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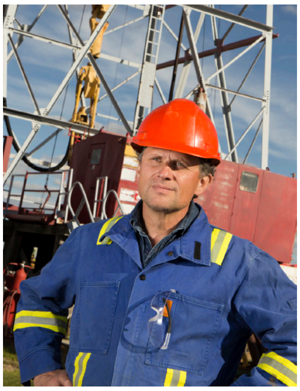

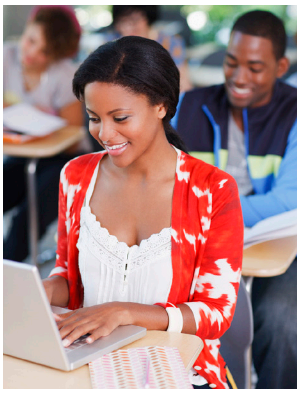

July 2013

Game changers: Five opportunities for US growth and renewal

The McKinsey Global Institute

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Susan Lund
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Preface

With the United States mired in a painfully slow recovery from the Great Recession, some economists project that years of tepid growth may lie ahead. But this view does not fully account for the resilience and innovative capacity of the US economy. In this report we identify "game changers"—catalysts that can spur productivity, boost GDP by hundreds of billions of dollars, and generate significant numbers of jobs by 2020.

After evaluating a larger universe of ideas, we arrived at a set of five opportunities that could accelerate growth: shale gas and oil production; increased trade competitiveness in knowledge-intensive manufactured goods; the potential of big data analytics to raise productivity; increased investment in infrastructure, with a new emphasis on its productivity; and a more cohesive and effective system of talent development in both K–12 and post-secondary education.

These game changers are different in nature, but mutually reinforcing. Some are relatively sector-specific, while others are broad and cross-cutting. Some are already rapidly unfolding and can boost demand to speed the recovery, while a renewed emphasis on infrastructure and workforce skills will lay the foundation for long-term growth, delivering even larger returns by 2030. But they all share a common thread: an immediate window of opportunity for substantial impact. In all five of these areas, forward-thinking investments and continued innovation from the public and private sectors alike could place the United States on a faster growth trajectory by 2020—setting the stage for higher living standards and greater prosperity in the decades that follow.

This report is part of a large body of MGI research on the US economy. Recent publications in this series include *Urban America: US cities in the global economy; An economy that works: Job creation and America's future*; and *Growth and renewal in the United States: Retooling America's economic engine*. This research was led by McKinsey Global Institute principal Susan Lund and MGI director James Manyika, along with McKinsey directors Scott Nyquist and Lenny Mendonca. The project team was managed by Sreenivas Ramaswamy and included Marie Louise Bunckenburg, Peter Chen, Nirant Gupta, Rebekah Lipsky, Suhrid Mantravadi, Brian Pike, JJ Raynor, Marc Sorel, Ekaterina Titova, John Valentino, and Emmanuel Verrier-Choquette. Thanks go to Lisa Renaud for editorial support and to other members of the MGI communications and operations team—including Deadra Henderson, Julie Philpot, Rebeca Robboy, and Marisa Carder—for their many contributions. We also extend thanks to our MGI research colleagues, including Michael Chui, Jan Mischke, and Jaana Remes, as well as Tim Beacom, Eduardo Doryan Jara, Jan Grabowiecki, Moira Pierce, and Vivien Singer, who provided us with analysis, expertise, and support.

We are grateful to the academic advisers whose insights enriched this report. Martin N. Baily, the Bernard L. Schwartz Chair in Economic Policy Development at the Brookings Institution; Laura Tyson, the S. K. and Angela Chan Chair in Global Management at the Haas School of Management, University of California, Berkeley; and Richard Cooper, Maurits C. Boas professor of international economics at Harvard University, all provided guidance. We are indebted to McKinsey directors Byron Auguste, Toos Daruvala, Doug Haynes, Vik Malhotra, Gary Pinkus, and Tim Welsh for their support and continued thought partnership on topics related to US growth and renewal. We thank McKinsey's director of publishing, Rik Kirkland, and Franz Paasche, head of external relations, North America, for their assistance.

We also benefited from the perspectives of academic, policy, and industry experts, including Ted James, Jeffrey Logan, and Alan Goodrich of the National Renewable Energy Laboratory; Doug Arent and Morgan Bazilian of the Joint Institute for Strategic Energy Analysis; Jeffrey Jones and Glenn McGrath of the US Energy Information Administration; David Sandalow, Brandon Hurlbut, John Richards, and Robert Fee of the US Department of Energy; Elizabeth Klein and Neil Kornze of the US Department of the Interior; William Colton, Peter Clarke, and Dong Fu of ExxonMobil; Peter Ragauss of Baker Hughes; Steve Raetz of C. H. Robinson; Kati Haycock of Education Trust; John Danner, formerly of Rocketship Schools; Rick Hess of the American Enterprise Institute; Matt Miller, a senior adviser to McKinsey and a columnist with *The Washington Post*; Jeanne Holm of Data.gov; and Ed Morse and Daniel Ahn of Citi Global Perspectives and Solutions.

This report is the result of a collaborative effort that drew on the expertise of many McKinsey colleagues across multiple offices and industry practices. For their insight into our energy research, we thank Matt Rogers, a director in the San Francisco office; Thomas Seitz, a director in the Houston office; Bob Frei, a director in the Chicago office; Jeremy Oppenheim, a director in the London office; Stefan Heck, a director in the Stamford office; Jonathan Harris, a director in the New York office; and Scott Andre, Thomas Czigler, Tim Fitzgibbon, Markus Hammer, Tommy Inglesby, Katie Jolly, Mike Juden, Paul Kolter, Michael Linders, Ed Schneider, and Ken Somers. The infrastructure chapter benefited from the insights of Jimmy Hexter, a director in McKinsey's Washington, DC, office; Robert Palter, a director in the Toronto office; and Tyler Duvall, Brandon Kearse, Simon Kennedy, Douglas Mehl, Erika Schroederus, and Carrie Thompson. We thank Mona Mourshed, a director in McKinsey's Washington, DC, office; Andre Dua, a director in the New York office; and Diana Ellsworth, Nora Gardner, Bryan Hancock, Martha Laboissiere, Andy Moffit, Annie Rittgers, and Jimmy Sarakatsannis for their valuable insights into education and training. We thank Jacques Bughin, a director in McKinsey's Brussels office; Aamer Baig, a director in the Chicago office; and Michael Ebeid, Peter Groves, Carl March, Doug McElhaney, and Matt Welsh for their expertise on big data. Our work on knowledge-intensive trade was enriched by Katy George and Christopher Simon, directors in McKinsey's New Jersey

office; Hans-Werner Kaas, a director in the Detroit office; Nick Santhanam, a director in the Silicon Valley office; and Andrew Gonce, Jeff Holland, Phil Jones, Ricardo Moya-Quiroga Gomez, David O'Halloran, and Lou Rassey.

This report aims to provide a fact base on the trends that will shape the years ahead. We hope this work will spark a constructive discussion among business leaders and policy makers about creating a more competitive and productive US economy that will generate jobs and opportunity. As with all MGI research, this report is independent and has not been commissioned or sponsored in any way by any business, government, or other institution.

Richard Dobbs
Director, McKinsey Global Institute
Seoul

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July 2013

Breakout opportunities...

50%

annual increase in US shale gas and oil production since 2007

1.7 million

jobs created economy-wide from shale energy development

10%

annual growth of greenfield FDI in the United States since 2003

135%

growth of US aerospace net exports since 2009

$325 billion

incremental annual GDP from big data analytics in retail and manufacturing by 2020

…for growth and renewal

$180 billion

additional annual investment
required in US infrastructure

1.8 million

jobs created by increasing
infrastructure investment through 2020

40%

potential improvement in infrastructure
productivity due to better selection,
delivery, and operation

9

US states that have raised student test scores
by nearly one grade level within a decade

$1.7 trillion

annual increase in GDP by 2030 through
improving the US talent development pipeline

Contents

Executive summary

Five years after the start of the global financial crisis, the longest downturn in US postwar history has given way to a lackluster recovery. Deleveraging, a fragile housing market, restructuring in the financial system, and fiscal austerity have posed formidable headwinds to US growth. In late 2012, however, the Congressional Budget Office issued a report revising potential GDP downward for reasons that have received far less attention: weak investment in the underlying productive capacity of the economy, demographic shifts, and a slowdown in productivity growth.[1]

There is more at work here than simply the business cycle, and this decline in future potential should be a call to action. Structural problems have been brewing in the US economy for decades. Today the national unemployment rate has ticked down to 7.6 percent, but improvement in this number masks the fact that labor force participation has dropped from 67.3 percent in 2000 to 63.4 percent in May 2013, touching a 34-year low. Despite the recovery, the US economy still has two million fewer jobs than when the recession began.

If young Americans are to enjoy the same increase in living standards over their lifetime as previous generations, the United States must expand employment, make its workforce more competitive, and sharply accelerate productivity growth that is driven by innovation and higher-value goods and services. The latter will be a challenge, not least because a large share of the economy is now composed of sectors with historically stagnant or below-average productivity growth, including health care, government, education, and construction.

But the United States does not have to resign itself to sluggish growth. While fiscal and monetary issues have dominated recent public debate, we believe it is time to shift the conversation toward growth-oriented policies that can mobilize investment and job creation in the private sector. We set out to find "game changers"—catalysts that could spur productivity gains, boost GDP, and generate significant numbers of jobs by 2020. By narrowing down a larger universe of ideas, identifying a set of critical and mutually reinforcing opportunities, and then sizing their potential impact, we hope to spark a discussion across government, the private sector, and civil society about national economic priorities and a path forward.

This report identifies game changers in energy, trade, big data, infrastructure, and talent. Within each of these areas, we explore the most promising opportunities for growth, including the continued expansion of shale gas and oil production; increased US trade competitiveness in knowledge-intensive goods; the potential of big data analytics to raise productivity within sectors; increased investment in infrastructure, with a new emphasis on its productivity; and new approaches

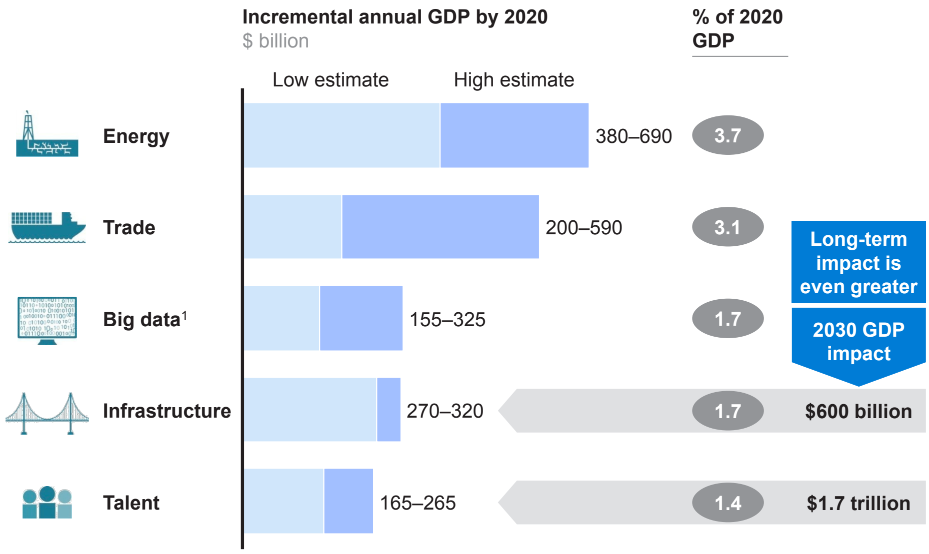
1 *What accounts for the slow growth of the economy after the recession?* Publication 4346, Congressional Budget Office, November 2012.

to both K–12 and post-secondary education.[2] This list includes specific sectors in which momentum is already unfolding, such as shale gas and oil, as well as fundamental enablers that will underpin competitiveness across the broader economy, such as talent development. Several can immediately boost demand to accelerate the recovery, and all of them provide a foundation for long-term growth.

We calculate that each one of the game changers could boost annual GDP by hundreds of billions of dollars by 2020 and create millions of jobs—with infrastructure and talent delivering even more dramatic gains by 2030 (Exhibit E1). There are solid reasons to believe that conditions are right for the United States to capture these opportunities by moving now.

Exhibit E1

Each of the game changers could substantially raise US GDP by 2020



1 Figures reflect additional GDP in retail and manufacturing sectors only. Big data could also produce cost savings in government services and health care ($135 billion–$285 billion), but these do not directly translate into additional GDP.
NOTE: These figures are based on a partial-equilibrium analysis that estimates only first-order effects and therefore cannot be summed to calculate the full economic impact.
SOURCE: Economist Intelligence Unit; IHS Global Insight; McKinsey Global Institute analysis

Although they will require substantial up-front investment, these game changers can ultimately ease the challenge of reducing fiscal deficits and debt by raising GDP growth. Federal funding and policy changes could speed results, but gridlock does not have to pose a barrier to undertaking these goals. Despite the stalemate in Washington, a great deal of policy experimentation and initiative is happening at the state and local levels. The US economy remains one of the most innovative and flexible in the world, and the private sector can drive much of the investment and realize much of the opportunity. Taking action now could mark a turning point for the US economy and ensure prosperity for this generation and the next.

2 A recent MGI report, *Disruptive technologies: Advances that will transform life, business, and the global economy*, describes a dozen breakthroughs, including advanced oil and gas exploration and several big data–related technologies. While *Disruptive technologies* is global in scope, this report takes a complementary look at how these and other opportunities may unfold in the US economy, sizing their impacts on GDP, productivity, and jobs.

WHAT CONSTITUTES A GAME CHANGER?

Over the past five years, the McKinsey Global Institute has studied the performance of the US economy from multiple angles, including the jobless recovery and labor market mismatches, large multinational companies and eroding competitiveness, the productivity challenge, savings and the demographic transition, and deleveraging from the financial crisis.[3] Drawing on this body of work, we set out to look for game changers—that is, catalysts that can reignite growth and reestablish a higher potential trajectory for the US economy. We find large opportunities waiting to be seized.

These five game changers were chosen from a longer list of ideas we considered, and they are drawn from broad categories that are foundational to the US economy. (See Box E1, "Selecting the five game changers," for more detail on our selection criteria.) They are possible today because of technology breakthroughs; changing costs of capital, labor, and energy around the world; policy innovation at the state and local levels; or new evidence-based understanding of how to address long-standing problems.

Some may disrupt entire industries—and all have the potential to impact multiple sectors (Exhibit E2). Moreover, the five game changers presented here are mutually reinforcing. The shale boom, for example, is boosting trade competitiveness, particularly in energy-intensive manufacturing, as the shift in input costs caused by cheap natural gas has made the United States a more attractive place to base production. Big data can play a role in raising the productivity of knowledge-intensive manufacturing for export, maximizing infrastructure assets, and facilitating new personalized digital learning tools. Shoring up US infrastructure is necessary to capture the potential of the shale energy boom and facilitate greater trade. A talent revolution is needed to train tomorrow's energy engineers and big data analysts, as well as the skilled workforce needed for a 21st-century knowledge economy.

These opportunities can exert two types of economic impact: more immediate demand stimulus effects that can get the economy moving again in the short term, and longer-term enabling effects that build competitiveness and productivity well beyond 2020. The shale boom, for example, has already provided an immediate spark as it coaxes private capital off the sidelines and leads to new investment in both oil and gas production and energy-intensive manufacturing. Increased trade competitiveness can have a relatively rapid impact by leveraging global demand and building on US strengths in innovation. Big data, by contrast, is already being adopted by a range of US companies, but it will take time to reach critical mass and raise sector-wide productivity. Infrastructure investment can be a powerful short-term stimulus and boost to employment, but as with talent development, it also has important long-term enabling effects on the rest of the economy. The impact of these two game changers would grow in magnitude from 2020 to 2030 as the US stock of human capital and infrastructure deepens.

3 See MGI reports *Debt and deleveraging: Uneven progress on the path to growth*, January 2012; *An economy that works: Job creation and America's future*, June 2011; *Growth and renewal in the United States: Retooling America's economic engine*, February 2011; *Growth and competitiveness in the United States: The role of its multinational companies*, June 2010; and *Talkin' 'bout my generation: The economic impact of aging US baby boomers*, June 2008.

Box E1. Selecting the five game changers

Many ideas have been offered for reviving economic growth. Startups, renewable energy, and the "reshoring" of manufacturing are commonly offered as solutions that can accelerate the current weak recovery. In this research, we have attempted to sort through the possibilities to identify the opportunities with the greatest potential for economic impact. While acknowledging that some options not discussed in this report also hold promise, we believe that we have identified a set of five priorities that could spur growth and renewal in the US economy by 2020.

To narrow down the possibilities, we set the following parameters: Each development had to be a catalyst with the ability to drive substantial growth in GDP, productivity, or jobs. It had to be poised to achieve scale now and capable of producing tangible impact by 2020. And it had to have the potential to accelerate growth across multiple sectors of the economy. We also looked for areas in which new technologies, discoveries, or other factors are creating a unique window for action.

We started with a broad set of potential candidates and narrowed the list.[1] Some topics were combined into one larger category. For example, K–12 education reform, workforce skills, and immigration were consolidated into one game changer on talent development. Other ideas were important, but the impact was not likely to be realized at scale within our time frame, such as the broad adoption of smart grid technologies that can boost energy efficiency. Difficulties in measurement caused us to exclude others, such as innovation. The link between innovation and economic growth is widely accepted, but proxy metrics that are typically used to measure innovation—R&D spending, patents, number of scientists and engineers—provide only a partial picture of innovative activity. Other metrics, such as the vitality index, have been proposed but are hard to quantify.[2]

Finally, we excluded other topics because they address mainly cyclical challenges rather than long-term opportunities. Reviving business startups is an example. The rate of new business creation collapsed in the Great Recession, falling nearly 25 percent from 2007 to 2010 and erasing the potential for 1.8 million jobs that would otherwise have existed today. Reviving the startup engine is an important priority, as new businesses that are less than one year old generate nearly all net new jobs. However, a longer historical perspective shows that, apart from the past few years, startup creation in the United States has remained remarkably stable as a share of the civilian labor force since 1990. Furthermore, a gradual recovery in the number of startups is already under way. Although their recovery is not complete, it appears that business creation is primarily a cyclical rather than a chronic issue.[3]

We also considered possibilities for raising the productivity and performance of specific large sectors of the economy—health care, the public sector, and manufacturing, in particular. Although transforming these sectors could have a major impact, we chose instead to focus on opportunities that can benefit multiple sectors and lay a new foundation for growth. However, we do analyze in detail the potential to raise productivity in health care and government services through big data analytics, and we discuss the impact of several of the game changers on manufacturing in Box E2, "The future of US manufacturing," later in this executive summary.

1 Among the other ideas considered were foreign investment, reshoring, advanced robotics, advanced materials, 3D printing, broadband, genomics, nanotechnology, renewables, and resource efficiency.

2 Created by 3M, the vitality index has been adopted by many other companies to measure new product revenue as a percentage of total revenue. Measuring this economy-wide and over time would be challenging due to data limitations.

3 There are many different views on the state of US entrepreneurship. The Kauffman Index of Entrepreneurial Activity shows that business creation actually increased during the recession. Other studies attempt to distinguish between self-employed entrepreneurs and newly incorporated firms that are more likely to have employees. See Scott Shane, *The Great Recession's effect on entrepreneurship*, Federal Reserve Bank of Cleveland, March 2011; and Zoltan Acs, Brian Headd, and Hezekiah Agwara, *Non-employer start-up puzzle*, SBA Office of Advocacy working paper, December 2009.

Exhibit E2

The game changers will benefit multiple sectors of the economy

Sectors potentially affected by each game changer

● Primary
○ Secondary

Sectors of the economy	GDP, 2012 $ billion	Jobs, 2012[1] Million	Game changers that strongly impact sector: Energy	Trade	Big data	Infrastructure	Talent
Resource extraction (e.g., oil and gas, mining, agriculture)	453.8	2.9	Primary			Primary	Secondary
Knowledge-intensive manufacturing (e.g., autos, aerospace, chemicals)	894.3	4.8	Secondary	Primary	Primary	Primary	Primary
Resource-intensive manufacturing (e.g., metals, pulp, refinery products)	427.8	3.1	Primary	Secondary	Secondary	Primary	Secondary
Labor-intensive manufacturing (e.g., apparel, furniture)	544.6	4.1		Secondary	Secondary	Primary	Secondary
Construction and utilities	863.0	6.3	Primary			Primary	
Retail	949.1	15.0		Secondary	Primary	Secondary	Secondary
Wholesale, transport, and logistics	1,367.2	10.2	Secondary	Secondary	Primary	Primary	Primary
Information and media	690.6	2.7		Secondary	Primary		Primary
Financial, legal, and technical services	2,730.2	15.9	Secondary	Primary	Primary		Primary
Real estate	1,926.3	1.9			Primary	Primary	
Hospitality and other services[2]	1,466.1	27.5					Secondary
Education and health care	1,344.7	20.5			Primary		Primary
Government	2,026.2	21.9			Primary		Primary

1 Jobs column shows seasonally adjusted employment statistics as of December 2012.
2 Includes administration and support services, accommodation and food services, arts and entertainment, repair and maintenance, and personal services. These sectors will benefit indirectly from higher employment and spending.

SOURCE: US Bureau of Economic Analysis; US Bureau of Labor Statistics; McKinsey Global Institute analysis

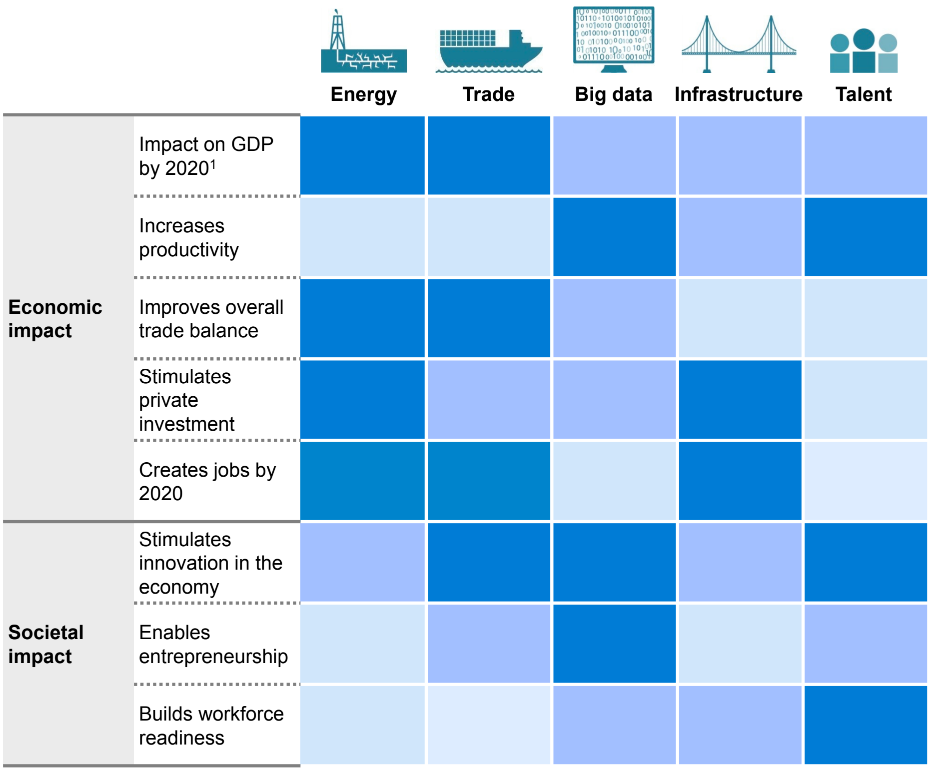
Each of the five game changers has the potential to boost annual GDP by at least $150 billion by 2020. In most cases, the potential is much greater—almost $700 billion by 2020 for shale energy, and up to $1.7 trillion by 2030 for talent. The impact on employment is also striking, with three of the game changers (energy, infrastructure, and trade) potentially creating more than 1.5 million new jobs each.

More subtly, concerted action to realize these opportunities can build general confidence that encourages investors, companies, and would-be entrepreneurs to focus their energies on the United States, creating a positive cycle. In addition, the game changers will have far-ranging economic, social, and policy implications (Exhibit E3). Although the benefits of pursuing these goals simultaneously would vary across different parts of the US economy, the resulting complementary effects would enhance the nation's overall competitiveness, productivity, innovation, and quality of life.

