perish

China's volume of scholarly papers nearly eclipses the United States



Source: Calculated by Science-Metrix using the Web of Science (Thomson Reuters).

The government's commitment of public capital deployed toward strategically important and fast-growing areas of research has put China on the map in genomics, clean energy, space science, supercomputing, and defense technology, yielding impressive and tangible results. China became the third country to put a human being in space in 2003, and is currently developing plans for a space station and a satellite probe to Mars.[34] In January 2010 the Beijing Genomics Institute purchased 128 gene sequencing instruments, the largest purchase of such equipment by any country or institution in history, putting China in the race with only six other countries working to decode the human genome.[35]

China is also famously home to the world's largest hydroelectric dam, the Three Gorges Dam across the Yangzi River, and the world's fastest bullet train, a Chinese-made CRH380, which runs between Shanghai's western suburb of Hongqiao and the city of Hangzhou.[36]

China's competitiveness in information technology is also on the rise. In May, a Chinese-built supercomputer was recognized as the world's fastest machine, topping the world's now second fastest supercomputer housed at the Department of Energy national laboratory at Oak Ridge, Tennessee.[37] The percentage of China's population with Internet access skyrocketed to 22.5 percent in 2008 up from 1.8 percent in 2000, and in 2009 alone the country added 100 million mobile phone users. [38]

According to the World Economic Forum, China ranks 22nd globally in Internet access in schools, and impressively, 7th in the world in terms of primary school enrollment rates.[39] These are just some of the many impressive indicators of the rapid growth of China's innovation economy. High technology exports made up 17 percent of all manufactured exports from China in 2007, and approximately 3 million Chinese trademark and patent applications were filed that year.[40]

Chinese innovation and economic planners are also well aware of the importance of agglomeration, sometimes called "clustering," a strategy in which policymakers encourage Chinese companies in similar industries to cluster together to improve their access to incremental innovation, share supply chains, and boost the competitiveness of their workforces. This practice began decades ago when China set up foreign investment zones to attract foreign companies to invest in China, and gained speed as different cities became famous for being the shoe capital or button capital or Christmas tree ornament capital of China.

Today, China is building on this cluster model to create new enterprise zones for more cutting edge technologies—a strategy that continues to draw companies such as Applied Materials, Microsoft and others to invest in China.[41]

The "import/assimilate/re-innovate" model

China is famous for its reliance on "reverse engineering" to replicate other countries' technologies, and in a way its approach to innovation follows the same path. China's heavy investment in cutting-edge equipment, information technology, research infrastructure, and high-tech manufacturing capabilities allows China's firms and researchers to excel at what innovation experts call "process innovation," or "incremental" innovation on existing technologies that are absorbed from abroad.

In a recent report by the Center for American Progress titled "Out of the Running: How Germany, Spain and China Are Seizing the Energy Opportunity and Why the United States Risks Getting Left Behind," we noted that:

> *One of the historical features of China's technology innovation is the role of foreign technology in the innovation chain. To achieve its goals of indigenous innovation, China's government has adopted a model of "import/assimilate/re-innovation." Thus, the early stages of all technology development include heavy reliance on foreign technologies.*[42]

While condemned by some as "ugly," unfair, and even illegal, this model works well to fuel China's economic growth and technological development.[43] It works by first capitalizing on the immense size of China's consumer markets to attract foreign direct investment from high-tech manufacturers and other technology companies. In exchange for access to the cheap Chinese workforce and parts of the Chinese domestic market, these foreign firms are often required to turn over their technology to Chinese companies, which then work quickly to absorb, improve, and adapt the technology to local conditions.

Ultimately, many Chinese firms armed with these re-innovated technologies use a combination of government export assistance and an artificially deflated currency to sell these technologies at lower prices than the original foreign technology source.

Cases in point include:

- **High-speed rail:** While North American, European, and Japanese companies were initially persuaded to sell their rail technology to state-backed partners in exchange for market access, they currently find themselves competing globally with Chinese companies selling versions of their high-speed technology at discount prices.[44]

- **Aerospace:** China has been extremely aggressive in pursuing international agreements that provide it with access to aerospace technology. The result has been a rapid expansion of its aerospace industry, which now consists of more than 200 enterprises and poses an emerging threat to current producers and suppliers of commercial aircraft.[45]

- **Telecommunications:** Although Chinese companies initially experienced difficulties successfully adapting and redeploying foreign telecommunications technologies, recent years have seen a surge in growth and competition. In a 2006 report by the Boston Consulting Group, 18 of the top 100 emerging global companies based in rapidly developing economies were Chinese telecom and IT companies.[46]

This kind of technological piggybacking, combined with aggressive export-oriented economic and trade policies, has been previously used effectively in various countries to climb the economic ladder, especially in East Asia. Think Toshiba and Sony in Japan, Hyundai and Samsung in South Korea, or Acer and Taiwan Semiconductor Manufacturing Co. in Taiwan. But China, because of the size of its marketplace and its workforce, can command more in the way of technology transfer than any of the other Asian economic powerhouses ever could. And China's public investments in innovation building blocks and its strategic clarity are further draws for foreign companies and individuals to participate in this re-innovate strategy.

All of these efforts have begun to pay visible dividends. China is becoming a more attractive environment for innovation and R&D. Here's just a short list of industrial and service-sector companies where China now boasts globally competitive companies:

- Huawei Technologies boasts registered assets of RMB 3.2 billion ($483 million by today's exchange rate) and 85 overseas branch offices, a research center, and factories, through which it has deployed wireless terminal technologies in over 100 countries.[47]

- Air China, with a capitalization that exceeds RMB 20 billion, has an annual profit ranked ninth in the global aviation industry each year, and serves 78 domestic and 39 international cities from its Beijing hub.[48]

- Lenovo Group is now a multinational computer technology corporation, ranked the fourth largest vendor of personal computers in the world in 2009. It also recently launched LePhone, a rival to the Apple iPhone that costs about half as much and is customized for Chinese users.[49]

These are just some of the national champions China has created through its well-honed innovation and competitiveness strategies.

China's innovation liabilities

But then there are the liabilities inherent in these kinds of economic development strategies. China's nascent science and innovation programs have yet to show they are capable of producing truly game-changing new technologies on their own. Despite China's success in clean energy, space technology, gene sequencing, and super-computing, none of these technologies were actually *invented* there. The intellectual property behind 90 percent of China's high-technology exports is developed and owned by foreign firms, not Chinese ones.[50]

This means many Chinese firms have mastered the art of making and exporting other people's high-tech goods, such as solar panels, for profit, but they still lag behind in inventing new technologies themselves. As the World Economic Forum notes in the Global Competitiveness Report, the import/assimilate/re-innovate model tends to result in diminishing marginal returns, as economies "approach the frontiers of knowledge, and the possibility of integrating and adapting exogenous, [or imported,] technologies … disappear[s]."[51]

In essence, the model that propelled China to this point cannot work forever. As China's technological prowess approaches that of the rest of the developed world, it will eventually run out of high-tech industries to assimilate. This will leave China to confront the question of how to develop the kind of truly homegrown innovation system that can not only approach the frontiers of science and technology, but actually expand them.

China is investing in the long-term building blocks of indigenous innovation, such as science and math education, university research, and commercialization of indigenous technology, to overcome this challenge. But hurdles such as academic fraud, bureaucratic inefficiency, corruption, and lack of intellectual freedom all stand in the way of China fulfilling its long-term potential.

What's more, its political model is hugely inefficient at resolving these problems due to the authoritarianism of its rulers, even though some in the Chinese leadership understand that more democracy with a little "d" is needed to clean up their political and economic system.[52] And then there are the demographic factors working against China—factors that could mean China grows old before more than a few of its citizens grow even moderately wealthy.[53]

So let's examine each of these liabilities to understand how disruptive they may be to the challenge posed by China to the United States.

Academic fraud

While China's science system is growing rapidly, achieving good governance in this arena remains a key challenge. [54] Though the number of published articles has grown steadily in recent years, the articles put out by Chinese scientists are often far from top-rate. More than half of Chinese scientists are personally familiar with cases of scientific misconduct, according to a survey conducted by the China Association for Science and Technology.[55] Whole industries known as "black journals," where academics can pay to be published to meet their academic requirements even without original research, exist to facilitate this surplus of poor quality output.[56]

Fang Zhouzi, a crusader for academic honesty in China who is frequently the target of lawsuits and government intimidation, has documented hundreds of cases of scientific misconduct on his Chinese blog "New Threads." [57] Examples range from scientists padding their resumes with international awards they did not receive to claims of the discovery of new planets that do not exist. Most go unpunished. China's General Administration of Press and Publication has stated its intention to reform scientific publishing in the country, but so far has offered very few specifics other than requiring "termination" of these low-quality journals where plagiarism thrives.[58]

Politics and bureaucratic inefficiencies ensnare science funding

There is very little incentive for government officials to do quality control over either academics or grant-makers, and according to Fang, many officials are not expert in the fields they are responsible for funding.[59] This leads to inefficient allocation of resources at best, and favoritism and corruption at worst. A recent World Economic Forum executive opinion survey in its annual Global Competitiveness Report showed that "corruption" and "inefficient government bureaucracy" were identified as the third and fourth most problematic factors for doing business in China.[60]

According to Fang, government officials who dole out science funding at the Ministry of Science and Technology have no incentive to ensure the money is going toward legitimate research, and no incentive to investigate or punish allegations of scientific misconduct.[61] Journalists likewise are better off staying away from a sticky story of academic misconduct than risk becoming the target of persecution by university or government officials well-connected in the Chinese Communist Party.

The capability of China's bureaucracies to meet the goals of its leaders' five-year plans is constrained by the same inefficiencies. In her book about China's environmental policies, "The River Runs Black," acclaimed China scholar Elizabeth Economy sums up this problem. She argues that the Chinese central government's environmental policies parallel its economic development ones, with the central government relinquishing substantial control and allowing local governments, private individuals, and the international community to fill the gaps—even when this approach runs counter to its top-down five-year plans. [62]

The result is that progress towards the country's five-year goals goes in fits and starts, and is subject to substantial regional variation. Measures of performance are often made up, admitted Li Keqiang, China's executive vice-premier, in one of the cables brought to light by the Wikileaks data dump.[63]

Bureaucratic inefficiency, favoritism, and corruption aside, many innovation scholars also posit that centrally-directed technology policy can never lead to truly homegrown innovation-driven economies, even if implemented transparently and effectively. Experimentation and competition are key inputs to the innovation equation, as has been shown in the process of carrying new clean energy sources to market.[64]

Labor market and demographic shifts

Another challenge China faces is that its cheap labor supply won't last forever. Currency appreciation, rising wages, and production costs, combined with simple demographic realities, are putting pressure on China's economic development model of the past several decades.[65]

With an aging population as a result of the one child policy, a tightening of labor markets lies not far along the road for China, even as foreign companies continue to move into the interior in search of cheaper wages.[66] Reuters reports:

> *"The number of Chinese between the ages of 15 and 24 has hovered around 200 million to 225 million for the last 20 years. That number is likely to fall by one-third during the next 12 years, giving more bargaining power to the young people pouring into the workforce."*[67]

This means that production costs are also on the rise due to a combination of other factors beyond labor supply, namely an emboldened new generation of Chinese workers demanding rights. As economist Arthur Kroeber put it,

> *"Ultimately, the teeth that lies [sic] behind (labor conditions) is the workers' notion that 'if we strike, we'll be thrown out of a job and there's another 10,000 people to replace us.' Now the teeth are removed because there aren't another 10,000."*[68]

As markets tighten, this will raise production costs, which will in turn raise the relative cost of manufacturing in China. A recent CAP analysis noted that "China may be approaching a so-called Lewis Turning Point, which occurs when a developing economy experiences a labor shortage allowing workers to demand higher wages and better working conditions."[69] Data surveying the first half of 2010 corroborates these trends; the Hong Kong Trade Development Council estimates that production costs will increase for mainland China due to increased wages and a labor shortage, among other factors.[70]

Costly top-down government misinvestments

China's massive economic stimulus package of 2008, amounting to RMB 4 trillion, is often cited as smart policy not just in immediate economic activity to help combat the Great Recession of 2007-2009, but also as an example of far-sighted invest-

ments in major infrastructure projects to boost the country's long-term economic competitiveness. Huge investments were made into public infrastructure, rural development, and renewable and efficient energy projects, for instance.

No doubt some or perhaps even a majority of those funds will contribute to those two goals, but the price paid in so-called "malinvestments" in the economy could well offset the gains over the medium to long term. Malinvestment is a term that describes poor investment decision-making—in China's case the massive amount of money that went into speculative real estate investments in the wake of China's stimulus push in the wake of too much money flowing to property development over the previous decade.[71]

Indeed, businessinsider.com in December presented a graphic illustration of the extent of the bubble—20 new cities being built every year, which the report refers to as "ghost cities"—and citing evidence that "there are enough vacant properties in China to house half of America," an estimated 64 million apartments and homes empty for over six months as of September last year.[72] The satellite photos of these ghost cities exemplifies the "malinvestment nightmare" that Asianomics economist Jim Walker recently noted will be responsible for an anticipated property market crash of historic proportions, with major implications for the health of China's banking sector and its provincial and municipal governments, which are behind much of the speculation.