Exhibit E3

The game changers will have broad economic and societal impact by 2020

Primary
Secondary
Other impact



1 Talent and infrastructure have much larger GDP impact by 2030
SOURCE: McKinsey Global Institute analysis

The projections associated with each game changer are based on quantitative analysis as well as the insights of multiple industry and policy experts. While it is tempting to add these numbers together into a rosy forecast for trillions of dollars in additional GDP, we caution that these scenarios are not meant for simple addition.[4] Each one was calculated in isolation and did not consider the second-order effects on prices and exchange rates. Our calculations are also not predictions of how much of the opportunity will actually be realized. They are meant to demonstrate the size of the potential impact and explore the actions needed by both business leaders and policy makers to pursue these game changers.

4 Each one is a partial-equilibrium comparative static analysis that estimates only the first-order magnitude of impact. These calculations do not take into account second-order effects such as those due to changes in the value of the US dollar, interest rates, or inflation.

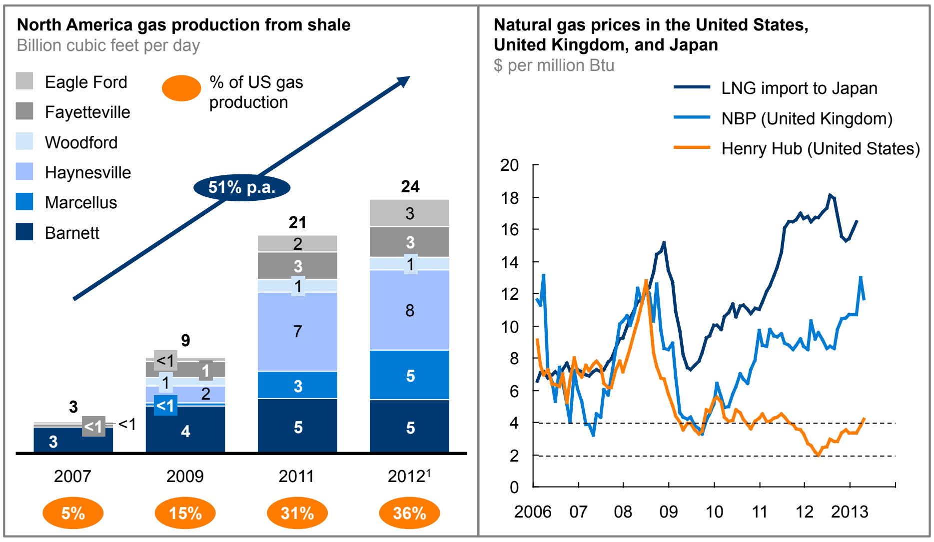
ENERGY: CAPTURING THE SHALE OPPORTUNITY

After its peak in the early 1970s, US oil production experienced three decades of decline, and energy grew to account for half of the nation's trade deficit in goods. As recently as five years ago, there was little evidence that this trend could be reversed.

Today the picture is changing rapidly, driven by technological advances in horizontal drilling and hydraulic fracturing. This process has unlocked large deposits of both natural gas and oil trapped in shale—resources once considered too difficult or costly to extract. From 2007 to 2012, North American shale gas production climbed by more than 50 percent annually (Exhibit E4). Today, production of so-called light tight oil is growing even faster.[5]

Exhibit E4

Shale gas production in North America has grown by 51 percent annually since 2007, lowering the price by two-thirds



1 Marketed production levels at wellhead. Includes Lower 48 onshore and Gulf of Mexico offshore volumes.
NOTE: Numbers may not sum due to rounding.
SOURCE: Energy Insights (a McKinsey Solution); Hydrocarbon Production Data; US Energy Information Administration; McKinsey Global Institute analysis

If the United States fully realizes the opportunity, shale energy could revitalize the oil and gas industry, have downstream benefits for energy-intensive manufacturing, and send ripple effects across the economy. We estimate that it could add 2 to 4 percent ($380 billion to $690 billion) to annual GDP and create up to 1.7 million permanent jobs by 2020. This could be an important source of high-wage employment for workers without college degrees, generating economic activity in parts of the country that have seen little investment in recent decades.

The impact is already being felt in the energy sector and beyond. We project that increased hydrocarbon production could boost annual GDP within the energy sector itself by $115 billion to $225 billion by 2020. It can also drive growth in manufacturing industries that rely heavily on natural gas as a fuel or feedstock. These include petrochemicals, fertilizer, and synthetic resins; iron and steel; and

5 This oil is called "light" because it is less dense than heavy oil, and "tight" because it is found in very low-permeability reservoirs and cannot be tapped without advanced drilling and completion processes.

glass, paper and pulp, and plastics packaging. Annual GDP in manufacturing could rise by $55 billion to $85 billion. And the ripple effects may extend even wider, as increased production will require support from other industries, including professional services, construction, transport, and trade, driving an additional $210 billion to $380 billion incremental increase in annual GDP.

Building the required infrastructure for the shale boom is providing short-term stimulus to the recovery. We estimate it would take up to $1.4 trillion in investment to complete the necessary pipelines, rail networks, and drilling and gathering infrastructure. This could generate 1.6 million temporary jobs during the build-out, mainly in the construction sector. And this investment boom is being financed mainly by private capital from the United States and abroad; it does not hinge on public funding.

Beyond the increase in output and jobs, the implications are significant. The surge in shale gas production has driven down the price of US natural gas from nearly $13 per MMBtu in 2008 to approximately $4 per MMBtu in spring 2013—sharply lower than prices elsewhere around the world and a level at which some wells are being capped as producers cannot recoup their investment. In response, the United States is considering exporting liquefied natural gas (LNG), a shift that would require converting underutilized import terminals to export terminals. The US Department of Energy has approved two applications for such projects to date, and 20 more are under review. Combining potential LNG exports with reduced demand for imports of crude oil, the United States now has the potential to reduce net energy imports effectively to zero in the next decade and beyond.[6]

Finding solutions for the environmental risks associated with horizontal drilling and hydraulic fracturing—including groundwater contamination, fugitive methane emissions, and potential seismic effects—will be essential. The full extent of these risks is debated, and the long-term cost of damage in a worst-case scenario, should it occur, could be quite high.[7] It is in the interest of energy producers themselves to create transparency on these risks, build public confidence, and adopt rigorous operational standards (with special focus on the soundness of well casings and best practices for the disposal of wastewater). If they fail to do so, local and state governments may prohibit hydraulic fracturing, as some states have done, or a single disaster could turn public opinion sharply negative. While policy makers will have to set clear standards on drilling, well maintenance, and emissions, the industry would be well served by proactively addressing these issues.

There are additional challenges as well, including land-use impacts on local communities and the intensity of water use for drilling in drought-prone regions. But if the United States can successfully manage these issues, the shale boom could generate economic growth, high-wage jobs, and a secure supply of affordable energy that enhances US competitiveness.

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6 *World energy outlook 2012*, International Energy Agency, November 2012.

7 See *Shale gas extraction in the UK: A review of hydraulic fracturing*, Royal Society and the Royal Academy of Engineering, Final report, June 2012; R. D. Vidic et al., “Impact of shale gas development on regional water quality,” *Science*, volume 340, number 6134, May 2013; and *The inventory of US greenhouse gas emissions and sinks: 1990–2011*, US Environmental Protection Agency, April 2013.

TRADE: INCREASING US COMPETITIVENESS IN KNOWLEDGE-INTENSIVE INDUSTRIES

"Competitiveness" has become shorthand for a broad range of success factors: the ability to win share in export markets, attract global investment, create dynamic new companies, and draw a steady stream of talented students and workers from around the world. Historically one of the best places to do business, the United States continues to be a magnet for foreign direct investment (FDI) and the headquarters of many of the world's most successful companies. Since 2008, the United States has attracted more inward FDI relative to the size of its economy than Germany, France, and many other advanced economies.

But by some measures, the United States may be losing its edge and falling behind its international peers. Many US business executives, for example, say that permitting, regulation, and taxes are increasingly impediments to investing in the United States, and some of the fundamentals of the economy, including talent and infrastructure, are eroding.[8]

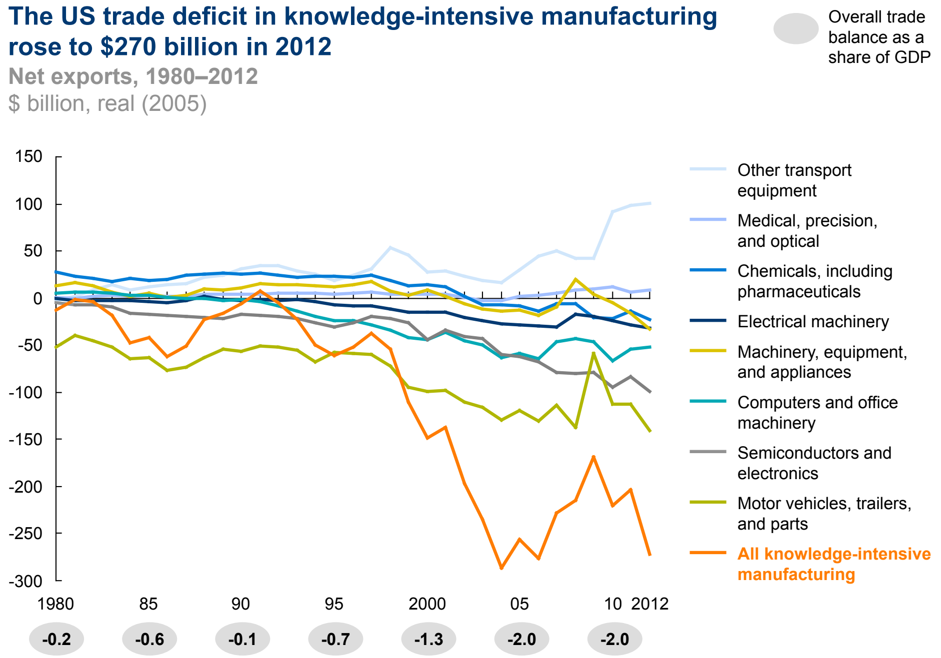
And surprisingly, given its track record for scientific research and technological innovation, the United States is one of the only advanced economies in the world that runs a trade deficit in knowledge-intensive manufactured goods. This category includes automobiles, aerospace, semiconductors and electronics, medical and precision equipment, and chemicals and pharmaceuticals. These industries are R&D-intensive and match up well with traditional US strengths, and they account for 50 percent of US manufacturing value added and 40 percent of employment. Yet the US trade deficit in these categories has gone from $6 billion in the early 1990s to $270 billion in 2012 (in 2005 dollars; Exhibit E5).

Exhibit E5

The US trade deficit in knowledge-intensive manufacturing rose to $270 billion in 2012

Net exports, 1980–2012

$ billion, real (2005)



SOURCE: IHS Global Insight May 2013; McKinsey Global Institute analysis

8 *Growth and competitiveness in the United States: The role of its multinational companies*, McKinsey Global Institute, June 2010.

The trade balance of any nation reflects a range of factors, including the value of its currency; its saving and investment rates; tax, regulatory, and trade policies; and the productivity and competitiveness of companies. This study does not consider macroeconomic policies that can address the first two of these issues; instead we focus on other measures that policy makers and the private sector can take to improve this trade deficit in knowledge-intensive goods by enhancing US competitiveness.

Our own analysis, as well as interviews with a broad range of industry executives and experts, reveals that there may be opportunities to increase US domestic production in specific categories of knowledge-intensive manufacturing in the years ahead, thereby increasing exports and/or reducing imports, either of which would improve the trade balance.

We project, for instance, that US petrochemical production will increase significantly in the years ahead due to cheap natural gas unlocked by the shale boom. This would transform the current $25 billion trade deficit in chemicals into a substantial surplus even if other parts of the chemicals sector, such as pharmaceuticals, remain unchanged. In aerospace, US exports of aircraft have nearly doubled in real terms since 2009, driven by demand growth in Asia and the Middle East. Industry analysts project that global aircraft fleets will double in size by 2031, and the United States is well positioned to capture a large share of this growth. In automotive, which makes up nearly half the total trade deficit in knowledge-intensive manufacturing, foreign auto producers are investing in the southeastern United States. Some foreign manufacturers, such as BMW, even export vehicles from the United States. Japanese automakers were at the forefront of establishing US production in the 1990s and eventually began sourcing parts in the United States; European, South Korean, and other foreign carmakers may follow that path as well, reducing US imports of parts and components. In addition, US automakers can consolidate a competitive edge in next-generation vehicles, including hybrid and electric models, exporting to global markets from the United States. And there is existing growth momentum that can be maximized in other categories, such as medical devices.

Five broad strategies can reduce the trade deficit in knowledge-intensive industries: building world-class infrastructure and talent as a foundation for business; sustaining a commitment to R&D, innovation, and staying at the forefront of emerging new technologies; improving the US business environment through tax and regulatory reform; aggressively pursuing new export markets as the consuming class grows in developing countries; and attracting more production from both foreign and domestic companies to the United States. These will in turn strengthen the already considerable success the United States enjoys as an exporter of knowledge-intensive services, where its trade surplus has shown consistent 9 percent annual growth, reaching $200 billion in 2012 (in nominal terms).

US businesses will need to move quickly to take advantage of growth in emerging economies, new technologies, and changing factor costs. Policy makers must also work toward creating an environment that will attract investment and production. Offering a "one-stop shop" for foreign companies that want to set up operations in the United States is one idea; the US Commerce Department has made this initial step with the establishment of SelectUSA, which could be taken to greater scale. The United States could also bring its corporate tax rate into line with other OECD countries through a revenue-neutral approach that broadens the base while simplifying the complexities of the tax code. Continued bilateral, regional, and global trade negotiations can expand market opportunities.

If the United States were to enhance its business environment and if the private-sector companies in knowledge-intensive industries can rise to the challenge, the impact on US GDP and jobs would be substantial. We examine a conservative scenario in which the trade deficit in knowledge-intensive manufactured goods is reduced from 2 percent of GDP (its level in 2012) to 1.3 percent of GDP (its level in 2000); this could raise US GDP by $200 billion annually by 2020 while creating 600,000 new jobs. If the United States makes a more concerted push to roughly close the trade deficit in knowledge-intensive industries, reverting to the same level as in the early 1990s, it could increase annual GDP by $590 billion annually by 2020 and create 1.8 million new jobs.

BIG DATA: HARNESSING DIGITAL INFORMATION TO RAISE PRODUCTIVITY

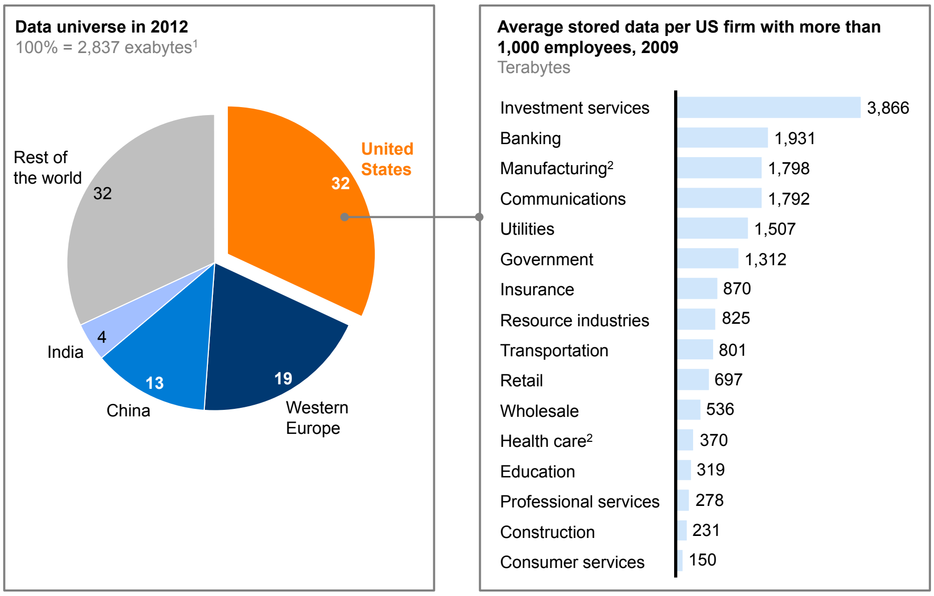
Given its aging population and the resulting fall in labor force participation, the United States will need to accelerate productivity growth by more than 30 percent, achieving a rate not seen since the 1960s, to maintain historic growth rates in per capita GDP.[9] A convergence of breakthrough technologies in big data and advanced analytics may provide one critical solution to help meet the economy-wide productivity challenge.

Sectors across the economy can find new efficiencies by harnessing the deluge of data being generated by transactions, medical and legal records, videos, and social technologies—not to mention the ubiquitous network of sensors, cameras, bar codes, and transmitters embedded in the world around us. Thanks to advances in cloud computing and the development of software that can extract useful information, this sea of data can now be transformed into insights that create both efficiencies and innovative services. The potentially transformative impact of these technologies is only just beginning to be understood. But the United States owns a disproportionate share of the world's data assets (Exhibit E6), and its companies, entrepreneurs, and universities are leading the development of this technology.

9 *Growth and renewal in the United States: Retooling America's economic engine*, McKinsey Global Institute, February 2011.

Exhibit E6

The United States has one-third of the world's data



1 One exabyte = 1,024 terabytes, nearly 2.5 times as large as US Library of Congress web archive (as of May 2013).
2 The large number of firms in the manufacturing and health-care sectors reduces the available storage per company.
SOURCE: IDC; US Bureau of Labor Statistics; US Library of Congress; McKinsey Global Institute analysis

We have analyzed big data's potential to raise productivity in four large and markedly different sectors of the US economy: retail, manufacturing, health care, and government services. In these sample sectors alone, we estimate that the widespread use of big data analytics could increase annual GDP in retail and manufacturing by up to $325 billion by 2020 and produce up to $285 billion in productivity gains in health care and government services.

In the retail sector, for example, real-time data on inventory can be combined with demand forecasting to reduce excess ordering and stockouts. Analytics can make more accurate predictions of store traffic and associated staffing needs to optimize labor scheduling. We estimate that big data tools could generate up to $55 billion in annual productivity gains in retail. As more retailers adopt the new technologies, productivity will increase throughout the sector, translating into higher national GDP in the process.

Manufacturers can deploy big data analytics across the production process. In product design, engineers can combine computer-aided design with data generated from production systems to minimize production costs and raw material use. In the production stage, sensors embedded in equipment can minimize disruptions by monitoring wear and signaling for preventive maintenance. Companies can also use advanced simulation techniques to create 3D models of new processes, factory floors, and even entire plants before physically building them. All told, the adoption of big data could generate up to $270 billion in productivity gains in manufacturing. As in the retail sector, these gains contribute directly to GDP, and the investment comes from the private sector.

Controlling health-care costs is imperative for long-term public finances and for the business environment in the United States. Big data tools have the potential to support innovation in health-care delivery, significantly reducing costs while improving outcomes. Comparative effectiveness research, for example, uses powerful algorithms to analyze millions of records to identify the relative efficacy and cost of various treatments for specific patient profiles. The shift to electronic medical records, now under way, will be critical in enabling these gains. Clinical decision support systems can check physicians' orders against updated medical guidelines and generate warnings against adverse drug reactions. In medical R&D, big data analytics can streamline clinical trials, allow scientists to test molecules using simulations, and analyze genomic sequencing to move personalized medicine closer to reality. Cost savings in health care could total as much as $190 billion by 2020—in addition to the far broader benefits of improving the well-being of Americans.[10]

Big data has myriad applications to boost the efficiency of government services while reducing their cost, achieving up to $95 billion in productivity gains. In addition, big data analytics can reduce expenses, for instance by using algorithms to weed out erroneous payments in entitlement or social insurance programs and lowering procurement costs.[11] It can also increase government revenue by reducing tax fraud and improving tax collection.

Realizing the full potential of this game changer hinges on creating the right incentives and training the highly specialized talent needed to manage and analyze big data. Previous MGI research has estimated that by 2018, the United States will face a shortage of up to 190,000 data scientists with advanced training in statistics and machine learning as well as 1.5 million managers and analysts with enough proficiency in statistics to use big data effectively.[12]

Privacy and intellectual property laws must be reevaluated and updated to address the uses of big data; at present there are many gray areas. In some cases, privacy laws hamper the free flow or use of data for potentially beneficial uses; in other areas, the lack of explicit regulation affords consumers little or no protection. In addition, cybersecurity is an ongoing challenge that requires a continuously evolving response on the part of the public sector and private companies alike.

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10 An MGI report on big data from May 2011 calculated its value in US health care as $333 billion, including $226 billion in reduced national health-care expenditures. The approach used here is consistent, but the estimate of impact is smaller because we have reclassified items such as pricing and accounting changes as shifts in market share or consumer surplus. Furthermore, this research does not estimate the impact of big data beyond cost savings.

11 Although the potential cost efficiencies in government services and health care are large, they do not directly raise US GDP because of the way value added is measured in these sectors.

12 *Big data: The next frontier for innovation, competition, and productivity*, McKinsey Global Institute, May 2011.

Box E2. The future of US manufacturing

Both the employment and share of GDP driven by US manufacturing have declined over the past two decades, but the sector remains an important driver of prosperity. It produces 12 percent of US GDP but accounts for 70 percent of private R&D spending, 60 percent of US exports, and 30 percent of productivity growth.[1] Employment in the sector declined from 17.3 million in 2000 to 11.9 million as of May 2013, indicating that manufacturing will not be a solution to the nation's employment crisis. But the jobs that remain in the sector are valuable, as they pay higher compensation than those in service sectors while spurring ancillary jobs and market opportunities, whether in design, distribution, or after-sales service.

Half a million net new jobs have been created in US manufacturing since 2010, but this rebound does not necessarily add up to a broad-based "reshoring" trend. Nearly 80 percent of the jobs created are concentrated in just four industries that together make up one-third of US manufacturing employment. Two of these—motor vehicles, and machinery and equipment—respond primarily to growth in final demand from consumers and businesses, and usually locate their assembly facilities close to demand. The two other industries—primary and fabricated metals—provide intermediate commodity products mainly for domestic consumption, and nearly 60 percent of their output goes into motor vehicles and machinery. If we include other locally based industries such as food processing, nearly 90 percent of the manufacturing recovery can be attributed to a rebound in US demand during the recovery.

The research presented in this report does give some cause for optimism about a continued expansion in very specific parts of manufacturing in the United States. We find that the two-thirds decline in the price of natural gas due to shale production is leading to soaring new investments in petrochemicals, steel, and other energy-intensive industrial activities. This shift in relative costs will favor more domestic production, in part for export. Our chapter on the trade competitiveness of knowledge-intensive manufacturing reveals the potential to expand US production and improve the trade balance in some specific goods, including aerospace, automobiles, and medical devices. This report also describes how big data analytics tools can significantly raise productivity across the manufacturing process and value chain (reducing product development time by 20 to 50 percent, for example). Productivity is strongly correlated with sector competitiveness in the global economy, and this boost may enable increased production in a range of exports and import-competing products. And finally, the modernization of US infrastructure, discussed later in this report, will enable growth in US manufacturing, as it will improve the sector's ability to manage supply-chain logistics and shipping.

If the United States pursues these opportunities, its manufacturing output will continue to grow and more new jobs will be created. While it is only part of what is needed to boost broader US growth, it is possible to reinforce the important contributions that manufacturing makes to US productivity, trade, and innovation.

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1 *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute and McKinsey Operations Practice, November 2012.

INFRASTRUCTURE: BUILDING A FOUNDATION FOR LONG-TERM GROWTH

Years of chronic underinvestment in infrastructure are now catching up with the United States. With economic activity returning to more normal levels after the Great Recession, capacity constraints are once again looming. The backlog of necessary maintenance and upgrades is reaching critical levels—and the need is particularly acute for roads, highways, and transit as well as water systems.

The United States cannot defer hard decisions indefinitely while backbone systems deteriorate. The combination of high unemployment in the construction sector and the large economic multiplier effects associated with these projects makes a compelling case for investing now to accelerate recovery and avoid a legacy of deferred maintenance for the next generation. Currently low borrowing rates present a unique window of opportunity—but that window will not remain open indefinitely. In addition, the right infrastructure must be in place to enable the other game changers described in this report, from domestic shale gas and oil production to increased trade competitiveness.