Why does this matter to China's overall innovation-led economic growth strategy? Because a lot of this investment—both before and during the recent stimulus spending program—went into property development of science parks built around the idea of developing regional innovation clusters around specific industries.[73] Some of these investments will no doubt improve the nation's overall economic competitiveness, but much of it is little more than property development. Moreover, some of the nation's stimulus funds that went into cutting edge infrastructure development, such as high-speed trains, may run off the rails in the coming years.[74] Even China's own policymakers are now questioning the pace and scope of the high-speed rail program.

That said, even though some investments may appear to be obviously inefficient, such as building high-speed rail lines across sparsely populated rural regions , this can be seen as useful investment if it is creating demand that supports innovation and productivity growth in other parts of the economy—from engineering and manufacturing to, eventually, exporting high-speed rail systems. It may also be

that China is using today's wealth to build the infrastructure for tomorrow's anticipated populations in a way that will prevent other more wasteful spending later on. For instance, high-speed rail lines between cities may obviate the need for regional airports or additional highways, both much higher carbon-intensity solutions to moving people between places.

In sum, top-down government spending directives in China aimed at innovation-led economic development is not as wisely spent as some would argue. What's more, the manner in which these top-down directives are interpreted by provincial and municipal officials, who boast a lot of leeway in interpreting the directives, leads to further misinvestment in trendy arenas such as property development. This is an important policy liability that China's leaders in Beijing are still struggling to get a handle on.

China's assets and liabilities balance sheet

China may have a ways to go in fostering intellectual freedom, academic honesty, and efficient, transparent government institutions and policies and programs, but one thing is certain: 21st century China does not sit idle as problems fester. Chinese leaders are aggressively pursuing fixes to these structural liabilities. The upshot for the United States is this—challenges posed by China today will not necessarily be overwhelmed by these structural weaknesses. Our nation must respond to the current and future challenges posed by China, and soon. To this we now turn.

Facing China's challenges

The U.S. innovation ecosystem today is at once hugely complex and diffuse, but small in terms of actual federal government support, which runs to only about $150 billion annually for basic research and development.[75] In fact, we pride ourselves on this lack of government involvement in innovation. Instead, innovation-led economic development in our country is defined by bottom-up entrepreneurship rather than top-down government policies and programs. As President Obama noted last year, "We have always been about innovation, we have always been about discovery. That's in our DNA."

This poses unique problems when considering ways to meet the challenges China poses to the United States. The U.S. system generally values competition and trial and error as core elements of successful national innovation system, combined with an acceptance of risk taking buttressed by a well-designed intellectual property regime, and the "free, unhampered exchange of ideas" that Einstein famously lionized. [76]

Government-funded research, of course, plays a major role in the American innovation story, especially when university research, entrepreneurs, and sources of private financial capital can effectively collaborate to form nascent innovation networks.[77] The World Economic Forum ranks the United States first in the world on university-industry collaboration in R&D.[78]

Yet our once unassailable position atop the global innovation food chain is not impregnable. Overall, nondefense R&D spending as a percentage of all discretionary government spending has fallen from a high of 25 percent in the mid 1960s at the height of the Apollo space program, to between 12 and 13 percent since the early 1980s.[79] We need to summon the courage to invest in innovation on the level that we did in the space race because our most serious economic competitor, China, is doing so. Doing so will not only help us compete globally, it will also lift up the general knowledge and technological prowess of the world as a whole, as we share technologies and ideas with other nations, including China.

So let's look at several of the key challenges China poses to our nation's innovation preeminence, which of course will underpin (or not) our economic preeminence in the 21st century.

The renewable energy challenge

The different approaches taken by China and the United States toward the development of 21st century energy solutions epitomize the real challenge posed by China. On the basic research front, U.S. government spending on energy R&D declined from a high of $9 billion in 1980 to roughly $3.2 billion in 2006 in inflation-adjusted dollars. Likewise, private investment in energy research and development has shrunk from a high of nearly $7 billion in 1980 to approximately $2.5 billion in 2006.[80]

In contrast, China's overall spending on R&D has risen at nearly twice the rate of economic growth in recent years, climbing from 0.6 percent of GDP in 1995 to over 1.2 percent in 2004.[81] The number of researchers in China increased by 77 percent during that time, placing China second worldwide for total number of researchers (just behind the United States).[82] In clean energy specifically, China's spending has been impressive, with numerous and sophisticated incentives programs dumping millions of dollars daily into their renewable energy sector. According to U.S. Commerce Secretary Gary Locke, China's investment in all forms of clean energy technology acceleration and export expansion today amounts to as much as $12 billion monthly.

Our relative underinvestment leads to a situation where new ideas are born here—the United States is still the leader in emerging renewable energy technologies—but then are often spirited away by other countries, especially China, for development, commercialization, and manufacture.

Indeed, China's dedicated pursuit of alternative energy technologies illuminates the strengths of its innovation system, and the weaknesses of our own, at the critical point where a new technology is ready for commercialization. Thanks to forced technology transfer and aggressive process innovation, as well as a policy framework that provides strong market pull and public investments, China is well on its way to becoming a world leader in both the manufacture and installation of renewable energy technology.[83]

That means incremental innovation will happen in China, not here, by Chinese design—especially if China also acts on its spoken commitment to addressing climate change through low-carbon development strategies. A member of the Chinese delegation to the United Nations Framework Convention on Climate Change, the international forum that is attempting to forge global rules for carbon reduction, said recently that China "will not copy the developed countries' old way of energy-intensive economic development."[84]

To support this, it is widely anticipated that China's twelfth five-year plan will likely include strict carbon intensity reduction targets and other aggressive climate mitigation and clean energy deployment measures. Of course, one of China's major liabilities is the inability of its central leadership to command its local and provincial leaders to follow the guidelines of their five-year plans.[85] Yet even setting the goals means that production and installation will proceed more quickly in China than in countries that do not have these goals, most pertinently the United States.

Indeed, as part of this push, the China Clean Development Mechanism, the government fund that invests money from carbon credits, announced an additional $1.5 billion for clean energy projects by 2012.[86] Though the Kyoto Protocol did not require emissions reductions from China, the United Nations-backed CDM fund allows industrialized countries to buy credits from developing ones, and Chinese companies have sold 229 million metric tons of so-called certified emissions reductions under the CDM since 2005. [87]

These kinds of public investments bring results. In 2008, China had nearly twice the installed capacity of renewable electricity of the United States in absolute terms.[88] In 2009, Chinese investment in renewables, at $34.5 billion, rose to first in the world. Meanwhile, the United States invested only $18.6 billion in 2009.[89]

China's push in solar energy is equally striking. Six of the top ten global photovoltaic solar cell manufacturers are now in China, and the country's solar manufacturers produced nearly 2 gigawatts of panels in 2008, or roughly one-quarter of global production.[90]Although a large majority of this production was exported to Europe and the United States in 2009, the country is also aggressively ramping up its domestic market through Solar Roof and Golden Sun Projects, which provide subsidies to eligible firms and local provinces for distributed solar installation and transmission projects.[91]

During this past December's climate change talks in Cancun, Mexico, the Chinese Finance Ministry announced an even more aggressive ramp up of public investment in domestic solar installation through new incentives and subsidies—the creation of 13 industry zones, covering up to half the price of equipment for solar power projects, and a subsidy of 4 to 6 yuan per watt of generating capacity.[92] When a team from the Center for American Progress travelled to China to investigate developments first hand, we discovered this dedication to solar was very real. (see box)

Solar is just one piece of the puzzle. Global consultancy Ernst and Young's November 2010 report ranks China the "clear leader in the global renewable market," giving China the top spot of 71 out of 100 points for country attractiveness in their November 2010 *All Renewables index*. The United States came in second at 66, five points behind China. This metric measures wind,

Yingli eye-opener

In April 2010, CAP staff went with a bipartisan group of U.S. Senate staffers to Beijing and the surrounding area to look at the country's progress on clean energy innovation and manufacturing. The trip confirmed the main findings of this report: China is moving quickly beyond its old reputation as a low-cost, low-tech manufacturer and into the highly advanced production that characterizes most renewable energy industries.

On our trip, we visited the highly efficient Yingli Solar factory, where workers fully produce 14 percent of the world's solar panels. Yingli is also expected to produce nearly 70 percent of the panels subsidized by the Chinese government's Golden Sun program.[93] The factory relies on engineers and trained workers who are encouraged to stop the production line if they see problems, a characteristic of developed countries' manufacturing plants but something only recently seen in China.

Engineers also are encouraged to identify possible improvements to the plant's equipment and systems. At the same time, the factory relies almost entirely on high-tech machinery produced in other countries, including the United States, Japan, Germany, and Switzerland.

In some ways, factories like Yingli Solar are a microcosm of the country as a whole. They take an invention from another country (solar panels were invented in the United States), then use high-quality imported equipment to produce that technology and export it on a massive scale. The question is how long it will take China to invent new technology that leapfrogs U.S. innovation in solar energy as well as manufacture the core capital equipment in China.

Perhaps not long. Much of the equipment in the Yingli factory was made by Applied Materials, one of the world's leading manufacturers of the materials for solar panels and the equipment used to make them. Several years ago, Applied Materials located its largest research and development facility in Xi'an, a city in fast-growing Western China. When members of the CAP delegation talked to the chief technology officer of Applied Materials, Mark Pinto, he argued that it made sense to locate the facility in China not only because of its enormous market for new energy products, but also because of the high number of engineers the country graduates from its universities each year.[94]

solar, biomass, and other renewable potential to provide "an overall score for national renewable energy markets, renewable energy infrastructures, and their suitability for individual technologies."[95]

If Beijing follows its own plans, as much as 15 percent of Chinese power could be generated from renewable sources by 2020. In comparison, the United States might possibly reach 10 percent by 2020, but only if policy, funding, and deployment can be vastly accelerated.[96] This huge market for clean energy and the burgeoning supply of young scientists and engineers has lured companies such as industrial giant DuPont and Applied Materials to set up their solar photovoltaic R&D facilities there. And China's investment in smart grid technology has attracted the interest of other American companies, among them General Electric, who are looking for profitable opportunities overseas in the absence of any U.S. commitment to developing new markets at home.

And that's why the U.S. position in renewable energy innovation is slipping. In a CAP report earlier this year, CAP staffers compared the United States with China, Germany, and Spain to find that the United States has failed to make significant strides towards clean energy deployment because it lacks the long-term, stable policy environment to do so.[97] Whereas these other countries all have promoted comprehensive policies to enlarge their clean-energy sectors via policies that help build markets, provide critical financing, and build long-term infrastructure such as the transmission grid, the United States has so far relied mostly on short-term or state-based policies.

New technologies sometimes require a source of "demand pull" in order to bridge the commercialization gap and scale up. Without this critical factor, renewable energy technologies in particular languish in a premarket purgatory unable to bring their potential benefits to society. The U.S. marketplace is vibrant and dynamic, yet many critical clean energy industries have been unable to introduce new products and services based on new technologies, whether due to market failure, regulatory and jurisdictional chaos, or perverse subsidies.

This lack of a strong and long-term market signal means that investment in U.S. clean energy innovation is underperforming. When coupled with a lack of an overall national competitiveness strategy—as we will discuss in our concluding set of recommendations beginning on page 32—these developments put the United States's economic leadership in serious jeopardy. In the clean energy transformation and beyond, the U.S. still retains an edge in innovation and commercialization, but our footing is beginning to slip as China barrels along full steam.

The commercialization challenge

Americans are rightfully proud of our long history of public investment in research and development—basic R&D that sparked many of the 20th century's breakthrough innovations. The microwave, the photovoltaic cell, and the Internet, just three of a host of inventions, all came out of Department of Defense investments in basic research and development, without which they may have taken years or decades longer to be invented and commercialized.

Yet federal R&D budgets have diminished in recent decades relative to GDP growth, and are not adequately focused on the critical commercialization phase of technology development.[98] What's more, only a handful of the top research universities in the country are adept at moving new ideas from the lab to the marketplace by creating U.S.-based companies to commercialize the innovations of their scientists. Many more university innovations are simply sold to the highest bidder, often foreign venture capital firms looking for good ideas to bring back to their own nation to commercialize.

At the same time, scholars such as Krisztina "Z" Holly, vice provost for innovation at the University of Southern California and previously executive director of MIT's Deshpande Center for Technological Innovation, believes that we've only picked the low-hanging fruit in the terms of new innovative ideas in our universities, and that much more needs to be done to maximize the impact of universities in our national innovation system.[99] Specifically, she recommends we meet this commercialization challenge by supporting programs that "expand the commercial potential of ideas and innovations that result from" university research. She proposes the creation of a $20 million pilot program that would invest federal funding to create experiments that "test and demonstrate clear, replicable methodologies to bring existing research results into the U.S. commercial marketplace" through 10 demonstration sites.