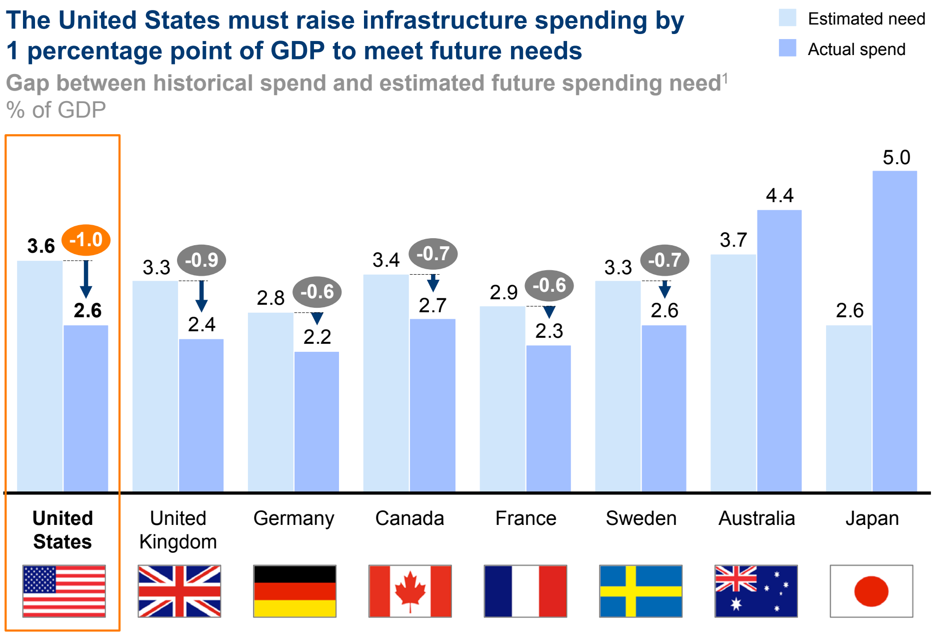
Our analysis shows that the United States will need to increase infrastructure spending by 1 percentage point of GDP on a sustained annual basis to compensate for past underinvestment and set the stage for future growth (Exhibit E7). This equates to additional investment of $150 billion to $180 billion annually for the next 15 to 20 years.

Exhibit E7

The United States must raise infrastructure spending by 1 percentage point of GDP to meet future needs

Gap between historical spend and estimated future spending need[1]

% of GDP



1 Actual spend calculated as weighted average annual expenditure over years of available data, 1992–2011. Estimated need based on projected growth, 2013–30.

SOURCE: McKinsey Global Institute analysis

This would have a powerful short-term stimulus effect, adding 1.4 to 1.7 percent (or $270 billion to $320 billion) to annual GDP between now and 2020 and creating up to 1.8 million jobs. Sustaining this level of investment will eventually bring the nation's infrastructure stock up to the level of peer countries such as Germany by 2030.

In addition to investing more, the United States can substantially raise the productivity of infrastructure investments. In an era of funding constraints, the United States cannot afford to have major projects run over budget and behind schedule, as is too often the case. If strategic infrastructure investments are made with a new and more efficient approach to project selection, delivery, and operation, we estimate that annual GDP would rise by an additional $600 billion by 2030 through the combined effect of a higher and more productive national infrastructure stock.

One of the most effective ways to make infrastructure investment more productive is to choose the right mix of projects from the outset, using a systematic portfolio approach that incorporates rigorous economic analysis. Greater accountability and tighter management of the delivery and execution stages can protect the public interest and produce large efficiencies; based on 40 capital productivity studies, previous MGI research has found that typical delivery costs in infrastructure projects can be reduced by approximately one-quarter.[13] Speeding the approval and land acquisition processes, which can drag on for years in the United States due to fragmented decision making and process redundancy, could make a considerable difference.

Another strategy for increasing infrastructure productivity involves maximizing the life span and capacity of existing assets. In many cases, directing more resources to renewing existing infrastructure may be more cost-effective than new build-outs. There is a need to focus more attention on maintenance, refurbishment, and renewal. In addition, big data is enabling several innovations—including intelligent transportation systems and dynamic congestion pricing—that can avoid the need for costly investments in new capacity.

Given their current fiscal constraints, governments are increasingly turning to more creative funding mechanisms, including approaches that bring in private expertise and capital by offering investors long-term operating arrangements. Public-private partnerships, or PPPs, are commonly used for infrastructure projects across Canada, Europe, South America, and Asia, and they are now gaining traction in the United States. When successful, they can introduce incentives to manage costs by increasing efficiency in the design, construction, and operating stages of an infrastructure project. PPPs are not without their pitfalls, however, and governments and private investors alike must approach these deals with appropriate caution.

TALENT: INVESTING IN AMERICA'S HUMAN CAPITAL

One source of America's historic economic prosperity has been the high skill and education of its workforce. But this edge is now eroding as other nations surpass the United States. US student achievement measures have fallen near the bottom half in international rankings, and the nation's rate of tertiary education attainment for younger workers lags dramatically behind that of other countries (Exhibit E8). Moreover, even those who receive post-secondary education may not be acquiring the skills they need: a recent McKinsey survey found that more than 60 percent of US employers are skeptical of recent graduates' potential to succeed in their company.[14]

13 *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013.

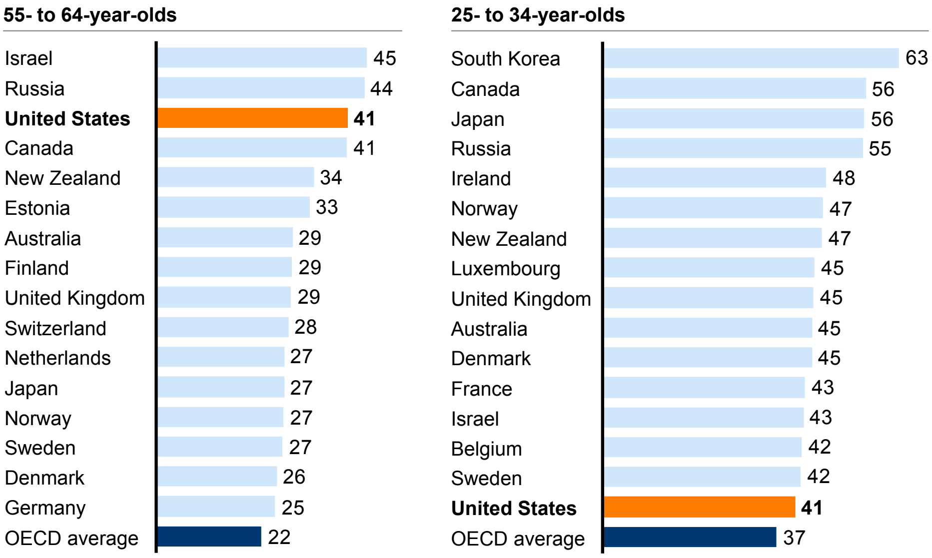
14 *Education to employment: Designing a system that works*, McKinsey Center for Government, December 2012.

Exhibit E8

The United States no longer leads the world in tertiary education attainment

Share of population with tertiary degrees, older versus younger cohort, 2009

%



SOURCE: Organisation for Economic Co-operation and Development (OECD), *Education at a glance 2011* statistical annex; McKinsey Global Institute analysis

Today the United States has an opportunity to fundamentally redesign its system of human capital development, which will increase its global competitiveness. This will also set the stage for capturing the other game changers outlined in this report, from big data analytics to shale energy to trade in knowledge-intensive industries. The talent game changer entails revamping post-secondary education and training as well as raising the quality of K–12 education.

Four initiatives can produce more career-ready workers with good job prospects. The first is expanding the number of apprenticeships and non-degree training programs that give workers marketable skills and credentials. This is particularly important for the millions of Americans currently looking for work, and especially the long-term unemployed. Second is a concerted focus on improving learning and labor market outcomes for graduates of two- and four-year post-secondary institutions. This includes providing better and more transparent information about career pathways and outcomes so that students can choose the most appropriate and effective programs. Boosting college completion rates is critical; fewer than one-third of students who start a two-year degree program at a community college, for example, complete it within three years.[15] Third, the United States needs more graduates with science, technology, engineering, and math (STEM) degrees to build a workforce capable of doing the calculations needed for modern manufacturing processes or interpreting the data that drive the economy. Finally, the United States must rethink its immigration policy to focus on attracting and retaining talent from around the world. Increasing the number of H-1B visas and offering a greater share of permanent residency permits to applicants with higher educational attainment would expand the pool of skilled workers and future entrepreneurs.

15 National Center for Education Statistics/IPEDS Graduation Survey.

Taking a longer view, the United States cannot remain competitive in the decades ahead without raising the quality of K–12 education for all students. Achievement in primary and secondary school lays the groundwork for future productivity and innovation and is closely linked to GDP growth—and US students are falling behind their international peers. But with the right reforms, it is possible to significantly raise student achievement within a decade, as countries such as Germany and Poland have done in a similar time frame. Individual states, including Massachusetts, New Jersey, and Texas, have also made impressive gains.

School reforms enacted by state and local governments and social entrepreneurs across the United States are producing successful models that can be replicated at scale. Three strategies in particular will be crucial: improving the quality of classroom instruction, turning around 2,000 high schools with the nation's highest dropout rates, and introducing new technology into the classroom. Forty-five states have now adopted Common Core State Standards, providing a consistent foundation for implementing reforms on a wider scale and supporting them with innovation and investment.

We estimate that a dual focus on improving US K–12 education and post-secondary education could raise GDP by as much as $265 billion by 2020. The impact would grow larger over the following decade, as more students achieve better outcomes, graduate, and join the labor force, and as the skill profile of the labor force shifts. We estimate these reforms could add as much as $1.7 trillion (almost 7 percent) to GDP by 2030.

In a world powered by increasingly sophisticated technology, human capital is crucial to competitiveness, and the United States will be unable to capitalize on new developments in technology and trade without the right talent in place. It is within reach to build a more cohesive education-to-employment pipeline that gives current and future generations the skill sets needed for success in a 21st-century economy.

CAPTURING THE OPPORTUNITIES

Over the past few years of slow recovery, both US public policy and private investment have sometimes been tentative, but it will take a new mindset to accelerate growth. Unique windows of opportunity are opening for the United States to build a competitive advantage in energy, trade, technology, infrastructure, and education. Business leaders and policy makers alike will have to think long term and act decisively.

The United States has the resources to successfully realize these game changers, and much of the leadership—and the initial investment—will come from the private sector (Exhibit E9). Even in areas such as infrastructure and talent development, which have traditionally relied on government funding, there is an opportunity to inject greater private-sector capital and innovation. Policy makers at all levels will have an important role to play as well, by addressing a range of regulatory and legal issues raised by the game changers and spearheading some necessary policy shifts.

Each of the five game changers identified in this report can have a powerful impact that reverberates throughout the US economy on its own, but pursuing these mutually reinforcing goals simultaneously would result in additional spillover effects. It could produce a virtuous cycle of growth that puts the nation back on the path to prosperity, increases employment opportunities, and improves its fiscal outlook.

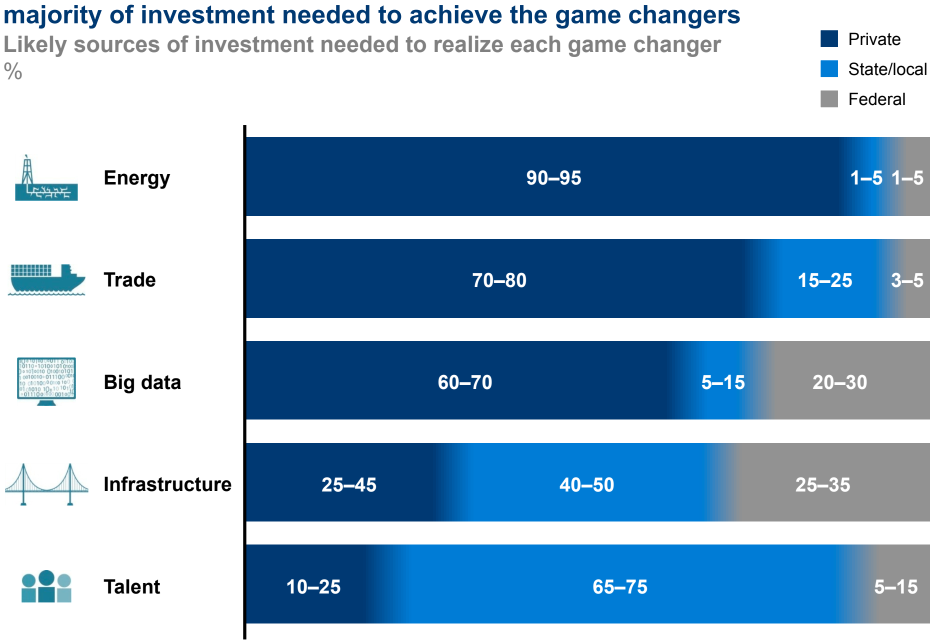
Exhibit E9

The private sector and state/local governments will provide the majority of investment needed to achieve the game changers

Likely sources of investment needed to realize each game changer

%

ESTIMATE



SOURCE: McKinsey Global Institute analysis

Private-sector investment and innovation are the key ingredients

Much of the outcome ultimately rests with the private sector. Many companies have the resources to increase investment where they see opportunity and are considering where to deploy their capital in an uncertain global environment.

The five game changers discussed in this report present sustainable medium- and long-term opportunities for investment and new business models in the United States—and the businesses that recognize them quickly will edge out their competitors. This is a pivotal moment for gaining a foothold in new markets and riding the next wave of disruptive technologies. The private sector is taking the lead in shale energy development and its supporting infrastructure, as well as energy-intensive manufacturing. Private companies are entering creative infrastructure partnerships, using big data to transform their operations, and exporting goods and services to fast-growing emerging economies. In talent development, the newly adopted Common Core State Standards are opening the door for educators, social entrepreneurs, publishers, tech firms, and open-source projects to develop new curriculum tools in public schools. Foreign companies are increasing their investment in the United States, and it is time for more domestic companies to follow.

Beyond the immediate opportunities, businesses have a role to play in addressing longer-term issues. In shale energy, oil and gas producers can take the lead in managing environmental risks by continuing to invest in equipment that incorporates new and cleaner technology as well as ensuring that all producers—both large and small—maintain best safety practices. There is a great deal at stake here: mitigating these risks is crucial to protecting the air and groundwater as well as allowing the industry and the US economy as a whole to fully realize the benefits. In addition, the private sector can become more actively engaged in developing infrastructure and shaping a first-class system for education and training, since US businesses cannot thrive without these crucial enablers.

Business engagement can drive considerable change without waiting for legislation or policy. Employers who see a skills gap, for example, are reaching out to local educators to build degree programs and short-term training programs that create their own talent pipeline while also giving workers the credentials and skills they need. Business executives across the country are actively partnering with state and local officials, universities, and industry associations to drive an economic renaissance in their communities and regions.

National policy makers can create the right environment for growth

In an age of globalization, when companies can and do move their operations anywhere in the world, it is more important than ever for the United States to maintain an attractive business environment. This will involve leveling the playing field on corporate taxes as well as addressing cumbersome regulations and slow permitting processes that add red tape and delay to many new projects. It is crucial to underline that these goals can be achieved in a balanced manner that does not reduce revenue or harm the public interest that regulation is meant to protect; it is a matter of simplifying, streamlining, and considering how US requirements measure up against best practices from around the world.

Governing by temporary measures or taking years to approve projects also creates policy uncertainty that discourages businesses from investing and slows economic momentum. There is tremendous scope to make the process of applying for business permits and environmental approvals more efficient, transparent, and coordinated without loosening oversight and public protections. This will be crucial to encouraging private-sector investment in energy infrastructure and new manufacturing plants. In addition, a new policy framework will be necessary to capture the maximum benefits of big data in health care and the public sector; establishing rules on privacy protections and clarity on data ownership is needed to govern its usage in the private sector.

National policy makers can also create structures that attract private capital to fund public infrastructure and education; this could open the door to greater accountability, innovation, and efficiency in public works projects. Similarly, policy makers can launch incentives and programs that encourage state and local experimentation and private-sector participation in education and workforce training. The Race to the Top, for example, accelerated school reform efforts across the country. A public-private partnership between the Skills for America's Future initiative and the National Association of Manufacturers created an industry-specific curriculum, allowing 500,000 community college students to earn credentials that will be a stepping-stone to jobs in the manufacturing sector. There is a great willingness on the part of business leaders to engage with these issues, and policy innovations can provide a framework for doing so.

Cities can build on these game changers to drive regional economic growth

Under the best of circumstances, the wheels of federal regulation and legislation turn slowly; in the current political stalemate, they often fail to budge at all.

Although the federal government could be a powerful catalyst, none of the five game changers presented here is fully contingent on action from Washington. Mayors, governors, and regional partnerships can also lead. Some of the most innovative policies, financing models, and approaches are emanating from the state and local levels, such as the Chicago Infrastructure Trust or New York's launch of Cornell NYC Tech, which will offer graduate degrees in science and cutting-edge technology. Cities and states are seizing the initiative on promoting export industries, attracting foreign direct investment, developing infrastructure, and creating vocational training.

Indeed, the economic vitality of its cities sets the United States apart from other nations. US cities are expected to generate more than 10 percent of global GDP growth between 2010 and 2025—more than the cities of all other advanced economies combined.[16] "Middleweight" cities with populations between 150,000 and ten million, including innovation hubs such as Boston, San Jose, and Austin, account for more than 70 percent of US GDP. The industry-specific clusters that have developed around many cities across the country are the hidden strength of the US economy. Silicon Valley and North Carolina's Research Triangle are well-known examples, but dozens of other economic clusters foster continuous innovation, from cybersecurity in San Antonio to medical devices in Minneapolis and aerospace in Wichita. These clusters, which often feature industry-academic-government research collaborations, become ecosystems that foster higher productivity and support advanced manufacturing.

Other countries are beginning to replicate this model of city and regional economic development, but the United States remains at the forefront. Realizing the game changers at the local level will be crucial to the success of the national economy.

□ □ □

Sluggish growth may not appear to be a problem that can galvanize decisive action, but it is quite damaging over time. An economy that performs below its capacity is a slow-motion crisis that erodes living standards. The United States can disrupt this status quo by mobilizing a new wave of investment that rebuilds the productive capacity of the economy. After considering a variety of growth policies, we have identified a set of five game changers with the potential to create a step change in US economic performance. By sizing these opportunities, we hope to focus national attention on renewing long-term growth and prosperity.

16 *Urban America: US cities in the global economy*, McKinsey Global Institute, April 2012.

Energy: Capturing the shale opportunity

Ever since domestic oil production peaked in the early 1970s, prompting urgent warnings that the nation was running out of oil and natural gas, US energy sector jobs and output have declined. Energy grew to account for half of the nation's trade deficit. As recently as a decade ago, the United States was staring at a future of growing dependence on energy imports, with all of the attendant geopolitical problems that would entail.

But now the combination of horizontal drilling and hydraulic fracturing has unlocked huge deposits of natural gas and oil once considered too difficult or costly to extract. In recent years, North American production of both shale gas and oil has risen sharply, and robust growth is expected to continue.[17] A sudden abundance of natural gas is fundamentally changing the US energy portfolio and lowering prices to the benefit of the power-generation sector and energy-intensive downstream industries. The International Energy Agency now forecasts that the United States will surpass Saudi Arabia and Russia to become the world's biggest oil producer by 2020—perhaps becoming a net oil exporter by 2030.[18] Already, the United States is projected to import fewer barrels of oil in 2013 than it has in any year since 1987, even though the economy has grown nearly twice as large during that period. And because production is moving forward so quickly, North America may be able to sustain its shale gas and oil advantage over other countries for the next ten to 15 years.

However, the shale boom entails a range of environmental risks—including groundwater contamination, fugitive methane emissions, and potential seismic effects—that should be addressed. If environmental damage were to occur, the potential long-term costs could be serious. The industry should create transparency on these risks and maintain rigorous operational standards, particularly for well casings, wastewater disposal, and transmission pipelines; by doing so, it can build public confidence. Regulators, those charged with enforcement, and industry leaders should work together to ensure that all producers (large and small) continuously improve and adopt best practices. The size of this economic opportunity argues for a careful approach to these and other issues, including land-use impacts on local communities and the intensity of water use in drought-prone regions.

Hydraulic fracturing and horizontal drilling techniques have been in use for a number of years, but the current wave of investment, development, and drilling is unprecedented. The impact is already clear in regions where this activity is

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17 In addition to shale gas, tight gas (extracted from concentrations of hard rock or non-porous limestone or sandstone) and coalbed methane (found in coal seams) fall under the broader category of "unconventional gas." Similarly, "unconventional oil" refers to oil produced using any technique other than conventional oil wells, such as processing oil sands. Although multiple types of unconventional oil and gas production are rising, this chapter focuses exclusively on shale gas and light tight oil. Since 2007, shale gas production has grown by 51 percent annually, while tight oil production has risen by 58 percent.

18 *World energy outlook 2012*, International Energy Agency, November 2012.

concentrated (including North Dakota, Texas, and Pennsylvania). While tight oil production is at an earlier stage of development than shale gas, its impact is potentially far greater. We estimate that by 2020, shale gas and tight oil production combined could add 2 to 4 percent ($380 billion to $690 billion) to annual GDP, create up to 1.7 million permanent jobs, and perhaps reduce the energy import bill to zero. In addition, the infrastructure required to capture the opportunity could involve up to $1.4 trillion of private investment and generate 1.6 million temporary jobs, mainly in the construction sector.

Looking beyond the numbers, the unconventional energy boom has brought investment and jobs to parts of the country that have seen little of either in recent decades. This is benefiting the very segment of the workforce that has been hit hardest by the long-term decline in industry and manufacturing, and the relatively high-wage jobs created by this development will have large multiplier effects in local economies.

INNOVATIVE EXTRACTION TECHNIQUES HAVE UNLOCKED PREVIOUSLY INACCESSIBLE GAS AND OIL RESOURCES

Enormous deposits of hydrocarbons lie trapped in shale rock formations across North America, but for many years, extracting these resources did not appear to be feasible or profitable. But new technological advances in horizontal drilling and hydraulic fracturing have unlocked previously unrecoverable or uneconomic shale gas resources in North America. (See Box 1, "What is 'fracking'?")

Box 1. What is "fracking"?

The word "fracking" is often used as shorthand to describe the full range of shale production activities: exploration, drilling, capture, transport, and waste disposal. But within the industry itself, "fracking" refers only to the specific process of hydraulic fracturing, which involves injecting a large volume of water mixed with sand and chemicals at high pressure to create fractures in shale rock. This frees trapped gas, allowing it to flow toward the well bore for capture and transport.

Hydraulic fracturing has been in use for decades, but it achieved new levels of effectiveness when combined with horizontal drilling, a technique pioneered in the Barnett Shale. This process involves drilling a vertical well through the rock and cementing steel casing in place to seal off the well bore from adjacent rock and any underground water sources that are nearby. The drill bit then moves laterally through the target shale formation to maximize potential recovery from each well.

The primary building block of natural gas (methane) is typically found with other hydrocarbons, such as ethane, propane, butane, and pentane. Processing involves separating these hydrocarbons and other fluids to derive "dry" natural gas that can be transported in a pipeline. The associated hydrocarbons are not waste by-products; these natural gas liquids have a variety of commercial uses in oil refineries and petrochemical products and are sold as separate products.

The combination of horizontal drilling and hydraulic fracturing is also being used to extract light tight oil. This oil is called "light" because it is less dense than heavy oil and "tight" because it is found in very low-permeability reservoirs and cannot be tapped without advanced drilling and completion processes.

Horizontal drilling and hydraulic fracturing have led to a boom in natural gas production

Shale gas formations stretch across large parts of the United States, Canada, and Mexico. The Marcellus and Haynesville formations are among the largest gas fields in the world. North Dakota, Texas, and Pennsylvania are hubs of new production, which is also ramping up in the wider surrounding regions. At the time of publication, total technically recoverable natural gas resources in the United States are believed to be between 2,000 trillion and 2,500 trillion cubic feet.[19] At current rates of natural gas consumption (roughly 25 trillion cubic feet in 2012), total US reserves will last anywhere from 90 to more than 100 years.