Of course, research and development in the United States does not happen in the public sector alone—far from it. The United States is home to 16,000 private companies that operate industrial research labs, 20 of which have annual R&D budgets of $1 billion or more. Yet our private-sector labs are nowhere near the cutting edge of basic research as they used to be in the heyday of Bell Labs and other corporate labs several decades ago, concentrating more on incremental innovations of their existing technologies.[100] This is not a bad thing in terms of commercialization, but

it is another indication of the downturn in applied private-sector basic research and development that is hampering our long-term innovative competitiveness.

Compounding these commercialization problems at the basic-research level is the so called "valley of death" financing gap faced by innovative new companies seeking the money they need to carry their new products and services from the design phase to the marketplace. This financing gap leaves young innovative companies with good ideas unable to fund the commercialization of those ideas due to the lack of seed-stage and early-stage venture capital financing.[101]

The changing nature of venture capital in the United States is making the financing gap more acute, not less. As one of the venture industry doyens, Thomas Gephart, notes, the pool of venture capital is dramatically smaller today than it was just five years ago crimping the creation of new ideas into new businesses ready to hire Americans by the score.[102]

Indeed, in a recent presentation in the National Venture Capital Association's *Venture Capital Industry Update, October 14, 2009*, NVCA president Mark Heeson shows that the steady, though historically slow, growth in VC fundraising from 2002 to 2007 began a considerable decline in 2008 such that the VC industry is at a new and much lower level.[103]

The upshot: Our nation's unique strength, our venture capital industry, is in danger of drying up just when we need it the most. In contrast, China is learning from the U.S. experience with venture capital, enticing foreign VCs to invest in China, creating joint venture VC firms, and funding state-supported VC firms—providing the financing piece of their "import/assimilate/re-innovate" model of innovation and competitiveness.[104]

The United States, of course, boasts a long history of purely private-sector entrepreneurship alongside a vibrant and complex financial system that makes capital available to new ideas in the form of angel, seed, venture, and other kinds of early-stage finance and then the means to tap much larger debt and equity capital market to grow and prosper. But especially in today's capital-constrained environment, federal support is needed to encourage the flow of private capital to fund innovation in sectors of national priority—strategies we will discuss in the next section of our paper.

The manufacturing challenge

The U.S. manufacturing economy is still vibrant in some sectors, but many assembly lines remain idle, and the U.S. manufacturing capacity utilization rate hit a near all-time low of 65 percent last June.[105] Overall, manufacturing now just makes up 12 percent of U.S. GDP, down from 28.3 percent at its high point in 1953.[106] On the other hand, the 12 percent figure does not include the many service jobs dependent on the manufacturing sector: accountants, researchers, transportation jobs, engineers, and many others. In fact, the National Association of Manufacturing calculates that every dollar's worth of manufactured goods creates another $1.43 in activity in other sectors—twice the "multiplier effect" of services, where a dollar creates only $0.71 in other activity.[107] If the United States becomes a country that only comes up with ideas, but does not have the resources to produce and commercialize those ideas, we will lose not only direct manufacturing jobs but also these related jobs, and the economic growth that comes with them.

Moreover, if we turn our focus away from manufacturing, we risk losing the opportunity to profit from the process innovations that take place more often on assembly lines and in manufacturing facilities than in labs. These are the very same incremental technological improvements that are driving China's rapid efficiency gains and fueling its export-driven growth.

In 2010, the Harvard Business Journal hosted a debate entitled "Is the U.S. Killing its Innovation Machine?" The debate focused entirely on the question of whether the United States's declining manufacturing sector is also ushering in a decline in the "industrial commons," a set of related industries including those in the highly-prized knowledge-based economy.

In the opening article of the debate, Professor of Business Administration at the Harvard Business School Gary Pisano argues that the erosion of the industrial commons undermines "the ability of the United States to manufacture high-tech products [and] seriously damage[es] the country's ability to invent new ones."[108]

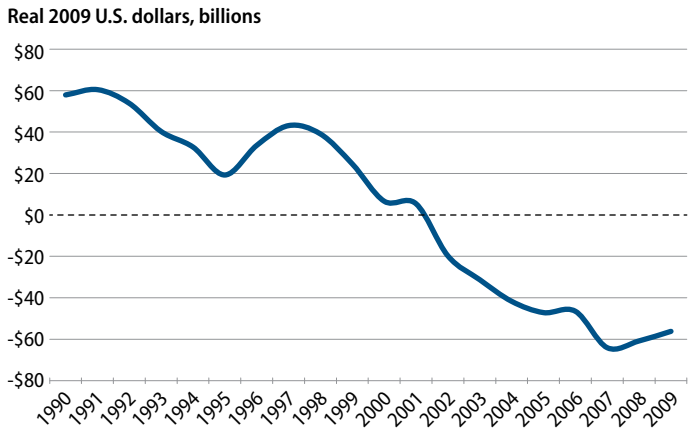
Other experts, among them Andy Rappaport, a venture capitalist with the Silicon Valley firm August Capital, note in the debate that not only service jobs but also the skills associated with these jobs can go overseas when advanced manufacturing migrates.[109] Rappaport points to the advanced battery, now a staple in hybrid and electric vehicles, as an example. "The United States has ceded both innovation in the critical building block (the battery) as well as leadership in the integration of these blocks into downstream value (autos)."[110]

The Obama administration is well aware of this challenge from China, where advanced battery manufacturing is largely based. In July, President Obama touted the creation of a new Compact Power battery plant in Holland, Michigan, which received $151 million in stimulus funds to make electric-vehicle batteries.[111] The stimulus grant was largely responsible for attracting the interest of LG Chem, a South Korean company of which Compact Power is a subsidiary. The factory is expected to create approximately 300 local jobs and is just one example of the impact that the $2.4 billion in stimulus spending aimed at encouraging the development of new battery and electric-vehicle technology can have on the American workforce.

FIGURE 3

Our 21st century manufacturing exports on the decline

The United States balance of trade in advanced technology goods has been declining steadily. We are now buying more foreign technology than we are selling.



Source: "Foreign Trade Statistics" (Washington: U.S. Census Bureau), available at http://www.census.gov/foreign-trade/balance/c0007.html.

But much more needs to be done. Indeed, even in high-end technology goods, the United States is now posting a trade deficit with the rest of the world. As CAP has noted, there is no single reason for this:

> *"The high-tech trade statistics indicate that our trading partners are moving up the value chain in high-tech products, possibly by identifying individual product niches they can concentrate on to boost their competitive edge over the United States."*[112]

And as we emerge from the worst recession since the Great Depression our competitive edge is continuing to slip as our high-tech deficit deepens.[113] A key indicator of our national competitiveness, high-tech sectors must be built up at home to keep us in the running. (see chart)

As a nation, we need to commit to manufacturing of high-end products in the United States, which will require a strategic vision that at present is lacking. Our recommendations to remedy this huge problem will be detailed in the next section of the report.