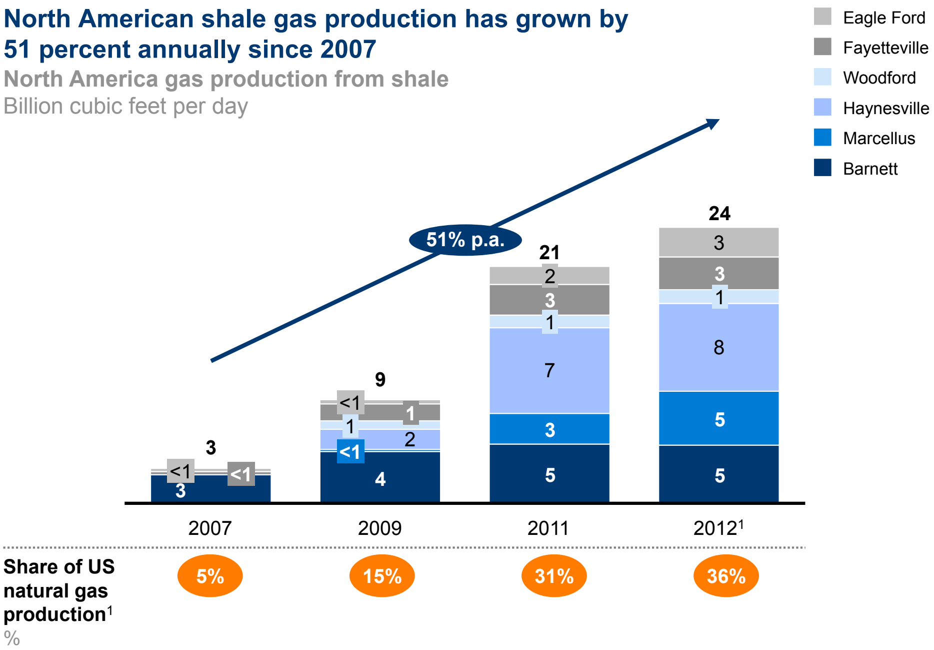
The production of shale gas took off beginning in the mid-2000s and has rapidly expanded. The United States has moved faster than any other nation to deploy these technologies and develop its resources (see Box 2, "North America has seized the early advantage in shale gas development"). Shale gas accounted for an estimated 36 percent of total US gas production in 2012, up from just 5 percent in 2007. Annual output grew from three billion cubic feet per day in 2007 to 24 billion cubic feet per day in 2012, for an annual growth rate of 51 percent (Exhibit 1).

Exhibit 1

North American shale gas production has grown by 51 percent annually since 2007

North America gas production from shale

Billion cubic feet per day



1 Marketed production levels at wellhead. Includes Lower 48 onshore and Gulf of Mexico offshore volumes.

SOURCE: Energy Insights (a McKinsey Solution); Hydrocarbon Production Data; US Energy Information Administration; McKinsey Global Institute analysis

19 See estimates of technically recoverable resources from the US Energy Information Administration in 2013, National Petroleum Council surveys in 2011, and the Potential Gas Committee in 2011. Various other industry and academic sources have also tried to estimate US resources.

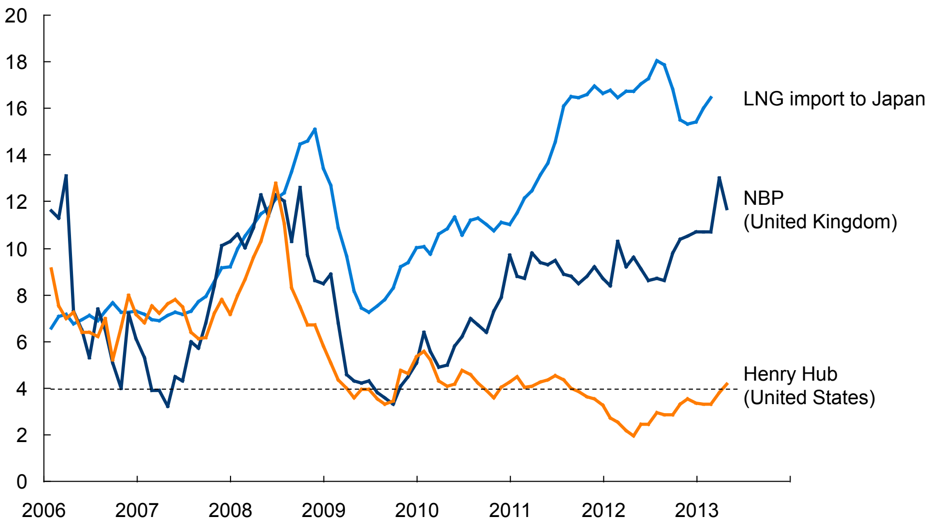
As a result, prices have declined dramatically since 2008. The Henry Hub benchmark price of US natural gas has fallen from nearly $13 per MMBtu in 2008 to approximately $4 in spring 2013—and fell below $3 per MMBtu occasionally in 2012.[20] By contrast, the price of natural gas in the United Kingdom (National Balancing Point, or NBP) exceeded $10 per MMBtu in 2012, and the price of imported liquefied natural gas (LNG) in Japan exceeded $16 per MMBtu. As US natural gas supply has outpaced demand, prices have fallen to the extent that revenue no longer covers production costs (Exhibit 2). Many producers are now diverting resources toward extracting tight oil instead, as we discuss later in the chapter.[21]

Exhibit 2

US natural gas prices have declined by two-thirds since 2008

Natural gas prices in the United States, United Kingdom, and Japan

$ per million Btu



SOURCE: Energy Insights (a McKinsey Solution); Hydrocarbon Production Data; US Energy Information Administration; McKinsey Global Institute analysis

We expect that the US natural gas market will continue to be demand-constrained for the foreseeable future, keeping the price of natural gas below $6 per MMBtu even if the United States begins to export LNG. As it is, many smaller independent operators continue to produce gas even at current price levels; larger companies may boost production if prices start to rise—but that would increase supply, making it difficult for prices to exceed $6 per MMBtu.

20 MMBtu = million British thermal units. There are approximately 1.023 MMBtus in 1,000 cubic feet of natural gas.

21 Chesapeake Energy, ExxonMobil, and Encana Corp. were among the producers that scaled back natural gas production in 2012. In March 2013, ConocoPhillips announced that because of low natural gas prices, it was suspending exploratory drilling in New Mexico's San Juan Basin, although the company will continue to operate wells already in production.

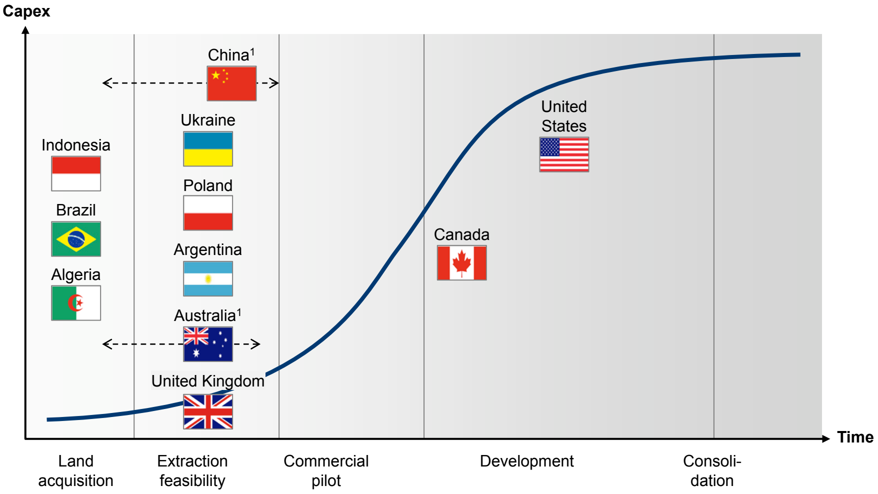
Box 2. North America has seized the early advantage in shale gas development

Several nations possess large shale deposits of gas and oil, though none has tapped its resources to the same extent as the United States and Canada. A combination of industry and regulatory factors has enabled the United States to exploit the shale gas opportunity quickly (Exhibit 3). First and foremost, the nation has a long history of oil and gas development; it has a wealth of industry expertise and developed the fracking technologies that have made shale extraction profitable. Although additional investment is now needed, the United States went into this new era with a vast network of transmission pipelines, refineries, gathering facilities, and other infrastructure already in place. US law permits individual landowners to lease the mineral rights to their property for energy development, while in most countries mineral rights are state-controlled. Regulation allowed for wide-open competition and quick scale-up. The presence of a large number of independent players has allowed risk and cost to be diversified. The size of the industry has enabled the ramp-up of support services. And last but not least, the industry was able to access water resources.

Exhibit 3

Other regions lag behind the United States in the pace of shale energy development

Current position of select countries on shale gas and oil production



1 Flags based on most advanced basins in China (Sichuan basin) and Australia (Cooper basin). Other basins are still at the land acquisition stage.

SOURCE: McKinsey Global Oil and Gas Practice; expert interviews; McKinsey Global Institute analysis

Although the United States has set the pace for shale development, China has the world's largest shale gas resources. The Chinese government is actively promoting plans to develop this resource, a move that could have profound implications for the country's LNG demand and for cutting its carbon dioxide emissions by switching from coal to natural gas. But China currently lacks the industry expertise and pipeline infrastructure, and developing these assets will take time. It also faces unique geologic challenges, and the dominance of national oil companies may limit competition and innovation in this sector.

Box 2. North America has seized the early advantage in shale gas development (continued)

The largest shale gas resources in Europe belong to Poland, which aims to shift from coal to natural gas for power generation and reduce its reliance on Russian imports. But Poland is still in the initial exploratory and startup phase; commercial production has yet to get under way. Multiple international players are actively exploring for promising sites, with strong government support, although few wells have been drilled to date (most of which do not have potentially viable flow rates). In February 2013 the Polish government announced a package of measures to promote shale development with an eye toward scaling up commercial production to between one billion and two billion cubic feet by the mid-2020s.

The biggest and most advanced play in Latin America is in Argentina—specifically in the oil- and gas-rich Vaca Muerta formation. Because Vaca Muerta is located near Argentina's traditional oil-producing region, the competencies and infrastructure are at hand to tap these reserves. Oil prices make it economical to drill, and the government recently raised the cap on natural gas prices to $7.50 per MMBtu, which may encourage production. Argentina already has a high share of vehicles powered by natural gas, which ensures local demand from the transport sector. In addition to YPF, which has been recently nationalized, international players such as Shell, Chevron, Apache, and EOG Resources are ramping up exploration activity. Argentina is quickly moving to the commercial pilot and early development stages.

Shale development is also getting under way in Australia, where some US energy names are partnering with local companies. Australia is well positioned to export LNG to Asia but has two disadvantages: its small population offers a limited domestic market, and pipelines have to cross vast distances.

Similar technologies have made it possible to tap light tight oil

From its peak in 1970, US domestic oil production declined by 48 percent before hitting its Great Recession low in 2008. But since then, production is up by 25 percent, reaching an estimated 6.5 million barrels per day in 2012. The US Energy Information Administration (EIA) projects that domestic oil production could rise further, to 8.5 million barrels per day in 2014.

The major driver behind this rebound is the rush to develop reserves of light tight oil. Employing the same extraction techniques used for shale gas, the United States produced some 1.5 million barrels per day of light tight oil in 2012, representing almost a quarter of total oil production. As demand for oil continues to exceed supply, the production of domestic light tight oil has been growing more rapidly than shale gas production (Exhibit 4). These methods are also being used to access new productive zones underneath mature conventional oil fields and maximize their yield.

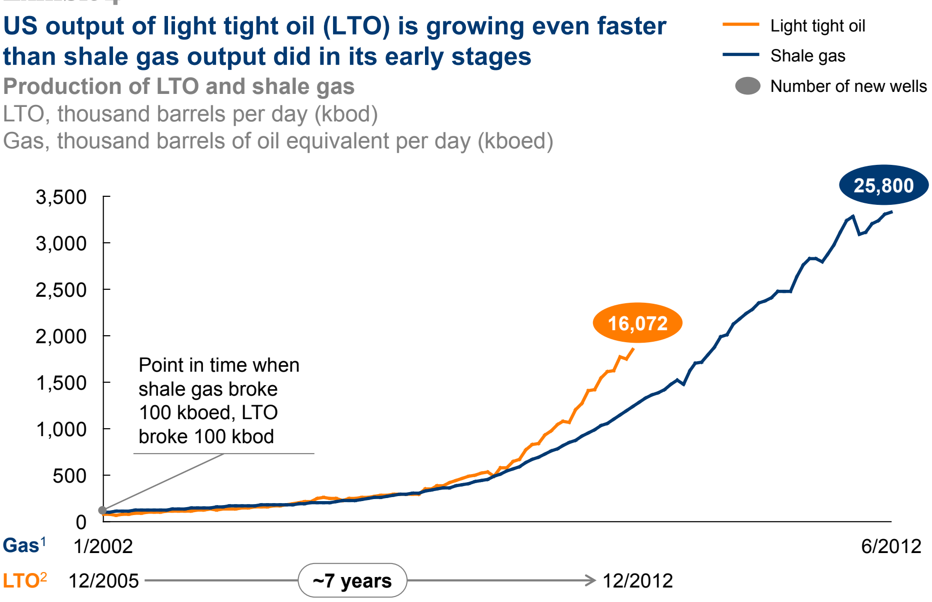
Exhibit 4

US output of light tight oil (LTO) is growing even faster than shale gas output did in its early stages

Production of LTO and shale gas

LTO, thousand barrels per day (kbod)

Gas, thousand barrels of oil equivalent per day (kboed)



1 Barnett, Eagle Ford, Fayetteville, Haynesville, Marcellus, and Woodford—only gas included.

2 Bakken, Eagle Ford, Granite Wash, Avalon, Mississippi Lime, Spraberry, Austin Chalk, Bone Spring, Niobrara, Woodford, Monterey—only liquids included; wells with production after January 2000.

SOURCE: Energy Insights (a McKinsey Solution); HPDI; US Energy Information Administration; McKinsey Global Institute analysis

The EIA notes that US monthly crude oil production is exceeding crude oil net imports in 2013 for the first time since the mid-1990s. Tight oil formations in the Williston Basin (the Bakken formation in North Dakota/Montana) and the Western Gulf and Permian basins (Texas) account for much of the forecast growth in production.[22] To put the scale of drilling activity in perspective, consider that in January 2011, some 2,116 wells were producing 275,000 barrels per day in the Bakken formation alone; just two years later, in January 2013, 5,161 wells in the Bakken formation were producing 673,000 barrels per day.[23]

Given the currently low price of natural gas, increased production of light tight oil generates greater economic impact than shale gas in the 2020 scenario detailed later in this chapter. (See the appendix for additional detail.)

CHEAP NATURAL GAS HAS ALREADY AFFECTED COAL AND POWER PRODUCTION AND COULD ALSO IMPACT RENEWABLES

The sharp price decline of US natural gas since 2008 has had an immediate effect on the nation's power-generation industry. Wholesale electricity prices have fallen, as have retail prices in some states. These declines in electricity prices may have already largely played out. In addition, there has been significant substitution of gas for coal. Cheaper gas means that utility-scale renewables will remain dependent on policy incentives to be competitive through 2020; distributed solar generation will be less affected because of the relatively smaller impact of cheap gas on future retail electricity prices.

22 *Short-term energy outlook*, US Energy Information Administration, March 2013.

23 North Dakota Department of Mineral Resources, Oil and Gas Division.

Electricity prices have declined and are expected to stabilize or rise slowly

Falling wholesale natural gas prices have correlated with falling wholesale electricity prices nationwide. For example, from 2008 through 2012, peak electricity wholesale prices in the PJM western region (which comprises Illinois, Indiana, Kentucky, Michigan, Ohio, Tennessee, and West Virginia) declined from $90 per megawatt-hour to less than half that level. Projections from various sources, including the EIA, indicate that electricity prices are now expected to stabilize or even rise slowly through 2020 and beyond.[24]

So far, retail electricity prices have fallen only in those states where electricity is deregulated and natural gas plays a sizable role in the power-generation mix; these include New York, Nevada, and Texas. Deregulated states such as Ohio and Montana actually experienced price increases, because gas accounts for less than 10 percent of their mix. Most other states—including the big industrial states—are not fully deregulated. The national average retail price for industrial electricity has stayed above 6.50 cents per kilowatt-hour since 2008.

There has been a significant shift from coal to natural gas in power generation

The US power industry has undergone substantial substitution of coal-fired generation with natural gas–fired generation in recent years. Between 2008 and 2012, roughly 250 to 350 terawatt-hours of power generation were switched from coal to gas; this equates to about 12 to 17 percent of 2008 coal-fired power generation. Total power generation from coal and gas has been reasonably stable in this time, so gas has been gaining share at coal's expense. Coal-to-gas switching has occurred between plants within the same region. Most of the switching took place in the Southeast, Mid-Atlantic, and Rust Belt regions.

While relative fuel prices are a key driver of switching, factors such as insufficient pipeline capacity, transmission constraints, and locational mismatches could limit the potential for additional switching from coal to gas in the near term. These factors can be overcome in the longer term as new plants come online or new transmission capacity is put in place. However, they could be offset by potential increases in the price of natural gas. In any case, the relationship between coal and gas in the power mix is primarily a substitution effect, barring any growth in coal exports. For the purposes of this analysis, we have treated the coal-to-gas substitution as having no net economic impact on aggregate US GDP.

Impact of cheap natural gas on renewables deployment

The impact of low natural gas prices on the development of renewables plays out slightly differently in utility-scale generation and distributed power generation.[25] To illustrate those dynamics, we consider the varying cases of onshore wind and large-scale solar in utility-scale generation, and rooftop solar photovoltaic (PV) in distributed generation.

24 See reference case projection for electricity prices by end-use sector, *Annual energy outlook 2013*, Energy Information Administration, April 2013. Also see Table 11, Comparison of electricity projections, in same report for a comparison of EIA's reference case projection with that of other sources.

25 "Distributed generation" refers to the deployment of small-scale power production on the end-user site.

In utility-scale generation, the development of renewables is currently dependent on policy incentives. The economics of wholesale electricity are such that renewables cannot compete with natural gas when it is below $9 per MMBtu without the support of federal investment and production tax credits or state-level renewable portfolio standards.[26] This is true even for the lowest-cost renewable energy sources, such as onshore wind in the best-endowed areas of west Texas and Iowa. Despite falling gas prices, the share of wind in US power generation has risen from 1.3 percent in 2008 to 3.5 percent in 2012; solar has grown even faster, though from a small base. But there is a risk that policy support for renewables may be scaled back when natural gas prices are low. North Carolina and Colorado, for instance, have even debated measures to lower mandates or broaden the scope of acceptable sources to meet renewables targets.

Over time, a decline in the installed cost of renewable energy sources could improve their competitiveness. For example, wind costs could be reduced by larger rotor and higher tower technology, competition in input markets, and improvements in installation and service. Under different scenarios of cost reductions and technology improvements, competitiveness with natural gas could be reached more or less rapidly for both utility-scale wind and solar PV (although likely not before 2020). The price of natural gas can shift this timing, however, through its impact on the wholesale price of electricity. Two other drivers may support the deployment of renewables in utilities and are worth mentioning, though their effect is harder to estimate. Industry experts suggest that some large commercial customers are supporting demand for renewables-based electricity at a premium to wholesale prices as a commitment to environmental sustainability and sometimes as a hedging strategy. Also, many utilities are adding renewables to diversify their "generation portfolios" and mitigate the risks of fluctuating fuel prices and potential moves toward more stringent clean-energy policies.

In distributed generation, low gas prices should have a much weaker impact on the development of rooftop solar PV. End-users assess the cost of distributed generation against prevailing retail power rates, where natural gas prices have only limited impact given that transmission and distribution account for more than 40 percent of charges. While Massachusetts and Texas, both deregulated states, experienced 10 to 15 percent retail price declines from 2008 to 2011, the prices have increased in many regulated states; nationally, the average retail price declined by only 1 percent over this period.[27]

Should declining costs continue to make the technology more attractive relative to retail power prices, the deployment of rooftop solar PV will continue to grow. Already, its generation cost is close to being competitive in states with high retail prices, such as Hawaii, New York, New Jersey, and Connecticut. The installed cost of distributed solar PV could still fall by up to 10 percent per year on average between now and 2020.[28] Following the recent drop in the price of polysilicon, reductions in the installed cost of solar PV could be sustained by increases in cell conversion efficiency, standardized and modular system design, and lean installation practices.

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26 These are state regulations on the share of power that is generated by renewable sources. For instance, Kansas requires that 20 percent of power generation must come from renewables by 2020.

27 *World energy outlook (*2009 through 2012 editions), International Energy Agency; McKinsey Global Institute analysis.

28 *Shale and renewables: A symbiotic relationship*, Citi Research, September 2012.

THE SHALE ENERGY BOOM COULD RAISE GDP BY $380 BILLION TO $690 BILLION ANNUALLY BY 2020

The shale gas and tight oil production boom could have a significant longer-term impact on the broader US economy. We measure this by creating low- and high-range scenarios for 2020, drawing on the projections for output and exports described below. (See the appendix for additional details on the methodology.) Building on these assumptions, we extrapolate the total effect on GDP, job creation, and balance of trade.

Increased shale production could increase GDP through four channels, which we discuss in turn below:

- Higher domestic oil and gas production directly generates jobs and GDP within the energy sector, as well as reducing oil imports and raising exports.
- Downstream energy-intensive manufacturing industries that use natural gas as a fuel or feedstock could increase production.
- Indirect gains accrue in services, construction, trade, and related sectors to support higher output in the energy and manufacturing sectors.
- Higher employment and wages lead to induced gains throughout the economy.

Higher domestic oil and gas production could increase GDP while reducing net energy imports to virtually zero

By 2020, we project an increase of $115 billion to $225 billion in annual GDP in the oil and gas production sector alone, which could add 110,000 to 215,000 jobs. This increased production comes from both shale gas and light tight oil.

Shale gas production is currently 24 billion cubic feet per day (bcfd), and supply outstrips demand. To estimate the GDP effect of higher gas production, we take the approach of estimating reasonable changes in demand and assume that production will increase as needed to meet that demand. Most of the demand increase is expected to be in power generation, downstream manufacturing, and net exports of liquefied natural gas (LNG).

We project that natural gas imports will marginally decline and exports may rise. The United States currently consumes around 65 bcfd of natural gas, with imports making up 14 percent of the total. In 2012, the nation imported nearly three trillion cubic feet of natural gas by pipeline (almost all from Canada). In the same year, it imported 174 billion cubic feet of LNG, a volume that fell by 60 percent in just two years' time. (The United States also exports a small amount of natural gas, roughly 4 bcfd.) Increased domestic production could reduce current total imports by up to one-third, although some level of imports will still be needed to smooth out the supply across regions.

Today the United States is considering whether to embark on a future as an exporter of LNG, a shift that would require converting some of the nation's increasingly underutilized import terminals to exports terminals. However, all applications for projects to export natural gas to countries with which the United States does not have free trade agreements require the approval of the US Department of Energy. As of May 2013, 20 applications were under review by the Department of Energy to export domestically produced LNG. These projects add up to roughly 30 bcfd of proposed LNG exports. To date, however, only two have been approved: Cheniere Energy's Sabine Pass project in Louisiana, with an expected export capacity of 2.2 bcfd, and Freeport LNG Expansion's project in Texas, with an expected export capacity of 1.4 bcfd. We consider two scenarios of additional approvals such that total capacity could support 6 to 15 bcfd of US LNG exports. At 2011 prices, this would add up to $11 billion to $27 billion of exports annually. We project that this level of LNG exports would not substantially alter the probability of gas remaining below the $6 per MMBtu price ceiling.

Compressed or liquefied natural gas can also be used as vehicle fuel, raising the possibility that natural gas could play a much greater role in the transportation sector.[29] Natural gas vehicles are already being used in some commercial and municipal fleets and public transit systems, but they have not caught on with US consumers for personal use. There are 14.8 million natural gas vehicles in use worldwide, but only 112,000 in the United States.[30] Despite the potential, the costs associated with building an adequate infrastructure to allow for easy refueling are substantial. We have not considered a scenario in which the United States embarks on a large-scale shift to natural gas vehicles in the near term and so have not included this as part of our 2020 forecast. If such a transformation does occur, the economic impact of shale gas would be even larger.

The United States currently consumes around 19 million barrels of crude oil on a daily basis, with imports making up 40 percent of consumption. In addition, the United States trades in refined petroleum products, with imports of 2 million barrels per day (mbpd) and exports of nearly 3 mbpd of refined product.