The education and workforce development challenge

Without technically trained students, technological leadership is impossible, and in education too, the United States is lagging. The Organization of Economic Cooperation and Development's Programme for International Student Assessment test, administered internationally to 15-year-olds, tested Chinese students for the first time in 2009. It showed Chinese student performance in math and science at 600 and 575 points, with U.S. students coming in much lower at 487 and 502 points in math and science, respectively.[114] Though the standardized test only tested students in the industrial powerhouse Shanghai and not across the country as was done in the United States, these top test scores shocked the world.

Though there is no comparable data for China, it is also sobering that in 2010 only 43 percent of U.S. high school graduates were ready for college-level work in math and 29 percent were ready in science, according to Change the Equation, a network of U.S. chief executive officers concerned about the long-term impacts of our education deficit.[115]

Even the Defense Advanced Research Projects Agency, or DARPA, the Department of Defense's agency for new military technology innovation and deployment, notes that the "significant national decline in the number of college graduates with [science, technology, engineering, or math] degrees" is effectively threatening our national security. This has huge implications for basic research as DARPA is the leading government investor in some of the most potentially cutting-edge technologies of the 21st century.

In his book "Mind Wars," University of Pennsylvania professor Jonathan Moreno lays out how critical DARPA continues to be for us:

> *"DARPA's overall mission is to bring discoveries from fundamental research to bear on the requirements of today's warfighters, accelerating the pace of applicable discoveries. Among DARPA's accomplishments in its continuous efforts to "fill the gap" between basic research and military use are the Saturn rocket, ground radar, the Stealth Fighter, and the Predator missile. DARPA-developed unmanned aerial vehicles have been used in Afghanistan and elsewhere. DARPA designed the computer mouse and, to give the mouse something to click for, the innovation that might prove to be the most socially transforming of them all: the Internet, first called the Darpanet."*[116]

The United States's weak investment in its education system, and in particular in the so-called STEM disciplines—science, technology, engineering and mathematics—is already dragging down our economy and threatens to make us less and less competitive in the innovative industries that will create the jobs of the future. While China ranked seventh globally in primary education enrollment according to the World Economic Forum's *Global Competitiveness Report*, the United States came in astoundingly low at 79th.[117] And according to the report, the United States ranks only 48th in quality of math and science education, far behind countries such as Canada, India, Poland, and even Tunisia and Qatar. China comes in at 35th.[118]

Indeed, less than one-third of U.S. eighth graders show proficiency in mathematics and science, according to a report prepared by the President's Council of Advisors on Science and Technology.[119] Meanwhile, in 2003, eighth graders in China's Taipei outscored American eighth graders on a standardized science test by 44 points.[120] Carrying this trend through the college years, international data show 59 percent of Chinese undergraduates receiving degrees in science and engineering, compared with only 32 percent of undergraduates in the United States.[121]

Similarly, many American workers are struggling to provide for their families amid a jobless economic recovery while also trying to learn new skills in order to enter better paying professions—many because they have lost their jobs to factories in China. Indeed, there's a new name for these workers challenged by the offshoring of their jobs to Asia, "working learners," and they are a key to our national economic competitiveness.

Working learners comprise the nearly 75 million Americans, or 60 percent of our workforce, who lack any kind of postsecondary education credentials from a university or community college. These working learners also include a range of individuals who never completed high school or who have low literacy and English language skills. They are the workers our nation will need to compete more effectively in the global economy and yet they are woefully ill-equipped to do so.

Postsecondary education is demonstrated to increase national innovation, economic productivity and individual incomes and prosperity, yet we are failing to educate this large portion of our workforce, as our colleagues at CAP Louis Soares and Christopher Mazzeo note.[122] The U.S. Bureau of Labor Statistics estimates that more than 71 percent of employment opportunities through 2016 will require postsecondary credentials. Of those working learners who actually begin their college education only about 34 percent have an associate's degree or college

degree after six years of study. And our nation's workforce investment system, which is largely designed to help workers who are suddenly unemployed find new jobs quickly, offers workers few chances at earning postsecondary credentials such as associate's degrees, technology certificates, or occupation licenses.

When well-prepared with the right skills and credentials, however, working learners can muster the exact mix of technical knowledge, business acumen, and creativity necessary to compete in today's highly mobile, innovation-driven economy.[123] Science and technology are creating innovation-enabled 21st century job opportunities for working Americans in frontline jobs such as biomedical and energy-efficiency technicians, social media communications assistants, new materials production workers and advanced manufacturing factory floor laborers. But these are the kinds of jobs that require learning new skills on the job and outside of the workplace. The capability of these working learners to compete at all levels of the U.S. economy is in turn important for economic recovery and essential to sustained economic growth.

As President Obama said in January, "Make no mistake: Our future is on the line. The nation that out-educates us today is going to out-compete us tomorrow." Bill Gates, the multibillionaire innovator and founder of Microsoft Corp., shared similar concerns when he said, "When I compare our high schools to what I see when I'm traveling abroad, I'm terrified for our workforce of tomorrow."

Tackling China's challenges

China and the United States face different challenges to fostering innovation-driven economic growth, but they are both competing for the same prize. As in any sport, insights can be gained from a thorough assessment of the strengths and weaknesses of the competition.

Some of China's strengths—in particular its import/assimilate/re-innovate model of process innovation and aggressive export-expansion policies—will eventually wear out as it approaches the frontiers of absorbable technology and investment rates. But others—its heavy public investment in tangible and intangible infrastructure across the innovation lifecycle from science education to university research to research and development to targeted industry market creation—can actually serve as lessons for U.S. policymakers. This is the topic of the final section of our report.