In 2012, the United States produced 6.5 mbpd of crude oil, including 1.5 mbpd of light tight oil. Our scenario for 2020 assumes that light tight oil production could rise by anywhere from 4 to 8 mbpd. Since nearly all domestic production is light crude, it is likely that the United States will continue to import medium and heavy varieties of oil. Considering the average US oil import price (2011) of $103 per barrel, the additional tight oil production of 4 to 8 mbpd is equivalent to an import substitution effect of $150 billion to $300 billion, potentially large enough to reduce US net energy imports effectively to zero (Exhibit 5). See also Box 3, "The impact of shale gas and light tight oil on the US trade deficit."

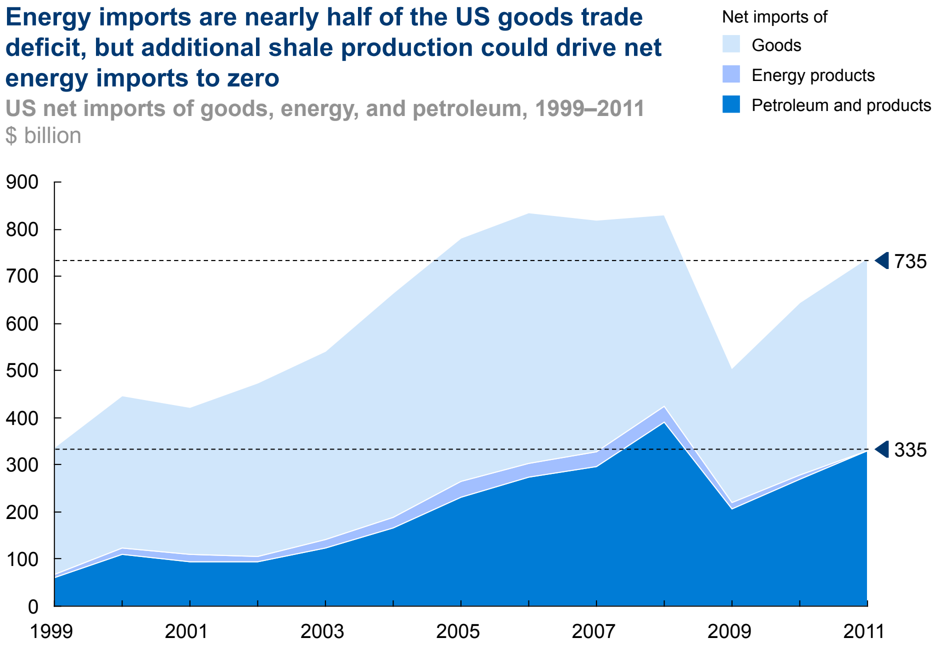
29 LNG is natural gas that is cooled until it becomes a liquid, which greatly reduces its volume for easier transport. Once delivered, it is reheated to again become a gas.

30 Alternative Fuels Data Center, US Department of Energy.

Exhibit 5

Energy imports are nearly half of the US goods trade deficit, but additional shale production could drive net energy imports to zero

US net imports of goods, energy, and petroleum, 1999–2011
$ billion



SOURCE: US Bureau of Economic Analysis; McKinsey Global Institute analysis

The United States could also boost output of refined products. In 2011, the United States became a net exporter of refined products for the first time since 1949. Even without new refinery capacity added by 2020, utilization of existing US Gulf Coast refineries could increase from the current 87 to 90 percent of capacity to 97 percent of nameplate capacity. This boost would add 0.5 to 0.6 mbpd of refined output to current export levels of 2.4 mbpd.

Box 3. The impact of shale gas and light tight oil on the US trade deficit

Net US imports of goods, petroleum, and energy products totaled $735 billion in 2011, nearly half of which ($335 billion) was made up of petroleum and other energy products. Increased production of domestic light tight oil means that US petroleum imports—nearly 8 million barrels per day, or 40 percent of daily crude oil consumption—can be driven down substantially. If domestic tight oil production can achieve the high-end estimate of eight million additional barrels per day, the US net import of crude can effectively fall to zero. It should be noted, however, that this does not imply US gross oil imports will decline to zero; the medium and heavy crude that is currently consumed cannot easily be switched to light crude and may continue to be imported.

In addition, our assumptions of LNG and refined product exports (and overall production of petrochemicals, fertilizers, resins, and primary metals) also affect the net import bill for goods through higher exports and import substitution.

The general equilibrium impact on the overall trade deficit is more difficult to estimate, for two reasons. First, when net oil imports are reduced, the US dollar may be affected, which could alter the dynamics of other trading sectors such as manufacturing. The steady-state outcome of any adjustment to the US dollar is hard to predict. Second, any decrease in the overall trade deficit means the current account deficit must also decrease. There must be corresponding changes in national savings relative to investment so as to reconcile a narrowing current account deficit. The current account deficit cannot decrease because of a fall in investment—presumably, national investment would have to increase during this time to enable the additional production of oil, gas, and energy-intensive goods. Therefore, national savings would have to rise in order to reconcile the higher investment needs and a lower current account deficit. Some of this rise in national savings could be achieved through higher corporate savings, which would incorporate the effect of gross investments, but it is hard to pinpoint the trend in the national savings rate that would account for a lower trade deficit.

Regardless of where the trade balance ends up, the reduction in net energy imports is likely to be a net benefit. For example, even if the exchange rate adjustment were to offset the balance of trade impact, the United States would enjoy an improvement in the terms of trade; for any given trade deficit, the dollar would be higher and imports would be cheaper for US consumers.

Energy-intensive manufacturing industries are the prime downstream beneficiaries

The shale boom initially sparked a wave of speculation that cheap natural gas could lead to a renaissance in US manufacturing. But this overstates the likely impact, since the cost of energy is only one among many factors that goes into a company's decision on where to base production. Other considerations that influence manufacturing location decisions include labor costs and skill availability, demand growth and market proximity, transport and logistics infrastructure, innovation and intellectual property rights, and business and regulatory environment.[31] Moreover, as noted above, the declines in wholesale electricity costs have already played out.

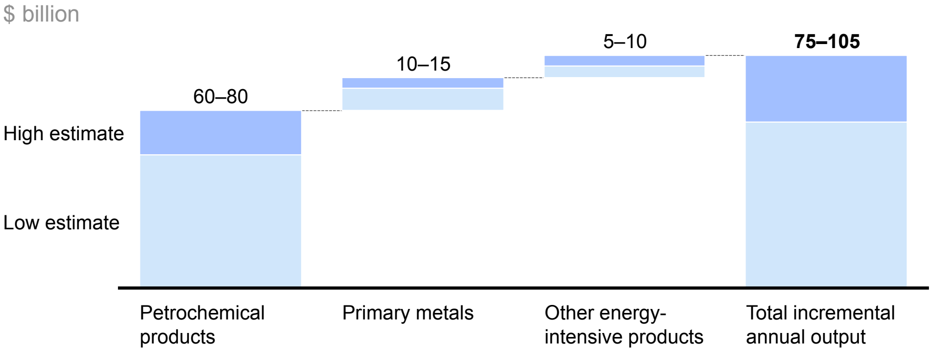
The greatest benefits will accrue to a select set of manufacturing industries that rely heavily on natural gas as a fuel or feedstock. These include petrochemicals, fertilizer, and synthetic resins; iron and steel; and, to a lesser extent, other energy-intensive industries such as glass, paper and pulp, and plastics packaging. These industries collectively produce $400 billion in GDP and account for about 18 percent of the total output produced by the US manufacturing sector. We project that cheaper gas could stimulate additional production of $75 billion to $105 billion in these industries, create $55 billion to $85 billion of annual GDP in manufacturing, and support up to 270,000 additional jobs (Exhibit 6).

Exhibit 6

Cheaper natural gas could increase gross output in energy-intensive manufacturing by $75 billion to $105 billion by 2020

Additional annual output by 2020[1]

$ billion



	Petrochemical products	Primary metals	Other energy-intensive products	Total incremental annual output
Examples	Methane and ammonia products (e.g., fertilizers), PVC and other synthetic resins, ethylene and other ethane derivatives	Steel, aluminum	Glass, cement, paper and pulp, plastic packaging, rubber	

1 Relative to 2012 output as the baseline.

SOURCE: McKinsey & Company; US Energy Information Administration; INGAA Foundation (Interstate Natural Gas Association of America); KKR; McKinsey Global Institute analysis

The largest impact is likely to be felt in the petrochemicals industry, where we estimate an additional $60 billion to $80 billion in annual output by 2020, driven by an abundant domestic supply of natural gas and natural gas liquids, or NGLs. Four specific product categories in particular are poised for growth: ethane derivatives such as ethylene (used in antifreeze, tires, plastic bags, detergent, clothing, and many other products), methane (used to produce antifreeze,

31 *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute, November 2012.

solvents, fuel, fertilizer, and more), ammonia (predominantly for fertilizer, but also for a range of industrial products), and PVC resin (used in pipes, electric cables, construction, and many other industrial products).

The production of ethylene and other products derived from ethane is likely to increase by 40 to 50 percent, with most of the additional output going toward exports. Producing ethylene requires a complex process that uses heat to "crack" the ethane molecules into smaller chemical components. So-called cracker plants are complexes with large storage capacity and miles of pipes, and with affordable raw materials at hand, the industry is investing heavily to build new facilities. In 2012, Shell Oil announced plans to build a major cracker plant in the Pittsburgh area, while Dow Chemical chose Freeport, Texas, for its new facility. More than five million tons of new US ethylene production capacity should come online in the next five to seven years. Natural gas is also a feedstock for producing ammonia and other fertilizers; increased domestic production could almost entirely replace current imports of 14 million tons per year. In addition, cheap natural gas liquids can support higher production of naphtha-derived compounds, propane, and derivatives. To enable the additional output in manufacturing, $65 billion to $80 billion in new investment is needed in domestic petrochemical manufacturing alone.

In the iron and steel industry, benefits are likely to be realized in the form of higher production of direct-reduced iron (DRI)—an increase that can reduce, or potentially even eliminate, net imports. DRI plants use natural gas to "directly reduce" iron ore pellets into a form called sponge iron, which is a component of steel and raw iron. Because they are more energy efficient, DRI plants may replace traditional basic oxygen (or blast) furnaces over time, although this development is not certain. In mid-2013, Nucor Corporation is opening a DRI plant in Louisiana, which is expected to produce $700 million in annual output.[32] Nucor and other companies (including some foreign players) have several additional plants in the planning stages; together these facilities could account for $2 billion to $3 billion in additional annual output.

We anticipate that low-cost natural gas will directly benefit the industries and commodities mentioned above but that it will have only limited impact on industries even further downstream that use these commodities as inputs in their own production process (for example, the use of steel in automobile manufacturing). There are several reasons for this. Some of these commodities are globally traded and priced through a commodity exchange; others are priced regionally and could have a downstream benefit. However, in the latter case, the base commodity (e.g., ethylene) is usually easier to ship than any derivative products because of variations in local needs, difficulties in transport, and/or restrictions in market access.

Ripple effects create additional economic impact

Higher domestic production of oil and gas directly creates jobs and output in the energy industry and energy-intensive manufacturing industries, as described above. But the impact extends further, as increased production will require extensive support services from a wide range of industries that could register sizable indirect gains by 2020. The induced gains from the shale boom are also

32 "Cheaper natural gas lets Nucor factory rise again on bayou," *The Wall Street Journal*, February 1, 2013.

substantial, as job creation within the directly affected sectors causes ripple effects throughout the economy. The oil and gas sector is likely to add 110,000 to 215,000 jobs—and the average wage in this sector is twice that of the economy as a whole. Many of the jobs that will be added in manufacturing are relatively high-wage and high-skill positions. This could lead to increased spending and consumption, especially in the surrounding regions, on everything from housing and food to consumer goods.

Using input-output tables, we can size these indirect and induced effects. Annual GDP could rise by $130 billion to $235 billion in professional and business services, where 250,000 to 450,000 jobs could be added. Other sectors, including construction, transport, and trade, could post additional annual GDP of $80 billion to $145 billion while adding 385,000 to 725,000 jobs.

By 2020, shale gas and tight oil production could boost annual GDP by 2 to 4 percent and create up to 1.7 million jobs

Our forecast for the total economic impact of increased domestic shale oil and gas production by 2020 includes a low-case and a high-case scenario. It combines the projected sector-specific effects discussed above:

- **Gas and oil production sector:** $115 billion to $225 billion incremental increase in annual GDP; 110,000 to 215,000 jobs added

- **Energy-intensive manufacturing** (including chemicals, metals, paper and pulp, and rubber and plastics): $55 billion to $85 billion incremental increase in annual GDP; 165,000 to 270,000 jobs added

- **Services sector** (including financial, legal, business, and professional services; management; real estate; health care and education; waste management; and leisure and hospitality): $130 billion to $235 billion incremental increase in annual GDP; 250,000 to 450,000 jobs added

- **Other affected sectors** (including wholesale and retail trade, construction, transportation and warehousing, agriculture and forestry, mining, and government): $80 billion to $145 billion incremental increase in annual GDP; 385,000 to 725,000 jobs added

Together these impacts add up to an additional 2 to 4 percent (roughly $380 billion to $690 billion) in annual GDP by 2020 (Exhibit 7).[33] Decreasing reliance on energy imports and growing export capacity could reduce the net energy import bill substantially, possibly even to zero. Some 1.0 million to 1.7 million jobs could be generated—and to put this into perspective, the low end of this estimate is larger than the entire US auto manufacturing sector (including

33 A recent McKinsey Global Institute report, *Disruptive technologies: Advances that will transform life, business, and the global economy*, calculates an annual GDP impact of $70 billion to $335 billion by 2025. The two approaches are consistent, although there are four differences in parameters that explain the disparity in estimates. First, the 2025 estimate in *Disruptive technologies* is for North America, not for the United States alone as we have done here; second, the 2025 estimate assumes an additional 5.4 to 9 mbpd of tight oil, slightly higher than the estimates used here; third, the 2025 estimate covers a price range of $50 to $150 per barrel of crude, while this report assumes a price slightly higher than $100 per barrel (see appendix); and finally, the 2025 GDP impact is calculated for gas and oil production only and does not include downstream impacts on the manufacturing sector, or indirect and induced effects.

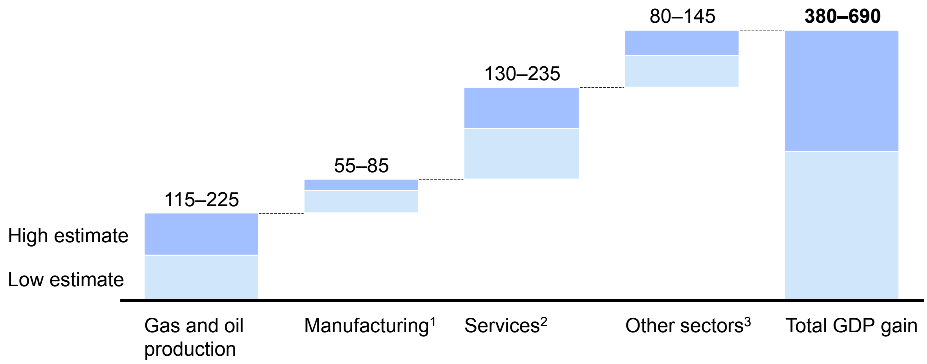
parts suppliers) and the high end is larger than the entire US food manufacturing sector.[34]

Exhibit 7

By 2020, shale gas and oil could boost US GDP by $380 billion to $690 billion annually and create up to 1.7 million jobs

Annual incremental GDP impact by 2020

$ billion



	Gas and oil production	Manufacturing[1]	Services[2]	Other sectors[3]	Total GDP gain
Jobs impact (direct and indirect)	110,000–215,000	165,000–270,000	250,000–450,000	385,000–725,000	1.0 million–1.7 million

1 Includes chemicals, metals, paper and pulp, and rubber and plastics manufacturing.
2 Includes professional services, management, real estate, health care, education, leisure, and hospitality.
3 Includes wholesale and retail trade, construction, transport and warehousing, agriculture, mining, and government.
SOURCE: US Bureau of Economic Analysis; Annual Survey of Manufactures; US Energy Information Administration; McKinsey Global Institute analysis

The jobs created by the energy boom are particularly significant. In regions such as the Appalachian Basin, the presence of some of the nation's richest shale deposits is generating an infusion of new investment and creating new employment for a middle class battered by the loss of manufacturing jobs that once offered a good standard of living. In the oil and gas industry in particular, the average wage is nearly twice that available in other sectors of the economy. Even the low-skill jobs added to the affected sectors will pay relatively high wages. The ripple effects will also tend to increase wages for other jobs (including service-sector jobs) in surrounding regions. In addition, most of the players pursuing these opportunities are US companies—meaning that jobs and profits will stay in the United States, and US tax revenue will increase.

CAPTURING THE FULL POTENTIAL HINGES ON OVERCOMING INFRASTRUCTURE, ENVIRONMENTAL, AND HUMAN CAPITAL CHALLENGES

Realizing the full economic benefits of the oil and gas boom will require completing a major infrastructure build-out, mitigating environmental risks, and heading off a potential talent shortage. But tangible solutions are at hand, as outlined below.

One of the challenges involved in mobilizing concerted action on all these fronts is the fragmented industry structure of the oil and gas producers involved. While some of the biggest names in the US energy sector are drilling for shale gas and light tight oil, the current boom is characterized by a large number of wildcatters

34 Marc S. Lipschultz, *Historic opportunities from the shale gas revolution*, KKR Report, November 2012; US Bureau of Labor Statistics data.

and small operators pioneering these efforts. This fragmentation reduces the industry's ability to cooperate on building the requisite infrastructure for extraction. It also increases the challenges of identifying and disseminating best practices—while magnifying the urgency of doing so. Centers of excellence can help in this regard. One such example is the Appalachian Shale Recommended Practices Group, whose membership includes companies operating in the Marcellus shale formation.

Significant infrastructure investment is needed

As new hubs of energy production emerge, the United States will need a major transformation of infrastructure and logistics. Companies are pouring billions of dollars into new pipelines to move oil and gas from wellhead to refinery to consumer. A build-out is already under way.

For decades, the United States has moved oil imports from the Gulf Coast to inland refineries, moving south to north. But now the surge in domestic production means that oil extracted from remote locations in Canada and North Dakota needs to move north to south. The existing US pipeline network will have to be reconfigured to serve new production hubs in the center of the country. In some cases, pipeline flow needs to be reversed, which will require new build-outs or refitting existing pipelines with giant pumps and multi-ton valves. Some natural gas pipelines may also be refitted to handle oil.

Increased production will also require major investment in midstream infrastructure, including transport systems such as rail networks and even oil barges. As domestic oil and gas production outpaces pipeline capacity, railroads are filling the gap. Oil shipments by rail have jumped from just 9,500 carloads of crude oil in 2008 to more than 200,000 carloads in 2012.[35] The volume of crude oil and petroleum products shipped by rail increased 46 percent between 2011 and 2012 alone. In North Dakota, roughly 75 percent of crude oil is shipped by truck to railcars, leaving shipments susceptible to interruptions such as accidents and weather events.[36]

As discussed earlier in this chapter, the United States could become a major exporter of LNG—but such a shift will require a build-out of export terminals. As of May 2013, 20 export terminal projects are under review by the Department of Energy; another two have been approved, and these projects will take time to complete. We examined a scenario of additional approvals such that total capacity could support 6 to 15 bcfd of US LNG exports.

In the medium term, $1.2 trillion to $1.4 trillion of additional infrastructure investment is needed to fully realize the opportunity (Exhibit 8). Nearly $1 trillion of this investment is needed in upstream infrastructure alone to support drilling, fracturing, and gathering activity. Every well requires some $5 million to $7 million in capital expenditure, and some 30,000 to 40,000 new wells are expected to come online. Each one requires extensive equipment, including drilling rigs, wastewater treatment operations, and gathering pipelines.

35 *Moving crude petroleum by rail*, Association of American Railroads, December 2012.

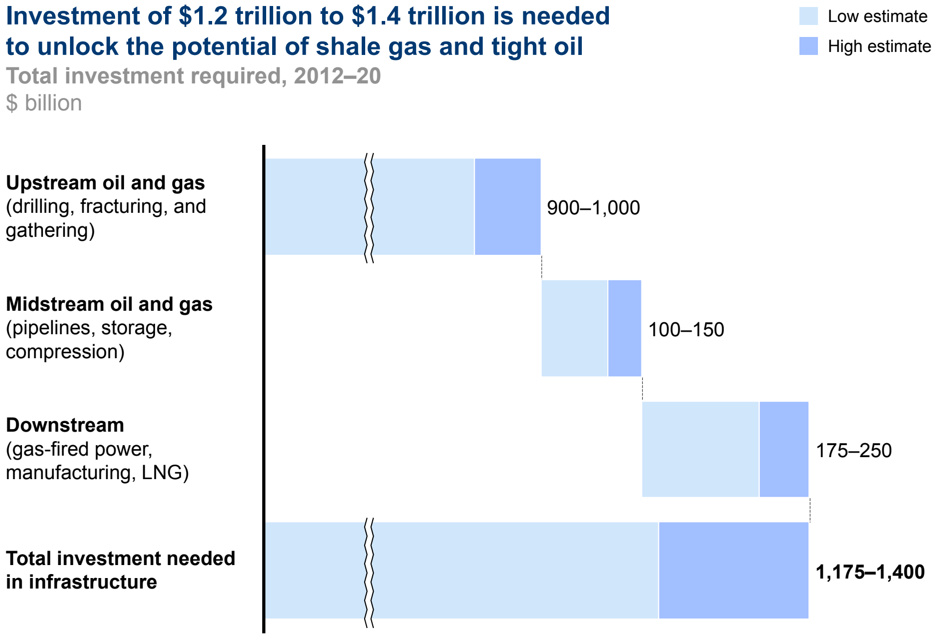
36 Energy Information Administration and Association of American Railroads.

Exhibit 8

Investment of $1.2 trillion to $1.4 trillion is needed to unlock the potential of shale gas and tight oil

Total investment required, 2012–20

$ billion



SOURCE: McKinsey & Company; INGAA Foundation; McKinsey Global Institute analysis

This up-front investment can have a substantial employment impact in the short term: more than 1.6 million short-term jobs could be created during this build-out, with 1.2 million of these in the construction sector. An additional 185,000 short-term jobs could be created in the services sector and 115,000 jobs in the manufacturing sector. These are in addition to the permanent jobs in the 2020 projected impact discussed above.

Environmental risks need to be addressed

Hydraulic fracturing and horizontal drilling entail a range of environmental risks that must be tackled. The key risks include:

- **Groundwater contamination.** Hydraulic fracturing involves injecting a large volume of water mixed with chemicals into shale formations to free trapped gas, and one of the most hotly debated risks is the potential for these chemicals to contaminate groundwater supplies, either during the fracturing process itself or via improper wastewater disposal. Regular groundwater testing and proper well casing and sealing can prevent gas and fracking fluids from migrating into nearby drinking water tables, while proper handling, storage, and disposal practices can prevent wastewater spillage.

  A study by the Royal Society and the Royal Academy of Engineering indicated that the risk of contaminating aquifers is low if extraction takes place at sufficient depths, but faulty wells, as well as leaks and spills associated with surface operations, pose greater concerns. Robust monitoring of well integrity should be a priority; independent specialists should be able to review the design of every onshore well, just as they can with offshore wells.[37] This emphasis on well integrity is echoed by research from the US

37 *Shale gas extraction in the UK: A review of hydraulic fracturing*, Royal Society and the Royal Academy of Engineering, final report, June 2012.

National Academy of Sciences, which found evidence for localized methane contamination of drinking water associated with shale gas extraction, although no evidence of contamination due to fracking fluids.[38] The US Environmental Protection Agency is conducting a study of the effects of fracking on drinking water supplies and is scheduled to release its findings in 2014.

Today companies are not required to disclose the full composition of the chemical mix used in the hydraulic fracturing process; some experts suggest greater transparency could help better assess the risks and allay public concerns.

- **Fugitive methane emissions.** Fracturing can release methane that is not captured during the extraction process (hence the term "fugitive"). Because methane is a potent greenhouse gas, any significant quantities that escape during drilling or transporting natural gas will increase the amount of greenhouse gases in the atmosphere. Recent research indicates that natural gas–fired power plants produce fewer greenhouse gas emissions than coal-fired plants, as long as methane leakage is less than 3.2 percent over the entire supply chain from natural gas wells to power plants.[39]

  To date, there is not clear evidence on how much methane is being released into the atmosphere and at what stage in the extraction and production process. A review of the scientific research surrounding this issue yields conflicting results. One recent study estimates that up to 8 percent of methane from shale gas production escapes to the atmosphere over the lifetime of the well.[40] However, a recent EPA report states that methane gas emissions from natural gas systems in the United States have declined by 10 percent since 1990.[41] Given the variability in these studies, scientists need a more complete picture in order to fully evaluate the extent of methane leakage and how to minimize it.

- **Potential seismic effects.** The hydraulic fracturing process involves injecting fluids into shale formations, and this could increase pressure in potential fault zones and lead to earthquakes. The research to date suggests that the seismic risk is low for the hydraulic fracturing process itself, given the amount of fluid used and short pumping times, but is greater if wastewater is disposed of in deep underground wells. One recent study of nearly 200 induced earthquakes since 1929 concludes that to date, hydraulic fracturing has had relatively benign seismic effects in comparison to other triggers such as mining, oil and gas field depletion, and geothermal operations.[42] However, in some regions, the wastewater associated with hydraulic fracturing is

38 Stephen G. Osborn et al., "Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing," *Proceedings of the National Academy of Sciences (PNAS)*, volume 108, number 20, May 2011.

39 Ramón A. Alvarez et al., "Greater focus needed on methane leakage from natural gas infrastructure," *Proceedings of the National Academy of Sciences (PNAS)*, volume 109, number 17, April 2012.

40 Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, "Methane and the greenhouse-gas footprint of natural gas from shale formations," *Climatic Change*, volume 106, number 4, June 2011.

41 *The inventory of US greenhouse gas emissions and sinks: 1990-2011*, US Environmental Protection Agency, April 2013.

42 R. Davies et al., "Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons," *Marine and Petroleum Geology*, volume 45, August 2013.

disposed of by injecting it at high pressure into deep underground wells, and studies have found that this process can increase seismic activity.[43] States are developing stricter regulations to govern pre-drilling site characterization, control the injection of fracking fluids in seismically sensitive sites, and create penalties for failure to monitor this issue consistently after drilling has commenced. Equally important will be guidelines on wastewater disposal.

Although active research is under way to better understand the environmental risks outlined above, the full extent and cost of these risks is unknown. Many of these risks can be addressed through rigorously managed operations, and much is riding on the oil and gas industry's ability to develop best practices and follow them consistently. One of the biggest challenges on this front is the fragmented nature of the industry, with its "long tail" of small, independent operators.

Shale drilling technology has been advancing rapidly, and new solutions are being introduced to mitigate environmental risks, such as plunger lifts, improved pneumatic controllers, and leak detection equipment to control fugitive methane. By investing to replace old equipment with new technology, producers may be able to achieve cost efficiencies and reduce greenhouse gas emissions by cutting down on lost production.

Regulation could play a constructive role in establishing standards that provide the public with reassurance and the industry with certainty. In one positive sign, the Texas Railroad Commission (the state entity that oversees the oil and gas industry) just issued a tighter "well integrity rule" for drilling and well casings. But in general, regulatory efforts have not caught up with the rapid pace of energy development. Standards and enforcement capabilities vary considerably across states; new federal regulations are being developed but have yet to be implemented.

In the meantime, the industry has begun to work with environmental groups to develop voluntary standards in some regions. In the Appalachian region, for example, the Center for Sustainable Shale Development was recently launched as a coalition of environmental groups (including the Environmental Defense Fund and the Clean Air Task Force), energy firms (including Chevron and Shell), and philanthropies (including the Heinz Endowments and the William Penn Foundation). The group's goal is to develop standards for environmentally safe shale development and establish an independent, third-party evaluation process to certify companies that meet these criteria.

Land and water use are concerns in some locations

Developing shale energy will require making some economic trade-offs. Land use and water scarcity are two examples. As shale gas and tight oil production increases, so does the number of wells being drilled. The number of natural gas wells in the United States rose by 50 percent in the past decade, from 340,000 in 2000 to more than 510,000 in 2011. As production continues to rise and moves from remote areas into urban or industrial settings, the land-use impact of concentrated drilling activity may be felt more strongly, particularly during the initial horizontal drilling and fracturing process due to the operation of large drilling

43 Cliff Frohlich, "Two-year survey of earthquake activity and injection-well locations in the Barnett Shale, Texas," *PNAS*, August 2012; Katie M. Keranen et al., "Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence," *Geology*, volume 41, June 2013.

rigs and frequent truck traffic.[44] States and municipalities are taking different approaches; for example, many use zoning rules to prescribe where wells can be sited; others have taken steps to regulate noise levels, minimize traffic impact, and require monitoring of all drilling activity. The industry is also taking steps to reduce the land-use footprint. For example, multiwell pads allow for the drilling of several wells—up to 12 in the Marcellus formation—from a single pad.[45]

Hydraulic fracturing is a water-intensive process, and in drought-prone regions such as Texas, Colorado, and California, water is a scarce resource. If development of California's Monterey Shale proceeds, for instance, it will intensify pressures on the state's water supply, which also has to serve the agriculture industry. Pennsylvania has moved to address these issues by developing state guidelines for water use in drilling the Marcellus formation; operators applying for permits to drill must specify their water sources and assess the potential impacts, as well as obtain approval from the local river basin commissions.[46] In all regions, producers can transport water via pipeline from well-supplied areas rather than drawing from local water tables, but this may be a costly option. As local water supplies grow strained, the industry will have to increase sustainable resource management by recycling water or substituting brackish for fresh water. Some experts believe that market-based pricing of water could resolve many of the water scarcity issues.

As production increases, the industry may face a talent shortage

Multiple interviews with executives from leading energy companies reveal that while there is still a good pool of talent, the competition for that talent is heating up. One oil company executive noted that this applies to a range of specialties with all levels of skills, including positions such as engineers and welders. It will be important for the industry to invest in expanding the domestic talent pipeline, since almost none of these new jobs can be done remotely.

The industry may lose some of its most valued expertise in the years ahead as engineers age out of the workforce. Some 18 percent of workers in oil and gas (and mining broadly) are over the age of 55—and while this is actually lower than the average of 21 percent across the US economy, it is still a matter of concern. To address this issue before it becomes problematic, the industry can continue to work with universities to increase the number of oil and gas engineering graduates. Partnerships with local school systems and community and vocational colleges (a strategy discussed as part of the talent game changer), combined with efforts to attract workers from other parts of the country, could help to avoid skills shortages in the future.

44 *Shale gas and tight oil: Framing the opportunities and risks*, McKinsey on Sustainability and Resource Productivity, Summer 2012.

45 Jim Ladlee and Jeffrey Jacquet, *The implications of multi-well pads in the Marcellus Shale*, Pennsylvania State University and Cornell University, September 2011.

46 Julia E. Stein, "Navigating water use and fracking in a water-scarce world," *Environmental Law News*, volume 21, number 3, winter 2012–2013.

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For decades, the nation's growing need for foreign sources of energy has been a concern for the United States and a drain on the trade balance. But now, with new technologies unlocking shale gas and oil, this situation is sharply reversing—and the United States is even contemplating a potential future of net energy independence. Shale gas and oil could generate substantial economic benefits, creating up to 1.7 million jobs and raising annual GDP by 2 to 4 percent by 2020. Today domestic energy production is already soaring: investment, exploration, infrastructure build-outs, drilling, and refining are shifting into high gear and generating jobs. The speed at which companies are moving speaks to the dynamism and flexibility of US industry, but it also increases the urgency for industry leaders and policy makers to work together to establish and execute the right environmental protections. Policy makers can further enable this game changer by quickly assessing requests to export.

Trade: Increasing US competitiveness in knowledge-intensive industries

National competitiveness is a frequently discussed topic in the age of globalization, but the term itself is used to mean many different things, such as a country's ability to raise the living standards of its citizens or to attract firms that can successfully compete in global markets. Many factors feed into a nation's competitiveness, including its productivity growth, innovation, human capital, infrastructure, and regulatory environment.[47] In this chapter we define a competitive economy as one that can attract global and domestic investment, sell goods and services in world markets, support dynamic and innovative global companies, and draw a steady stream of talented students and workers from around the world.

US performance across all these dimensions is mixed. On one hand, global investors and companies continue to gravitate to the United States. Many of the world's largest and most innovative companies are headquartered here, and most leading global firms have operations within the United States. America remains a magnet for international talent.

Yet there are signs that US competitiveness is eroding in other measures. Executives report in interviews and surveys that it is not as easy to do business in the United States as it once was, given a complex corporate tax policy, multiple layers of regulations and permitting that can take years to sort out, and infrastructure and workforce skills that have not kept pace with the demands of a 21st-century economy.[48]

One of the most concrete signs of deteriorating competitiveness is the growing US trade deficit in knowledge-intensive goods—a trend not seen in Europe, Japan, or most other advanced economies.[49] The relative strength of the US dollar has clearly exacerbated this trend. But this is not simply a matter of labor-intensive manufacturing relocating to countries with low-wage labor. Instead, the trade deficit has grown in sectors that match up well with traditional US strengths in R&D and innovation, such as automobiles and other transportation, equipment and machinery, pharmaceuticals and chemicals, and high-tech devices.

Based on interviews with industry experts in specific product categories, we find the United States may have an opportunity in the years ahead to reverse the expanding trade deficit in knowledge-intensive goods. There is already some positive momentum in select product categories; if the US can accelerate this momentum, it could reduce the net export balance in these industries to where it stood in 2000 (relative to GDP), or even to where it was in the early 1990s. Although the United States would remain far behind other advanced

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47 *How to compete and grow: A sector guide to policy*, McKinsey Global Institute, March 2010.

48 *Growth and competitiveness in the United States: The role of its multinational companies*, McKinsey Global Institute, June 2010.

49 *Trading myths: Addressing misconceptions about trade, jobs, and competitiveness*, McKinsey Global Institute, May 2012.

economies (such as Germany, Japan, or Sweden) that run large trade surpluses in knowledge-intensive goods, the impact on economic growth would be tremendous: we calculate that it could raise annual US GDP by $200 billion to $590 billion by 2020 while creating up to 1.8 million jobs.

To succeed, the United States will need to embark on several strategies at once. These include bolstering its transportation infrastructure and workforce skills, staying on the forefront of new product innovations, enhancing its attractiveness as a place to do business, tapping fast-growing and potentially lucrative new markets, and attracting more foreign production.

EVIDENCE ON US COMPETITIVENESS IS MIXED

Among US and global business leaders alike, the prevailing view is that the United States is losing its competitive edge.[50] In the World Economic Forum's Global Competitiveness Index, the United States topped the rankings in 2008–09 but has slipped in each successive year, falling to seventh place in 2012–13.[51] MGI's own survey of corporate executives revealed that many believe that current US policies on corporate taxes and immigration of skilled workers as well as the overall regulatory burden hamper US companies when they compete abroad and discourage investment at home.

Despite these perceptions, the United States continues to attract global firms and foreign direct investment (FDI).[52] It has also cultivated many of the world's most dynamic industry-specific economic clusters, building on a legacy of industry-academic-government R&D collaborations to drive growth. These factors should position the United States to be a strong exporter of knowledge-intensive manufactured goods—and yet a widening trade deficit has developed in this area over the past two decades.

The United States continues to attract global investment and global firms

Despite some volatility largely driven by the recent recession and weak recovery, the United States has maintained a three-decade record of strong FDI inflows. These have gradually risen from 0.5 percent of GDP in 1980 to 1.4 percent of GDP prior to the Great Recession. The US share of global FDI has declined relative to its share of global GDP since the late 1980s, but this is mainly due to the rise of emerging markets as well as the rapid growth in intra-European FDI flows that accompanied the creation of the euro. Since 2003, however, the United States has largely held steady in attracting some 13 percent of global FDI flows.

From 2008 to 2011, the United States outperformed other advanced economies, including France, Germany, and Japan, in terms of average FDI inflows as a

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50 See Michael E. Porter and Jan W. Rivkin, *Prosperity at risk: Findings of Harvard Business School's survey on US competitiveness*, Harvard Business School, January 2012. Also see *Rising above the gathering storm, revisited: Rapidly approaching Category 5*, prepared for the Presidents of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, National Academies Press, 2010.

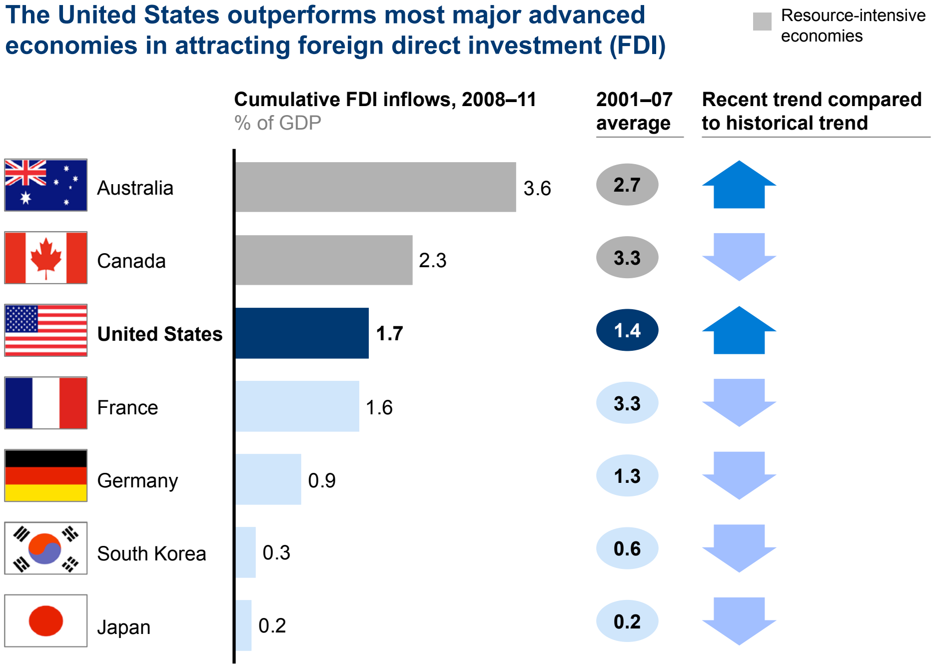
51 *The global competitiveness report 2012–2013*, World Economic Forum.

52 Foreign direct investment is defined as investments that acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It also includes companies setting up new operations and affiliates in foreign locations, known as "greenfield" FDI.

share of GDP (Exhibit 9). (Natural resource exporters Australia and Canada have attracted even larger waves of investment, reflecting the global commodity boom.) Greenfield FDI inflows—a measure of foreign companies setting up entirely new operational facilities—have posted a 10 percent annual growth rate since 2003. Despite a dip since 2010, the United States has been more successful at attracting these investments than other advanced economies, and this type of foreign investment has a stronger effect on economic growth and employment than FDI that entails acquisitions.[53]

Exhibit 9

The United States outperforms most major advanced economies in attracting foreign direct investment (FDI)



SOURCE: FDI Markets; McKinsey Global Institute Global Capital Flows database; McKinsey Global Institute analysis

The United States is also home to many of the world's largest companies, including 35 percent of the firms on the Financial Times Global 500 list of traded companies with the highest market capitalization. US-headquartered companies dominate the list in several sectors, such as health care (82 percent of the Global 500 companies), aerospace and defense (75 percent), and oil and gas (71 percent); more than two-thirds of companies in food production, technology, software, financial services, and industrial transportation are US firms. Even in sectors where US firms have low representation, many foreign firms on the list have significant operations within the United States. For example, only three of 17 automotive companies on the Global 500 list are headquartered in the United States, but 15 of the 17 have US operations. This ability to attract important companies is echoed in the *Forbes* list of the world's 100 most powerful brands. Sixty-one of the 100 companies on the list have headquarters in the United States and all of the companies have operations there.[54]

53 See Miao Wang and M. C. Sunny Wong, "What drives economic growth? The case of cross-border M&A and greenfield FDI activities," *KYKLOS*, volume 62, number 2, 2009.

54 "The world's most powerful brands," *Forbes*, October 2012.

But the United States continues to run a trade deficit in knowledge-intensive industries

Although the overall US trade deficit has shrunk relative to GDP since the Great Recession began, the long-term trend shows two decades of widening deficits. Some of this reflects the globalization of supply chains and the shift of labor-intensive manufacturing to low-cost nations, as well as energy imports. More surprising, however, is the large and growing US trade deficit in knowledge-intensive goods. We define knowledge-intensive manufacturing as including six broad industry groups: motor vehicles, trailers, and parts; other transportation equipment (which includes aerospace); chemicals (including pharmaceuticals); medical, precision, and optical equipment; semiconductors and electronics; and machinery and appliances.[55]

In the early 1990s, US net exports of knowledge-intensive goods ran a small deficit of $6 billion, which had widened to $150 billion by 2000; by 2012, the deficit had opened up to $270 billion.[56] In contrast, most other advanced economies have large trade surpluses in this category (although not in every individual product). Japan and several European countries run trade surpluses in knowledge-intensive goods of between 2 and 7.5 percent of GDP, while the US trade deficit in these goods is 2 percent of GDP.[57]

As a world leader in R&D spending, the United States should have a competitive advantage in these industries.[58] Yet despite its strengths in innovation and design, the nation increasingly loses out on manufacturing activity. Three large industries—motor vehicles; computers and office machinery; and semiconductors and electronics—drove most of the decline, though all of these manufacturing industries (with the exception of non-automotive transport equipment) experienced eroding export strength (Exhibit 10).

Enhancing US competitiveness in these industries would enable the nation to increase domestic R&D, production, and exports. Knowledge-intensive manufacturing industries account for 50 percent of US manufacturing value added and 40 percent of the sector's employment. Their R&D intensity is five to 12 times higher than all other manufacturing industries.[59] In addition, their labor

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55 This definition follows the UN's International Standard Industrial Classification, rev. 3.1. The machinery and appliances category covers machinery, equipment, and appliances; electrical machinery; and computer and office machinery.

56 Unless specified otherwise, all figures for goods trade deficits and surpluses in this chapter, including sector-specific figures, are expressed in real terms (2005 dollars), as the data are typically presented in that form. We make exceptions for two industries, using nominal values for semiconductors, communication equipment, and electronic equipment, and for computers and office machinery. See appendix for details.

57 The surplus in knowledge-intensive manufacturing is 2 percent of GDP for Finland, 2.5 percent for Sweden, 3.5 percent for the Netherlands, and 7.5 percent for Germany. Smaller countries such as Austria and Belgium also run a trade surplus in these industries.

58 Measured in absolute dollars, the United States spent $402 billion on R&D in 2009, accounting for nearly one-third of global spending on R&D, according to the US National Science Foundation's *Science and Engineering Indicators* report in 2012. China ranked second, accounting for $154 billion, or 12 percent of the global total.

59 R&D intensity, defined as R&D expenditure divided by value added, varies from 6 to 35 percent for these industries, compared with 1 to 3 percent for all other manufacturing industries. See *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute, November 2012.

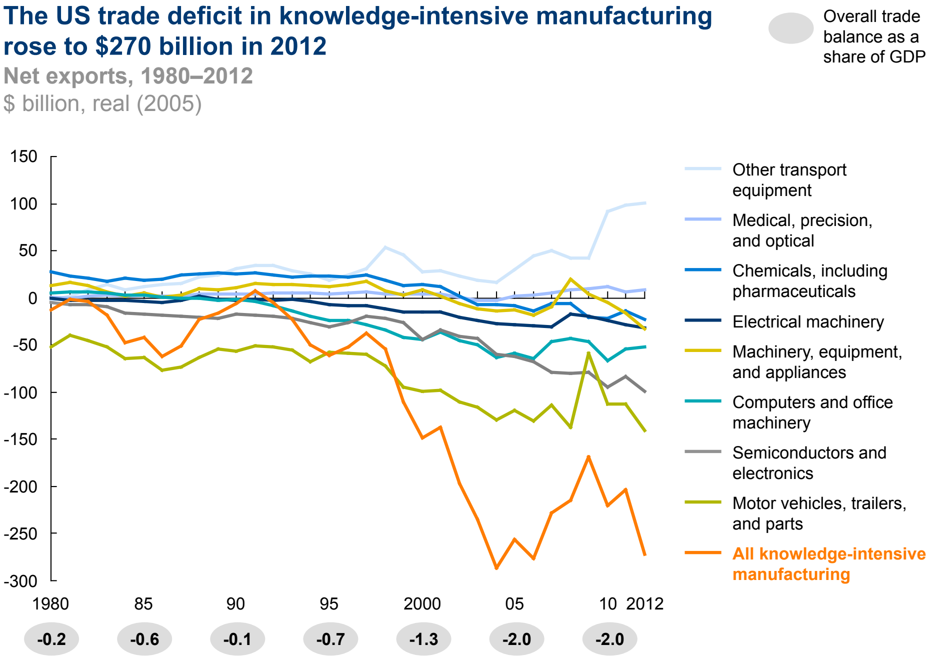
productivity is 20 percent higher than the average for the manufacturing sector.[60] Compensation associated with the high-skilled manufacturing jobs in these industries (including wages and benefits) is more than 20 percent higher than the average for manufacturing as a whole. Growth in knowledge-intensive industries can produce a strong multiplier effect, as these industries stimulate output in other parts of the supply chain and in commodity industries.

Exhibit 10

The US trade deficit in knowledge-intensive manufacturing rose to $270 billion in 2012

Net exports, 1980–2012

$ billion, real (2005)



SOURCE: IHS Global Insight May 2013; McKinsey Global Institute analysis

Global trade is fiercely competitive, but US success in tradable services offers reason for optimism. Net exports of knowledge-intensive services (such as research and development, financial intermediation, and architectural and engineering services) have been growing; only computer and information services have failed to share in this trend. In fact, the United States is a leader in global service exports, with a trade surplus in this area that has increased from $30 billion in 1990 to $200 billion in 2012 (in nominal terms), showing consistent 9 percent annual growth during the 2000s. If the United States could achieve similar performance in knowledge-intensive manufacturing, it would have a game-changing impact on the economy.

THE TRADE DEFICIT CAN BE REVERSED OR REDUCED IN CERTAIN KNOWLEDGE-INTENSIVE MANUFACTURING INDUSTRIES

There are several reasons to believe that the United States can now seize an important opening to improve its trade position in knowledge-intensive goods. The value of the US dollar relative to other currencies clearly matters, and it is

60 Calculated as value of production ($) divided by hours based on 2011 data. Petroleum and coal products manufacturing is excluded when calculating the average for the manufacturing sector.

subject to global forces.[61] But since 2002, it has gradually depreciated on a trade-weighted basis by 24 percent, and that has created more favorable conditions for producing in the United States relative to other countries. Moreover, there is a great deal that can be done to halt or reverse the decline in some specific types of knowledge-intensive manufacturing by raising the productivity of US firms. New technologies (including big data) and changing factor costs are disrupting many industries and causing shifts in global supply chains. All these trends suggest that this could be a game-changing moment for the United States. Indeed, the US trade deficit in knowledge-intensive goods had already begun to decline prior to the recession, from $287 billion in 2004 to $214 billion in 2008.

Our interviews with industry experts reveal that the opportunities vary widely. In aerospace and medical equipment, the United States already enjoys growing trade surpluses that can be further expanded. The auto industry has the potential to attract more domestic production for the local market as well as for export, while the chemical industry is poised for lower imports and perhaps even higher exports as cheap natural gas unlocked by the shale energy boom enables increased production of petrochemicals. In semiconductors, the United States saw a trade surplus in the 2000s despite (or perhaps because of) a shift to fabless operations, but the surplus eroded in the past two to three years as rising smartphone and tablet sales required production of complex parts and finished goods. It could return if value shifts back to fabless design as smartphone and tablet production becomes more commoditized. Finally, in the machinery, equipment, and appliances sector, there may be specific opportunities to export products such as specialized machinery for agricultural, mining, and construction use. Policy makers can facilitate momentum in many industries, as we discuss at the end of this chapter.

Aerospace and other (non-automobile) transportation equipment

The United States currently runs a trade surplus in non-automotive transport equipment. Trade in this sector is dominated by the aerospace industry, although it also encompasses shipbuilding, railway equipment, and other transport equipment. US net exports have grown from a deficit of $3 billion in 1980 to $100 billion surplus in 2012 (in real 2005 dollars). The aerospace industry accounts for nearly all the trade surplus in this sector and also explains the relative volatility in these numbers, as aircraft orders can vary significantly from year to year.