Giving the U.S. innovation and competitiveness engine a tuneup

In CAP's recent report *A Focus on Competitiveness*, we note that:

> *America will never follow the Chinese model of "state capitalism," although China's rise poses unique competitive threats we must address in other ways. The United States has always relied upon entrepreneurs, markets, and the private sector to identify ideas that will lead to new growth. But few dispute a proper role for government in spurring innovation and creating conditions that give the private sector the right incentives to make the right investments.*[124]

The need for a clearly defined competitiveness agenda is widely recognized. In 2008, then presidential candidate Sen. Barack Obama (D-IL) argued: "It's time for new policies that create the jobs and opportunities of the future—a competitiveness agenda built upon education and energy, innovation and infrastructure, fair trade and reform."[125] However, CAP's recent analysis finds that our economic policymaking is too fragmented to formulate a coherent strategy across these many different policy areas.[126]

Innovation and competitiveness are issues that touch on nearly every sphere of policymaking: economic policy, education, workforce, energy, science and technology, intellectual property, infrastructure, international trade, and immigration. Unlike many other developed and developing countries, the U.S. government does not have a single department focused on stringing these different policy threads together around a coherent competitiveness strategy. The siloed nature of U.S. federal policymaking must change if we are to thread together the necessary progress on the broad range of policy areas that drive innovation.[127]

The Center for American Progress has outlined a few mechanisms that should be put in place to increase the cross-cutting government collaboration necessary to design and implement a competitiveness agenda. We recommend:

- *A Quadrennial Competitiveness Assessment*, which would collect input and information from many sources and perform a horizon scan that identifies long-term competitiveness challenges and opportunities
- *A Biannual Presidential Competitiveness Strategy report*, which would lay out the president's competitiveness agenda and policy priorities, and captures the attention and buy-in of cabinet principals
- *An Interagency Competitiveness Task Force*, which would develop the biannual strategy, oversee White House coordination of competitiveness, and initiatives, and monitor their implementation by agencies

These cross-agency efforts can point the United States in the right direction.

In addition, we believe there are five areas that must be at the core of any innovation and competitiveness strategy:

- Modern infrastructure to allow businesses to more effectively collaborate and compete in domestic and international markets
- Science and math education and workforce development to ensure we will have workers able to participate in the technology-driven economy of the present and future
- Financing policies and strategies to make private capital available to innovators and bolster our culture of entrepreneurship that rewards risk and competition
- International trade policies that ensure access to foreign markets, and the free flow of goods, services, knowledge, and capital across borders
- Research and development policy that invests in not just basic research but the full innovation lifecycle from invention, to development, to commercialization.

Building a national innovation and competitiveness strategy is a big idea that will likely take years to come to fruition. But there are several policies the United States can tackle right away that can help shore up our innovation infrastructure and help our nation compete in the global marketplace. These include:

- Investing in future talent through strong science, technology, engineering and mathematics education programs
- Reforming immigration to foster U.S.-based innovation
- Investing in regional innovation clusters
- Facilitating regulatory reform to boost our growing clean energy economy
- Passing legislation to boost long-term innovation

Let's examine each of these in turn.

Investing in future talent through strong STEM education programs and workforce training

We need a concerted strategy to ensure the workers of the future will have the skills and technical know-how to contribute to the innovation economy, whether as inventors, engineers, advanced manufacturers and technicians, or simply as educated policymakers and consumers. These STEM educational efforts need to be broad-based, targeted at schools across all communities, to ensure all of our students obtain the skills necessary to work at good wages in the 21st century U.S. economy.

The core of this strategy should focus on teachers, the most important school-based influence on students' academic achievement. We need more teachers with the knowledge and skills to teach STEM subjects. Many current initiatives focus on bolstering the supply of STEM subject teachers at the secondary level, such as Change the Equation.[128] We shouldn't overlook the importance of elementary teachers in giving students a solid base of skills and confidence needed to persevere and thrive in STEM subjects through high school and college. Current teacher licensure and training falls short in this area (see No Common Denominator, National Council for Teacher Quality). At the very least, states should require prospective elementary teachers to score reasonably well on the math section of the basic licensure exam.

The National Research Council's 2005 competitiveness report outlines several specific proposals to achieve this, including an initiative to add 10,000 new STEM

teachers each year, and to strengthen the skills of 250,000 current STEM teachers by creating incentives for continued training.[129] The Business-Higher Education Forum has used dynamic systems analysis to show how these kinds of policies can potentially have a big impact over the long-run by improving STEM undergraduate education, reducing attrition rates of quality STEM teachers, and tapping the potential of students who are proficient but not (yet) interested in STEM.[130]

The Center for American Progress supports a variety of STEM efforts based on the sound analysis of the future STEM workforce needs of our economy. In particular, these include differentiating pay so that college graduates from STEM disciplines are more likely to teach, as well as providing incentives for continued training with built-in accountability and monitoring.

Similarly, Congress needs to focus on the unique needs of working learners as it considers the reauthorization of the landmark Workforce Investment Act of 1998. WIA was originally designed to unify a fragmented set of federal employment and training programs and create a single, universal workforce development system that could provide services for unemployed job seekers and employers. With an annual budget of about $3 billion for training, WIA was never intended to educate millions of working learners, yet the program occupies a unique place in federal public policy.

Indeed, WIA is the only program that explicitly attempts to build a bridge between education and the economy for all American workers. This bridge is critical in a labor market defined by an increasing demand for workers with postsecondary education and job churn that puts people in new jobs requiring new skills with new companies more often than ever before. In short, we need a more balanced WIA system that is able to work with both the unemployed and employed workers who lack postsecondary credentials, workers who are trying to balance work, learning, and family responsibilities while competing aggressively in the labor market.

The challenge for Congress when it reauthorizes WIA is that, at its best, the program was never intended to take on the challenge of providing postsecondary credentials at a national scale, while at its worst it is an underfunded and overly complex set of programs that place too many unemployed workers in quick fix low-paying jobs, does not invest enough in training, and is not measuring whether funded training yielded useful credentials valued by employers. To this end, our colleague Louis Soares recommends that Congress:

- Change WIA performance measures to focus on postsecondary attainment, not employment, to increase the number of working learners that obtain credentials valued in the labor market

- Create a Community College Innovation Center to research alternate education pathways for working learners that include occupational career pathways, compressed associate degree programs, and apprenticeships

- Eliminate WIA eligibility categories for adults and dislocated workers to better use limited resources to serve the needs of all working learners, including those who are low skilled, but employed

- Eliminate the WIA system's so-called sequence of services, which creates incentives for workforce development boards to pursue quick job placement for unemployed workers rather than further training to improve their job skills before job placement[131]

These recommendations are meant to help to improve labor market opportunities for working learners by building a sustainable a postsecondary education system that combines the labor market focus of the workforce development system with the pedagogical rigor and college credits of the higher education system.

Immigration reform to foster U.S.-based innovation

While we must continue to engage American-born students in the fields of science, technology, engineering, and math, we must also recognize that immigrants play a significant role in our innovation economy. Foreign nationals make up two-thirds of our Ph.D. students, and have founded 50 percent of Silicon Valley start up companies, but our current immigration system does not make it easy for these highly talented workers to stay and contribute to the U.S. economy.[132]

We need policy to streamline visa processing for international students, make it easier for students graduating with degrees in the STEM fields to remain in the U.S. and contribute to our economy, make the cap on highly-skilled visas more flexible, and create easier paths to permanent residence for highly-skilled workers with graduate-level degrees in these fields.