The aerospace sector is made up of several subsectors, including commercial aircraft, general aviation (business jets), rotary aircraft (helicopters), aircraft engines and parts, military aircraft, missiles and rockets, and spacecraft and satellites. Nearly 90 percent of US aerospace sector exports are of civilian aircraft, most of which are commercial airplanes (such as the Boeing 737-800 and 777-300) and their associated parts and spares.[62] The international market for commercial airplanes is robust, and the industry forecasts deliveries of 27,000 to 35,000 commercial airplanes by 2031 (Exhibit 11).[63] Global aircraft fleets are

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61 See Martin Neil Baily and Robert Z. Lawrence, "Competitiveness and the assessment of trade performance," in *C. Fred Bergsten and the world economy*, Michael Mussa, ed., Peterson Institute for International Economics, 2006. Also see Brock R. Williams and J. Michael Donnelly, *US international trade: Trends and forecasts*, Congressional Research Service, October 2012.

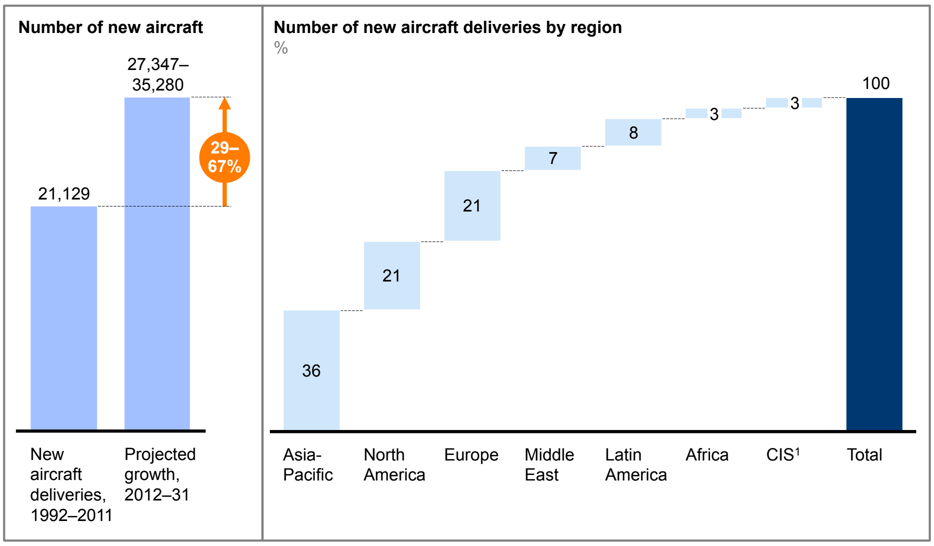
62 Aerospace Industries Association, 2011 year-end review and forecast.

63 Boeing Current Market Outlook, 2013–2032; Airbus Global Market Forecast, 2012–2031.

expected to double in size in this period, with more than half of deliveries outside Europe and North America in emerging economies. Between now and 2020, the global commercial airplane market is expected to record nearly 1,400 airplane deliveries every year.[64]

Exhibit 11

Commercial aircraft deliveries are forecast to be 27,000 to 35,000 over the next 20 years



1 Commonwealth of Independent States.
NOTE: Numbers may not sum due to rounding.
SOURCE: Airbus Global Market Forecast, 2012–2031; Boeing Current Market Outlook, 2013–2032; Teal Group World Aircraft Production History; McKinsey Global Institute analysis

The US aerospace industry is already capitalizing on rising global demand and is expected to see more growth in the years ahead. Since 2009, US net exports of aircraft have more than doubled in real terms, growing by 135 percent. Even before the 2008 recession, the commercial aircraft industry had accumulated backlogs on its order books equivalent to nearly eight years of production. Boeing's delivery of 601 airplanes in 2012 (including 416 to non-US customers) was 30 percent higher than deliveries in 2010 and is expected to increase by nearly 40 percent in total by 2020, according to industry forecasts.[65]

In addition to growing exports, the United States is attracting the operations of foreign companies in this industry, which could help to reduce aerospace imports. To tap into US strengths in aerospace and the lucrative US market, Brazilian jet maker Embraer opened a manufacturing plant in Florida in 2011 and has continued to expand its operations in the state, which has a pool of aerospace talent. In 2013, Airbus began building its first US assembly plant, which is expected to open in 2015 in Mobile, Alabama. The state provided an incentive package worth $158 million, including capital and equipment financing, workforce training, and supporting infrastructure, to attract this investment.[66] Airbus expects to produce 40 to 50 aircraft every year and hopes to increase its sales to the US market.

64 Teal Group commercial jetliner forecast for 2013–2022, May 2013.

65 Ibid.

66 "Alabama puts Airbus incentives at $158 million," *The Wall Street Journal*, July 9, 2012.

Automobiles and parts

Automobiles and parts account for nearly half ($140 billion, in real 2005 terms) of the total US trade deficit in knowledge-intensive manufacturing. Until the mid-1990s, the trade deficit for this industry was relatively stable at around $60 billion, but it had increased to $100 billion by 2000 and to $135 billion by 2008. The recession temporarily reduced US demand for imports, but with a recovery on the way, the trade deficit in automotive is once again on the rise. However, looking forward, there are reasons to believe the United States could improve its net trade balance in this area.

The deterioration can be explained in large part by changes in the domestic automotive industry. The Big Three US carmakers' market share among US car buyers declined from 75 percent in 1992 to 45 percent in 2012.[67] Toyota and Honda are the two largest foreign suppliers, and over the past decade, they have moved most production of their best-selling models for the American market to the United States. But even when Toyota's and Honda's US production is added to that of the Big Three, total domestic carmakers' market share has declined from nearly 90 percent in 1992 to less than 70 percent today. Other Japanese brands, as well as Korean and European imports, have gained strength. Since the signing of the North American Free Trade Agreement (NAFTA) in 1994, US automakers have increased their use of parts and vehicles imported from Mexico from 8 percent of US imports in 1994 to 22 percent in 2011. However, in the same period, US imports from Canada have fallen from 40 percent to 26 percent, so the overall share of NAFTA imports has remained steady at around half of total US imports. Mexico's combination of low costs and easy access to the US market has attracted production from Audi, Volkswagen, Mazda, Honda, and Nissan, as well as GM and Ford.

The decline in the US trade balance comes from imports of both assembled vehicles and parts. Roughly two-thirds of the 2012 trade deficit of $140 billion is driven by assembled vehicles, the rest by parts and components. While domestic car manufacturers (including Toyota and Honda) use 60 to 80 percent domestically produced parts in their most popular models, South Korean and European carmakers have lower usage of US parts—in some cases, even zero (Exhibit 12).[68]

The United States has long-standing strengths in the auto industry, including a skilled manufacturing workforce and a large and lucrative consumer market. Energy and other factor costs are shifting as well, and demand is continuing to recover. US automakers have highly sophisticated R&D operations, and today the industry's innovation capabilities have spread far beyond Detroit. Electric cars are being developed and built in California, and a new auto industry technology cluster is emerging around South Carolina's auto factories, for example.[69]

The United States is attracting more assembly by foreign companies of cars meant for sale in the US market, and even for global exports. BMW's X series of SUVs, for example, is exported worldwide from South Carolina. Expanding on this trend is important for improving the trade balance in automotive, and indeed

67 IHS Automotive, 2012. The Big Three are Ford, Chevrolet, and Chrysler.

68 American Automobile Labeling Act (AALA) Reports, National Highway Traffic Safety Administration, 2013.

69 *Manufacturing the future*, McKinsey Global Institute, November 2012.

for the future growth of the US auto industry, and there are tangible positive signs. New assembly plants have been established in the United States every year since 2005, including Hyundai (2005), Kia (2009), and Volkswagen (2011) facilities. A single assembly plant can produce 200,000 to 300,000 vehicles annually and generate gross revenue of $4 billion to $6 billion. The experience of Japanese carmakers in the United States shows an evolution: first, a foreign car manufacturer begins to assemble vehicles in the United States, with components imported from the home-country supply chain for local assembly. But eventually foreign carmakers may choose to expand local production of both parts and finished cars to establish better quality control and responsiveness to market demand.[70]

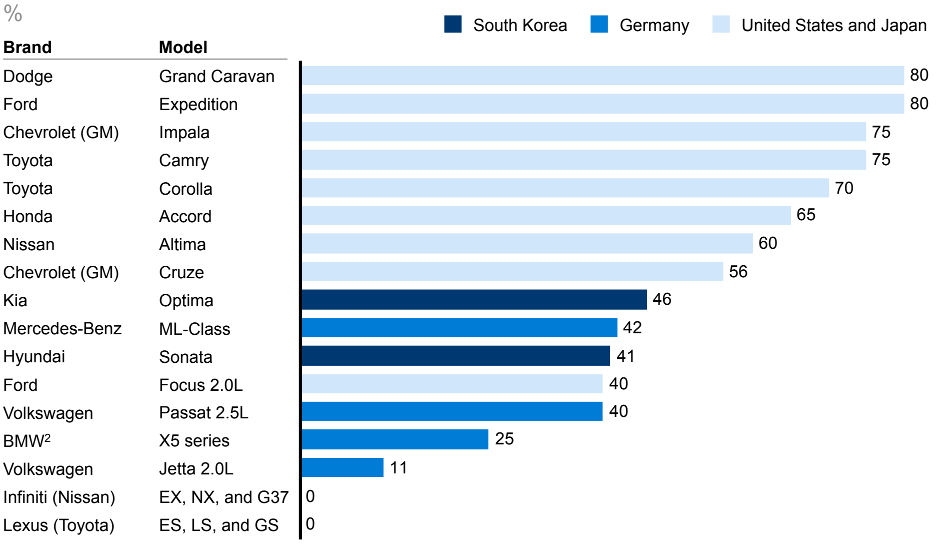
Exhibit 12

US and Japanese automakers use more domestically produced content than more recent foreign entrants to the US market

EXAMPLES

Share of US and Canada content in production of autos sold in the United States[1]

%



1 Based on top-selling cars in late 2012.
2 The popular BMW 320 Sedan has 0 percent US and Canadian content. This is the same for the Mercedes C-Class.
SOURCE: US National Highway Traffic Safety Administration; McKinsey Global Institute analysis

Successfully competing for automotive investment will require good infrastructure (including highways, railways, and ports), a continuing influx of skilled talent, and regulatory efficiency. But attracting automotive investment is not simply about enablers, or even financial incentives. The US automotive trade could also get a boost from production of next-generation alternative-propulsion vehicles and associated supply-chain technologies, including batteries, advanced materials, and drivetrains. There has already been some movement from foreign car manufacturers to base their hybrid segments in the United States. Toyota's Camry Hybrid is being produced in Kentucky, and brisk US sales could eventually lead to domestic production of the Prius. Nissan launched production of its Leaf hybrid model in Tennessee with support from the US Department of Energy. Most alternative-propulsion vehicles are assembled in the United States, but their engines and components are not always built there.

70 Regulation can also play a role, as with the "voluntary restraint agreement," or import quotas, that restricted US auto imports from Japan to between 1.7 million and 1.9 million cars annually in the 1980s.

The United States can also seek to expand exports, particularly to emerging economies. To pursue this strategy, US auto manufacturers will need to align their products more closely with the needs of emerging markets, which tend to favor small diesel cars. Tapping the high-end segments of these markets will require a focus on international branding as well as the development of high-quality and feature-rich vehicles. Another option is to focus on cultivating demand in markets where US-made vehicles (such as larger SUVs, crossovers, and light trucks) are likely to find a niche.

Chemicals, including pharmaceuticals

Before the late 1990s, US net exports of chemicals remained fairly constant, running a surplus of around $25 billion. Over the years, however, that surplus not only evaporated but turned into a $25 billion trade deficit in 2012, driven by rising imports of pharmaceuticals. In the years ahead, the United States is likely to achieve a trade surplus in chemicals once again, but due to the expansion of petrochemicals rather than pharmaceuticals. In 2012, US non-pharmaceutical chemicals ran a trade surplus of $25 billion, a figure that has remained relatively stable in recent years. But cheap natural gas unlocked by the shale energy boom is setting the stage for an increase in petrochemical production that can push this surplus even higher.

We estimate an additional $60 billion to $80 billion (nominal 2012 dollars) in annual output of petrochemicals, fertilizers, and resins by 2020, as noted in the preceding chapter on shale gas. Virtually all of that increased production will go to increased exports or reduced imports, thus improving the US trade balance in chemicals by an equivalent amount. The greatest growth is expected in ethane derivatives such as ethylene (used in antifreeze, tires, plastic bags, detergent, clothing, and many other products), methane, ammonia, and PVC resin. There is already a wave of investment in new “cracker” facilities for ethylene production, and substantially expanded production capacity should come on line in the next five to seven years. Natural gas is also a feedstock for producing ammonia and other fertilizers; increased domestic production could almost entirely replace current imports of 14 million tons per year. Petrochemicals alone can transform the trade deficit of $25 billion in the broader chemicals industry into a substantial surplus.

The challenge is much greater in pharmaceuticals, where net exports went from essentially zero in 1980 to a deficit of nearly $50 billion in 2012; the surge in imports since the mid-1990s has been growing almost twice as fast as exports. Imports are predominantly from three countries that have moved aggressively to become global pharmaceutical leaders: Ireland, Israel, and India. It is unlikely that certain types of pharmaceutical manufacturing could be reclaimed; India, for instance, has built its pharmaceutical industry on low-cost production of generics. Ireland has drawn companies with low corporate tax rates of 12.5 percent and strong support for R&D through tax incentives and government funding.

However, the United States may be able to stem the growing trade deficit in pharmaceuticals by focusing on innovation—in this case, building on its edge in genomics and big data to create next-generation clinical pathways and personalized treatments. This requires a highly skilled workforce, a favorable R&D environment, a streamlined approval process, and continued emphasis on productivity growth. Currently, there is a perception that the US market is overregulated and that decision making is slow. The Food and Drug

Administration (FDA) will need adequate resources and expertise to keep the process running smoothly as it prepares for the next era of cutting-edge drugs. Furthermore, there are still some opportunities for US production for the domestic market; highly productive pharmaceutical plants in advanced economies continue to be cost-competitive in their home markets on a landed cost basis versus plants in low-cost nations. And there is room to improve: in advanced economies, including the United States, a productivity performance gap of up to 40 percent still separates the most efficient pharmaceutical plants from the least efficient ones.

Semiconductors and electronics

The United States could stem the growing trade deficit in semiconductors and electronics, even though achieving surplus in this category is unlikely. The US trade deficit in this sector has worsened over the past three decades, growing from $5 billion in 1980 to $100 billion in 2012.[71] The negative trend accelerated sharply after 2000, with the trade deficit increasing by 7 percent annually as production moved outside the United States.

The sector comprises three large subsectors: semiconductors, communication equipment (e.g., routers), and electronic equipment (e.g., TVs). There appears to be limited potential for the United States to regain its strength in manufacturing in the latter two subsectors. In nominal terms, imports of communication equipment more than doubled in the past decade; imports of other electronic equipment also grew, although more slowly. The share of imports from China rose significantly in the past decade, from 15 percent in 2000 to more than 40 percent by 2010. But the trend in semiconductors has been markedly different.

In semiconductors, the United States still holds a leading position despite a trade deficit. Six of the ten largest semiconductor companies in the industry, including Intel, Texas Instruments, and Qualcomm, are American.[72] But in recent years, the sector has been transformed by the emergence of the "fabless" sector, which concentrates on design, innovation, and product development but outsources the actual fabrication of chips. While the United States retains some manufacturing of silicon wafers and integrated chips (and some large firms such as Intel continue to retain control over the fabrication function), many production foundries have moved to countries such as Taiwan.

In the United States, fabless production represents a move up the value chain to concentrate on a less capital-intensive and higher-value-added segment of the industry. A trade deficit turned into a $21 billion surplus in 2008 as economic value in the industry shifted toward fabless design and away from production. This coincided with a period of relative stability in the semiconductor value content of electronics after a decade of strong growth. Today, however, the US semiconductor industry once again runs a small deficit of $2 billion, possibly due to the growth of smartphones and tablets, which require more complexity and consequently higher value added in production. As these products mature, their production may become commoditized, again shifting economic value back

71 We use nominal values for semiconductors, communication equipment, and electronic equipment, as well as for computers and office machinery. In these industries, real values based on the hedonic price index yield unrealistically high growth rates. By using nominal values, we effectively use a price deflator of 1 instead of the hedonic price index.

72 Measured by 2011 revenue.

toward fabless design and thereby potentially returning the US trade position in semiconductors into surplus.

Building on US dominance in the fabless sector will require an inflow of highly specialized talent. Earlier MGI analysis has shown that labor productivity contributes up to 75 percent of the total productivity in the fabless segment, making high-skilled labor a key determinant of global competitiveness in semiconductors.[73] Increasing the number of STEM (science, technology, engineering, and math) graduates, a key component of the talent game changer, will be crucial.

Medical, precision, and optical equipment

Net US exports of medical, precision, and optical devices have shown a positive trend since 2004, and in 2012, this industry ran a small trade surplus of $9 billion, about 13 percent of gross exports. This surplus could grow substantially in the years to come. Within the overall industry, medical and measuring equipment accounts for 90 percent of gross exports, and this subsector has a growing trade surplus that reached $17 billion in 2012. (It was offset in the industry total by a deficit in optical equipment.) The United States can build on this strength, capitalizing on its position as a world leader in medical innovation. Many nations can produce simple medical equipment, but the United States has the capacity to produce sophisticated, state-of-the-art products such as imaging and diagnostic equipment and implantable devices. The United States is the world's largest market for medical devices, accounting for about 35 percent of all sales; seven of the world's top ten medical device manufacturers are US companies.

Global sales of medical devices have grown by about 10 percent a year since 2000, surpassing $310 billion in 2012. They are expected to maintain this strong momentum in the coming years and surpass $550 billion by 2020, potentially lifting US exports. Despite the impact of government austerity and limited population growth, advanced economies are expected to generate strong demand growth for medical devices in the coming years as their population ages. Emerging economies, with rising incomes and expanding health-care systems, provide another opportunity for growth; these markets now account for 22 percent of total US exports of medical devices, up from 13 percent in 2000.

Overall, medical devices have solid potential for increasing exports of high-end products in the coming years, though there are challenges in both advanced and emerging markets. For example, in the fast-growing Chinese market, some major US companies are successful at offering sophisticated products such as pacemakers, orthopedic implants, and imaging equipment. But local firms offer more value-oriented products that provide "good enough" functionality at lower price points, and they dominate segments such as patient monitors and disposable supplies. Local players may also have advantages in the form of more favorable reimbursement policies, deeper and broader hospital networks, and the ability to offer locally tailored services. In established markets such as Europe, medical product makers will have to deal with a broader set of stakeholders (e.g., non-clinical decision makers), increasing purchaser sophistication, and the growth of value brands.

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73 McKinsey Global Institute Sector Competitiveness Project, January 2010. Quantitative analysis covered the United States, the EU-15, Japan, Australia, and South Korea.

Machinery, equipment, and appliances

This category encompasses three industries: manufacturing of machinery, equipment, and appliances; electrical machinery; and computer and office machinery. Net exports are declining in all three industries, with some exceptions in select product categories. In machinery, equipment, and appliances, the United States saw a long-running surplus of $15 billion to $20 billion turn into a deficit in 2002; since then, the deficit has widened to more than $30 billion. The United States runs a small trade surplus in a few product categories such as engines and turbines ($6 billion) and specialized machinery for agriculture ($3 billion) and mining and construction ($6 billion). But this is not enough to offset a rapidly growing deficit in domestic appliances, driven by surging imports from China and Mexico. A similar trend is evident in electrical machinery (e.g., motors, cables, batteries), where the deficit widened to $30 billion in 2012, and in computers and office machinery, with a trade deficit of more than $50 billion.[74]

Mining and construction machinery ran a $6 billion surplus in 2012, but it may be difficult to grow exports, for two reasons. First, these large capital goods are costly to ship and are usually assembled close to final demand; that is why many US manufacturers already have operations in other countries, including emerging markets, rather than simply relying on domestic production to export. US multinationals such as Caterpillar, John Deere, and GE are industry leaders but have manufacturing facilities around the world to serve regional demand. Second, despite growing demand for infrastructure and resources in emerging economies, these countries may favor products that are vastly different from "standard" offerings made in the United States (or any advanced economy, for that matter) in terms of price point and performance. However, there are pockets of opportunity, including Mexico, where the government is launching an ambitious multiyear infrastructure plan.

The remaining categories have little potential for improving the balance of trade. Outside of specific product category exceptions, the machinery, equipment, and appliance industries have the lowest R&D intensity of all knowledge-intensive manufacturing. Domestic appliances, computers and office machinery, and electrical machinery also have relatively high value density (value-to-weight ratio). For such products, long-distance shipping is viable, and as production has become commoditized, it has steadily shifted to countries with lower-cost labor. US imports of domestic appliances from China, Mexico, and South Korea have risen steadily and now make up nearly 75 percent of all US appliance imports. This effect is even more pronounced in the computers and office machinery industry, where China alone accounted for 62 percent of US imports in 2011.

However, two strategies could at least mitigate these trends slightly. First, the US consumer market is high-end, lending itself to production of cutting-edge or premium products. Some firms may choose to locate their design, production, and service activities close to the market in order to respond quickly to consumer preferences and product demand. Second, lean operations and technology substitutions (such as robotics) could make US production more cost-effective. Some manufacturers are finding that the economics now work to shift some production to the United States—and they can maintain tighter control over

74 Note that we use nominal values for computers and office machinery and real values for machinery, equipment, and appliances, and electrical machinery. In computers and office machinery (as with semiconductors and electronics), real values based on the hedonic price index yield unrealistically high growth rates.

quality and shipping by more tightly integrating US design operations with actual production. GE, for instance, shifted some appliance manufacturing back to the United States with the reopening of its Appliance Park in Kentucky. Overall, however, a real reversal of the deficit in this category seems unlikely.

CLOSING THE TRADE DEFICIT IN KNOWLEDGE-INTENSIVE MANUFACTURING REQUIRES FIVE ACTIONS

Improving the US trade position in knowledge-intensive goods will require a set of coordinated actions. There are five key imperatives.

1. Build world-class infrastructure and talent, and focus on productivity

These are the pillars of long-term global competitiveness, and the three game changers that follow in this report offer a plan of action for improving US performance in these areas.

The ability to increase trade depends on having efficient, well-maintained infrastructure in place—and the United States has underinvested in its roads, bridges, and inland waterways for years. The result is congestion that detracts from the reliability of supply and distribution networks, and can raise the cost of doing business. Other nations have built modern and efficient infrastructure, and the United States will have to ensure that its transportation network measures up to the systems in peer economies. In addition, knowledge-intensive industries cannot thrive without a constant infusion of highly skilled talent. The United States needs to retool its education system to provide its future workforce with skills in science, technology, engineering, and math (STEM), as well as critical thinking. While infrastructure and workforce development both require more policy attention and public investment, the private sector can take on a much greater role in advancing these priorities. A growing number of manufacturers are working with local educational institutions to develop curricula and hands-on training programs to cultivate the specific skills their businesses need.

Finally, productivity growth is an imperative for US manufacturing plants to remain globally competitive—and this will require making investments in better operations and advanced tools and machinery. In addition, the United States has led the development of big data analytics. US manufacturers can build on this advantage, as we will describe in the next chapter, using big data tools for product and process design or sensor analytics to keep operations running at peak capacity.

2. Bolster US innovation

Companies that stake an early leading position in innovative products are often difficult to dislodge. The same often holds true for countries and regions: once another country captures production of certain goods, it is very difficult to regain it. (The United States and Europe pioneered flat-panel display technology, for example, but mass production moved to Japan, then South Korea and Taiwan. Two decades later, although US companies like Corning and Applied Materials are still leading innovators in the industry, production of flat-panel displays remains concentrated in Asia.)

The United States has a long history of innovation, and today, the nation is continuing to create the products and processes of the future: genomic sequencing, big data, cloud computing, advanced materials, nanotechnology, autonomous vehicles, hybrid and electric vehicles, and 3D printing. As new technologies are commercialized, they will create trade opportunities. For example, harnessing early advantages in genomic sequencing can lead to the development of personalized medicines in US-based labs that may stem the trade deficit in pharmaceuticals. In auto manufacturing, a similar focus on innovation has led to strong domestic production of hybrid and electric vehicles. But the United States will have to focus on strengthening and retaining its high-value-added manufacturing industries.