At the same time, we must ensure these workers do not become tools to help employers depress native-born workers' wages. As CAP's Marshall Fitz has written, "Current enforcement mechanisms are too weak to adequately prevent fraud and gaming of the system. And current regulations tie foreign workers too tightly to a single employer, which empowers employers with disproportionate control over one class of workers."[133] The result is that unscrupulous employers can pit groups of workers against one another to bring wages down.

Instead, as Fitz has argued, we must work toward an immigration system that both streamlines access to foreign workers and treats all workers employed in the U.S. equally.

Investing in regional innovation clusters

Regional technology clusters such as Silicon Valley's information technology industry, the biotech cluster along Boston's Route 128, or the advanced manufacturing cluster in the Eastern Midwest, have long fueled innovation and helped to drive the national economy forward.[134] The federal government must play a stronger role in helping to cultivate the bottom-up formation of these collaborative industry clusters and the innovation ecosystems that they breed.

Programs like the Energy-Regional Innovation Clusters initiative spearheaded by the Department of Energy and seven other agencies this year are helpful, but the scale needs to be bigger, the implementation cleaner, and the programs need to be insulated from the uncertainty of annual appropriations. In the *Geography of Innovation*, CAP's online magazine *Science Progress* lays out some core principles to guide federal policy in this arena, among them:

- Administer a competitive matching-grants program with established criteria used to ensure the greatest impact of federal funding among regions of our country, emphasizing local leadership from the private and public sectors, including universities and other research institutions, to boost innovation-led economic development

- Align these regional economic development initiatives with national priorities such as energy efficiency, advanced manufacturing, and new technologies when administering this matching-grants program

- Assist economically distressed areas of the country by pooling regional resources from within and outside of distressed areas in order to bring together a critical mass of university savvy, business acumen, and productive workers

- Consider ways for the federal government to participate directly in regional-led public-private partnerships to boost innovation-driven economic growth[135]

In these ways, the federal government could convene the most powerful American engines of economic growth—new ideas, entrepreneurs, competitive businesses, talented workers, and ample capital—to create and commercialize the new products and services of the 21st century.

Facilitating regulatory reform to boost our growing clean energy economy

Energy expenditures represent roughly 10 percent of global economic activity. Given the twin global challenges of climate change and energy insecurity, there is little doubt that clean energy will be a fertile ground for innovation, job creation, and economic growth in the foreseeable future. Nations around the world are already bidding for a piece of the multitrillion dollar clean energy market of the future, and as the 2009 report by CAP and the PERI Institute makes clear: Investing in these industries brings tangible economic benefits to families and communities as well.[136]

From cleaner air to increased energy security and price stability, to more job creation, to lower heating, lighting, and transportation bills, clean energy innovation is a win-win-win investment for our economy. As CAP laid out in the "Clean-energy Investment Agenda," investments must be made in three crucial areas to sustain strong, broad-based economic growth: markets, financing, and infrastructure:

- **Markets:** Expanding markets and driving demand for new clean and efficient energy products and services
- **Financing:** Encouraging and investing in research, development, deployment, and commercialization of the technologies needed to meet demand
- **Infrastructure:** Revitalizing and reinvesting in the nation's physical and economic infrastructure upon which the clean energy transformation—like all major industrial transformations in the past—will be built

In this way, we can align markets to build a robust economy that will move us beyond the Carbon Age while enhancing our national security and public health.

For these things to happen, the Obama administration and Congress must provide long-term, stable incentives for investments so businesses and entrepreneurs see the United States as a good place to invent, commercialize, manufacture, and deploy clean energy and energy efficient technologies.

Passing legislation to boost long-term innovation

With U.S. unemployment at 9.8 percent we cannot afford to wait to get started. Our economy needs to rebound strongly from the recent Great Recession while simultaneously laying the foundations for sustained, long-term economic growth. The 111th Congress left several pieces of critical innovation legislation unaddressed. The 112th Congress must step up to the plate to tackle the bipartisan issue of America's sagging innovation-led economic competitiveness by investing in the building blocks of innovation. The America COMPETES Reauthorization Act is a solid step, but it does not go far enough. Specifically, the following pieces of legislation need to be acted upon promptly in 2011:

- The Department of Energy Office of Science Authorization Act of 2010, which would direct the secretary of energy to pursue research, development, and commercial application activities in support of the Department of Energy's missions, including distributing grants that will provide the foundations for new energy technology research

- The ARPA-E Reauthorization Act of 2010, which would instruct the Advanced Research Projects Agency-Energy to expand the commercial application of advanced energy technologies and promote revolutionary advances in applied sciences

- The Energy Innovation Hubs Authorization Act of 2010, which would provide $860 million in grants over five years and encourage the establishment and operation of Energy Innovation Hubs to support the research, development, demonstration, and commercial application of advanced energy technologies in areas not being served by the private sector.

- The Economic Development Administration and Small Business Administration Reauthorization of Cluster Grants, which would maintain and grow regions where university-based scientists, engineers, local business, and public-sector institutions can work together and generate innovative new energy technologies[137]

By acting promptly on these pieces of legislation and getting them all to the president's desk for his signature, Congress will have put in place some of the key building blocks we need to meet the challenges posed by China.

Conclusion

As President Obama recently said on a trip to Asia aimed at opening new markets for U.S. products,

> *"The economic battle for these markets is fierce, and we're up against strong competitors. But as I've said many times, America doesn't play for second place. The future we're fighting for isn't as the world's largest importer, consuming products made elsewhere, but as the world's largest manufacturer of ideas and goods sold around the world."*[138]

The president is right, but the reality also is this—the size of the awakening Chinese market, coupled with its far-sighted innovation and competitiveness policies alongside its heavy investments in the acquisition and assimilation of foreign technology, have put China in a position to gain significant ground in developing its fledgling innovation economy. And China's moves to dominate key growth industries such as clean energy will mean stiff competition for the United States.

Make no mistake, we are engaged in a competition where two nations are vying for first place. And we cannot count on some of the inherent liabilities of Chinese innovation policies to come to our rescue. We need to act.

Our innovation engine has served us well and gotten us far, but with the stakes higher and the competition stiffer than ever before it is high time we gave that engine a tuneup. To compete in the 21st century our policymakers must implement a far-sighted competitiveness strategy that links policies across many different fields and agencies, and innovation must be at the center for that strategy. From specific pieces of legislation, to more structural agency changes and guidance, the Obama administration and Congress have the power to act swiftly to implement policies that foster the entrepreneurship and innovation our nation must rely on again to compete in the 21st century global economic race.

The ultimate question is not whether we can compete, but whether we have the leadership and vision to take the steps necessary to do so.

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