The United States has legacy advantages on which to build, including strong intellectual property rights protections, world-class R&D capabilities, and vibrant regional economic clusters (see Box 4, "The importance of economic clusters in knowledge-intensive industries"). The private sector, which funds most US R&D, can continue to make advances through creative research collaborations and commercialization efforts, including industry-academic partnerships. But policy makers will also have to make a sustained commitment to funding basic research. Government agencies, labs, and research entities—including the National Institutes of Health, the Defense Advanced Research Projects Agency (DARPA), and NASA—have pioneered many breakthroughs that have been successfully commercialized in the private sector, leading to economic value. In fact, the Department of Energy was instrumental in advancing the hydraulic fracturing technologies that led to today's shale energy boom.

Policy can support innovation by setting standards or mandating performance goals in order to spark the creation of new products. For example, automotive safety standards have provided the catalyst for innovations in airbags and ABS brakes—and today, fuel efficiency standards continue to spur innovation in a wide range of areas such as lightweight composites, energy storage, and hybrid and electric vehicles. Clear guidelines and standards can be helpful in many other emerging technologies (to qualify processes in additive manufacturing, for example, or to encourage the development of big data–related applications).[75]

Tax policy can also play a role in encouraging innovative activity. The United States, which pioneered the R&D tax credit in 1981, has not kept pace as other OECD countries have instituted even larger credits. Furthermore, the United States has kept its R&D tax credit "temporary" for decades, necessitating periodic renewals—a quirk that deprives companies of the certainty they have for R&D investments in many other jurisdictions. In addition, other tax incentives can be employed to foster new technologies and industries.

75 *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute, November 2012.

Box 4. The importance of economic clusters in knowledge-intensive industries

To regain trade competitiveness in knowledge-intensive goods, the United States can build on a core strength: it is a world leader in fostering industry-specific regional "clusters" that support exactly this sort of innovation and advanced manufacturing. Clusters are concentrations of firms, often located in proximity to a research university or a government research facility, that generate higher productivity and excel at innovation because of the cross-fertilization of ideas and collaboration that can occur. Talented workers with specific skills are drawn to these areas, facilitating knowledge spillovers. Related service industries, including legal, financial, and specialized accounting firms, emerge, and upstream supplier industries grow. Clusters can also support entrepreneurship through startup incubators, coordinating organizations, government research funding, industry-academic partnerships, and the availability of venture capital.

While Silicon Valley is by far the most famous example, the United States has nearly 250 industry-specific clusters, from chemicals in the Gulf Coast to machinery in Ohio.[1] Some support advanced manufacturing and the formation of local supply chains. Building on the leading-edge research capabilities of the Mayo Clinic and anchor firms such as Medtronic, Minnesota has built a flourishing medical devices cluster, while the presence of BMW in Spartanburg and the Center for Automotive Research at Clemson University have given rise to an automotive cluster in South Carolina. Wichita's aviation industry, in particular, has become a major exporter; its National Institute for Aviation Research coordinates collaborations among Wichita State University, NASA, the Federal Aviation Administration, and private-sector firms such as Lockheed Martin.[2]

1 Susan Helper, Timothy Krueger, and Howard Wial, *Locating American manufacturing: Trends in the geography of production*, Metropolitan Policy Program at Brookings, April 2012.

2 Mark Muro and Bruce Katz, *The new cluster moment: How regional innovation clusters can foster the next economy*, Metropolitan Policy Program at Brookings, September 2010.

3. Improve the US business environment through tax and regulatory reform

Making the R&D tax credit permanent, as discussed above, is only one piece of the necessary policy framework. The United States has entered a new era of global competition, and it will have to undertake a broader effort to create a tax and regulatory environment that attracts and retains firms that manufacture innovative products.

Tax rates, by affecting companies' cost of capital, rate of return, and relative competitive position, are among the factors that influence decisions about where to retain or expand operations. The example of the pharmaceutical industry shift to Ireland provides a vivid illustration of this phenomenon.[76] Recent studies have shown that the nominal US corporate tax rate is the highest in the OECD, and its effective rate is higher than the OECD average.[77] This makes the United States relatively less attractive as firms consider where to base production. Corporate tax reform could level the playing field with a broad set of other nations and could be revenue neutral if it were undertaken in tandem with broadening the tax base. Simplifying the tax code would remove a layer of complexity.

According to the World Economic Forum's Global Competitiveness Index, the United States placed 76th in the world for regulatory burden, a measure of how businesses view the cost of complying with administrative requirements such as those relating to permits, regulations, and reporting. The federal government as well as individual states can take steps to streamline cumbersome regulatory processes and red tape. This need not involve diluting regulations, but simply efforts to make the approvals process faster and more transparent. Ensuring that the FDA has the resources to conduct a streamlined and predictable approvals process is in the best interest of US firms in the medical devices industry, for example. The permitting process for building new plants and facilities is often fraught with delays; multigovernment and multiagency reviews can be coordinated in a much more harmonized manner. Another approach might be a new type of enterprise zone that emphasizes speed in permitting, and also offers some preapproved environmental and land-use permits.

Another area of reform is the modernization of export controls. These rules were put in place to limit the risk of sharing sensitive technologies with certain countries, but some of these regulations date back to the Cold War—and the countries in question are able to easily obtain the same goods from other trading partners. The Obama administration has begun an effort to overhaul these regulations; in May 2013, for example, draft rules were released that could eventually ease restrictions on exporting US satellite technology. Modernizing export control regulations could pave the way for some growth in defense and high-tech exports, but it will have to be conducted prudently.[78]

4. Pursue new export markets, especially in fast-growing emerging economies

Emerging economies are not only becoming centers of global production; they are also home to a large and growing pool of consumers. As these countries continue to urbanize and industrialize, the rise of emerging market consumers will present a $30 trillion opportunity by 2030. Between now and 2025, they will account for three-quarters of global growth, and nearly half will come from just 440 cities across the developing world.[79]

76 Academic research has found that taxation does play a role in investment and profit allocation decisions. See M. P. Devereux and G. Maffini, *The impact of taxation on the location of capital, firms and profit: A survey of empirical evidence*, Oxford University Centre for Business Taxation working paper 07/02, April 2006.

77 See Laura Tyson, *Why give corporations a tax break?* Project Syndicate, March 29, 2013. Also see Oxford University Centre for Business Taxation's CBT Corporate Tax Ranking 2012, June 2012.

78 Regulations on defense-related exports. See the President's Export Control Reform Initiative at http://export.gov/ecr/.

79 *Winning the $30 trillion decathlon: Going for gold in emerging markets*, McKinsey & Company, August 2012; and *Urban world: Cities and the rise of the consuming class*, McKinsey Global Institute, June 2012.

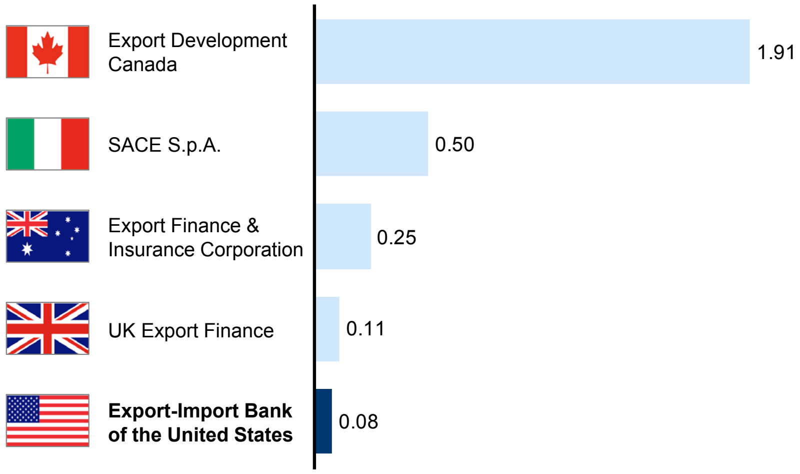
The United States can focus on increasing exports of knowledge-intensive goods to these markets; other advanced economies, such as Japan and Germany, have successfully built strong export industries in precisely these types of products. Policy makers and business leaders should jointly focus on introducing US products to new markets and promoting the United States as a base for FDI, attracting production not just for the domestic market but also for export. Initiatives can range from ensuring an adequate US presence at global trade fairs to undertaking more overseas trade missions. Some of the world's exporting powerhouses, such as Germany, Hong Kong, and Taiwan, take a more active and coordinated approach to export promotion than the United States, which will need to put additional resources behind this as a priority effort. The US Chamber of Commerce, as well as the Departments of State and Commerce, can play an expanded role in identifying opportunities and promoting US companies abroad. The US Export-Import Bank, which provides financing and credit insurance to overseas buyers of US exports, could also be expanded (Exhibit 13).

Exhibit 13

The US Export-Import Bank has a significantly smaller asset base than its counterparts in other developed economies

Total assets[1] of export credit agencies[2]

Share of GDP in local currencies, 2011 (%)



1 Comprises all assets on each agency's balance sheets, including the value of loans, guarantees, and insurance products.
2 Official export credit systems managed by private companies, as is the case in France and Germany, are excluded from this list.

SOURCE: Annual reports of export credit agencies; IMF World Economic Outlook; McKinsey Global Institute analysis

Multiple efforts are already under way to promote US export growth. The National Export Initiative, launched in 2010, seeks to double exports by 2014 (between 2009 and 2012, gross exports of goods and services increased from $1.6 trillion to $2.2 trillion, although the net trade deficit also increased from $380 billion to $540 billion). In many instances, individual states have taken the lead in marketing exports from specific industries and companies. The Alabama Development Office, for example, disseminates information on key foreign markets and opportunities and offers training for companies on how to export. In Florida, a public-private partnership called Enterprise Florida heavily markets the state's exporters and runs 12 foreign trade offices and seven in-state offices.[80] California's governor, Jerry Brown, personally led a delegation of state business leaders on a trade mission to China in 2013, focusing in

80 *Strategies for expanding California's exports*, Milken Institute, September 2012.

particular on opportunities to export clean technologies. But states vary widely in their resources and expertise. The federal government could more effectively spearhead such efforts with greater economies of scale, creating a more efficient point of contact for foreign buyers.

Providing accessible information and efficient support on specific export opportunities as well as the regulations, taxes, and processes involved is especially crucial in encouraging small and medium-sized companies to enter global markets. The federal government's export support services can be streamlined, expanded, and better marketed to make SMEs aware of opportunities.[81]

5. Attract more foreign production to the United States

Finally, the United States can aim to attract production from foreign companies and encourage more US companies to shift offshore production back home. Foreign firms already understand the importance of the lucrative US consumer market. US consumers are often among the world's first to adopt new and highly innovative products, and foreign companies can be encouraged to move some of their production to the United States to be closer to end-users and final market demand. Chinese computer maker Lenovo, for example, has established a manufacturing plant in North Carolina. It will be crucial to encourage the next wave of foreign car manufacturers to set up production and supply-chain networks in the United States.

In the past, it has largely been left to the states to compete for foreign direct investment. But in some cases, cities and states rely on costly incentive programs that create a "race to the bottom." Greater federal support and engagement could better coordinate these efforts. Setting up an effective "one-stop shop" for foreign companies that are interested in investing has proven successful for Ireland's IDA, Singapore's Economic Development Board, the Malaysian Industrial Development Authority, and the Costa Rican investment promotion agency, CINDE.[82] In 2011, the Obama administration adopted a similar strategy with the launch of SelectUSA (an initiative of the US Commerce Department) to promote the United States as an attractive destination for FDI. However, the program does not have the same scale as similar efforts in other advanced economies, which spend almost three times as much on investment promotion.[83] This effort might also gain traction if its leadership position were elevated to become a more prominent, high-level role.

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81 Emilia Istrate and Nicholas Marchio, *Export nation 2012: How US metropolitan areas are driving national growth*, Metropolitan Policy Program at Brookings, March 2012.

82 Theodore H. Moran, *Harnessing foreign direct investment for development: Policies for developed and developing countries*, Center for Global Development, 2006.

83 Testimony of Under Secretary of Commerce for International Trade Francisco Sanchez before the House Energy and Commerce Subcommittee on Commerce, Manufacturing, and Trade, April 18, 2013.

BOLSTERING US TRADE COMPETITIVENESS COULD ADD UP TO $590 BILLION TO ANNUAL GDP BY 2020 AND CREATE HIGH-VALUE JOBS

Given shifts in global industries, currencies, and new technologies, we believe that the United States could be poised to narrow its trade deficit in knowledge-intensive goods.

Estimating the GDP and employment impact of this opportunity is difficult, as product-specific trade is affected by a range of factors. Rather than tallying up the potential improvement in each of the six categories of knowledge-intensive manufactured goods, we instead consider two scenarios that describe a reversion to historical US trade deficits for this set of industries. Although we have highlighted the industries with the most promising opportunities above, these scenarios do not hinge on predicting which ones will narrow the trade gap and which will worsen it. (We did, however, check the robustness of the result by estimating the potential trade improvement in each product category to ensure that the top-down analysis does not imply implausible gains.)

In 2012, the overall US trade deficit in knowledge-intensive manufacturing (measured in real 2005 GDP) was 2 percent of GDP. If this ratio stayed constant in the coming years, it would rise to $375 billion (in real 2011 dollars) by 2020 based on our baseline GDP growth forecast. (See the appendix for details on the baseline GDP forecast.)

In the two scenarios, we consider the impact if the United States were to reduce its knowledge-intensive trade deficit to historical levels. In the low scenario, we consider the impact of reducing it, as a share of GDP, to its size in 2000 (1.3 percent of GDP). This implies that the trade deficit in these industries would be $125 billion lower than the baseline in 2020 (measured in real 2011 prices). Through the multiplier effect and consideration of imported inputs, this would add $200 billion to annual GDP by 2020 and create 600,000 new jobs. Roughly half of these jobs would be in knowledge-intensive manufacturing, a quarter in services, and a quarter in the rest of the economy (including other manufacturing).The jobs that would be created in either scenario are relatively high-wage and high-skill on average, adding to their economic impact.

In the high scenario, we consider roughly closing the trade deficit in knowledge-intensive industries, which was the case in the early 1990s. This would require increasing net exports by $375 billion from the baseline projection by 2020. This could generate $590 billion in additional annual GDP and create up to 1.8 million new jobs, with a distribution by sector and wage level similar to that of the low scenario (Exhibit 14). Achieving this scenario would also require significant progress on the talent game changer to prepare the US workforce for such relatively high-skill, technical, and rapidly changing jobs.

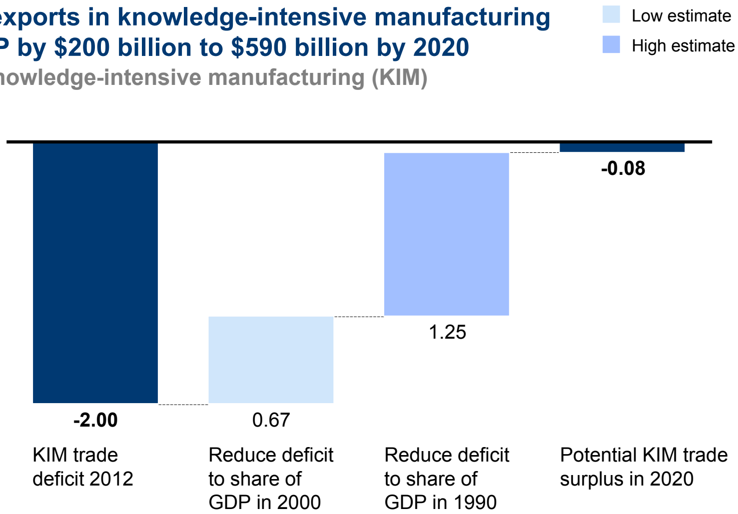
Not all knowledge-intensive industries can be expected to contribute equally to this outcome, and in neither scenario are we assuming that specific products revert to past performance. The production of some products, such as computers and appliances, has shifted overseas and will be difficult to recapture. But the United States now has a tremendous new opportunity to export petrochemicals, aircraft, medical devices, and other products. Overall, we believe that if the United States were to aggressively pursue this opportunity, it would be a game changer.

Exhibit 14

Improving net exports in knowledge-intensive manufacturing could raise GDP by $200 billion to $590 billion by 2020

Trade deficit in knowledge-intensive manufacturing (KIM)

% of GDP



GDP impact by 2020 $ billion	**200**	**to**	**590**
Job impact by 2020 Million	**0.6**	**to**	**1.8**

SOURCE: US Bureau of Economic Analysis input-output multiplier tables; Economist Intelligence Unit; IHS Global Insight; McKinsey Global Institute analysis

As a world leader in R&D and innovation, with a relatively well-educated workforce, the United States has a competitive advantage in exporting knowledge-intensive goods, as do other advanced economies. Yet despite its track record for ingenious product design, the nation increasingly loses out on manufacturing activity. Innovations conceived in the United States are more and more likely to be produced and built elsewhere. Labor-intensive manufacturing may have shifted to other parts of the world, but knowledge-intensive manufacturing does not have to follow suit. It can thrive in the United States and lead to an improved balance of trade as long as the right ingredients are in place: productivity, infrastructure, talent, and a continuous focus on maintaining a business climate that encourages investment and innovation.

Big data: Harnessing digital information to raise productivity

The United States needs to retool its economic engine so that it can sustain a higher growth rate for decades to come—and with an aging population, growth in labor productivity will need to offset slower growth in the labor force itself. This will be a daunting task: to maintain its historic rate of increase in per capita GDP, the United States will need to accelerate productivity growth by more than 30 percent, achieving a rate not seen since the 1960s.[84] A convergence of new breakthrough technologies may provide a critical solution that can help the United States meet this productivity challenge.

Big data and advanced analytics have the potential to raise efficiency and create value in large swaths of the economy. In the digital age, the world is awash in data, gleaned from sensors, transactions, GPS trackers, medical and legal records, videos, and much more. Data sets have grown exponentially with the arrival of electronic payments, online ordering, social technologies, and the so-called Internet of Things, the ubiquitous network of sensors, cameras, and transmitters embedded in physical objects in the world around us. Thanks to advances in computing power and the development of software that can extract useful information, this sea of data can now be transformed into insights that provide economic and societal benefits.

Just as new information technologies and the Internet itself fundamentally transformed business and sector competitiveness over the past 20 years, big data is poised to bring about the next wave of innovation, productivity, and growth. By exploiting big data and advanced analytics to improve decision making and unearth valuable insights, an individual company can significantly raise its efficiency and cost effectiveness; the most productive enterprises will gain market share. As the gains achieved by individual companies are adopted by competitors and spread throughout the industry, they create a cumulative boost to sector productivity. This translates into GDP growth and raises the competitiveness of the US economy. Big data also enables companies to create new products and services, enhance existing ones, and invent entirely new models; it speeds processes and makes R&D more productive. New firms are emerging that specialize in aggregating and analyzing industry data. Consumers are also capturing a large economic surplus as big data brings about price transparency and companies develop products better suited to their needs.

To understand the potential of big data to raise US economic performance, we analyze four large and markedly different sectors: retail, manufacturing, health care, and government services. In these sample sectors alone, we estimate that the widespread use of big data and analytics could produce up to $610 billion in annual productivity gains and cost savings. In retail and manufacturing, these productivity gains could translate into $325 billion in additional annual GDP by 2020. In health care and government, productivity gains may not affect US GDP due to limitations in the way GDP is measured. But big data can contribute to

84 *Growth and renewal in the United States: Retooling America's economic engine*, McKinsey Global Institute, February 2011.

improving the effectiveness of health-care delivery and government services, delivering better value and outcomes while lowering costs. We discuss but do not size the impact of big data on consumer surplus or on shifts in market share between industry players.

Public policy has yet to catch up with the rapidly growing reach of big data, however. To realize the economic opportunity of this game changer, the United States will have to take a number of critical steps: ensuring the competitive and fair use of data in the private sector; opening public assets for use in the general economy; providing clarity on issues such as data ownership and privacy; and building analytical talent in the labor force.

DATA GENERATION, COMPUTATIONAL POWER, AND ANALYTICAL TECHNIQUES ARE GROWING EXPONENTIALLY

The amount of digital data being generated is growing by the minute.[85] The estimated amount of data collected around the world expanded from somewhere in the range of 0.6 to 2.1 exabytes in 2000 to 2,700 exabytes in 2012—and the data universe is expected to reach more than 40,000 exabytes by 2020. It has been estimated that one-third of the world's total data assets reside in the United States.[86]

Big data that can affect a company's productivity derives from several sources. First, businesses generate data within their own operations: the cost of components, equipment performance, energy use, sales transactions, employee performance, and inventory levels are now collected and stored in digital format. Second, companies interact with their suppliers, partners, and external stakeholders (such as government agencies) in ways that generate data, including order and performance histories, schedules, prices, logistics, environmental impacts, and risk factors that may affect delivery. Companies can also purchase information from external data brokers. Finally, companies receive a growing volume of data from their customers, through their purchase history, response to price changes, and after-sales service and quality issues. Consumers are increasingly likely to share personal information, preferences, and reviews through channels such as Twitter, Amazon, and Pinterest. This data is used by companies to assess the effectiveness of their marketing and brand-building campaigns, to determine which features to add and remove from products, and even to make investment decisions and predict demand.

Although companies have collected data such as customer purchases for many years, only recently has the computational power been developed to gather, store, and analyze huge troves of unstructured data in useful ways. The computing power of servers has increased exponentially,[87] while the cost of

85 As data has proliferated, larger units of measurement are needed to describe the storage space required: 1,024 gigabytes = 1 terabyte; 1,024 terabytes = 1 petabyte; 1,024 petabytes = 1 exabyte. New terminology is ready for data to expand beyond exabytes to zettabytes, yottabytes, and brontobytes.

86 John Gantz and David Reinsel, *The digital universe in 2020: Big data, bigger digital shadows, and biggest growth in the Far East*, IDC View, December 2012.

87 The exponential growth of supercomputing power is recorded by Top500 (www.top500.org), a listing of the 500 most powerful commercially available computer systems. While no single metric can provide a comprehensive comparison of the overall performance of supercomputers, the performance of these systems is usually measured against a dense set of linear equations called the LINPACK Benchmark.

computation and storage has continued to decrease.[88] China's Tianhe-2, the fastest supercomputer as of June 2013, has 4,600 times the computing power of the ASCI White supercomputer, which set the standard in 2000. The computing power of the average desktop computer has increased by 75 times over the same period.

Big data's potential has dramatically increased thanks to its convergence with several major advances in computing and analytics. One is the emergence of cloud computing, which allows users to access highly scalable computing and storage resources through the Internet. It allows companies to tap server capacity as needed and expand it rapidly to the enormous scale required to process big data sets and run complicated mathematical models. If companies purchased, housed, and maintained their own servers and software to analyze big data, the setup costs would be prohibitive for most. But cloud computing lowers the price because the resources are shared across many users, who pay only for the capacity they actually utilize. Companies can access this capacity much more quickly, without the time and expense needed to set up their own systems, and they do not have to purchase enough capacity to accommodate peak usage. This makes it possible for even the smallest startups to take advantage of cutting-edge analytics, and it has enabled the creation of new companies specializing in data services.

Another trend making the big data revolution possible is the development of new software tools and database systems (such as Hadoop, HBase, and NoSQL) for large, unstructured data sets. Although some of the data now being collected is structured in familiar ways—such as customer purchase histories, inventory levels, and machine energy usage—much of it is unstructured, meaning that it does not conform to a pre-defined schema and cannot be easily searched, processed, or queried in traditional database systems. This would include, for example, blog posts by users around the Web, most video and audio content, research articles published in academic journals, and handwritten medical records. New software tools make it possible to process these unstructured data in quantities that would have been unheard of even several years ago; some of these systems are open source and easily accessible.

Finally, mathematicians, computer scientists, statisticians, and others are developing and refining analytical tools so that they can process vast quantities of data in near-real time. This includes algorithms and approaches such as clustering, neural networks, hidden Markov models, and Bayesian networks. For example, there have been rapid advances in the ability to synthesize unstructured data from multiple sources (e.g., social media feeds, clicks and usage patterns on web pages, GPS tracking data, crowdsourced reports on traffic and road incidents) and apply it to answer new questions: whether a 10 percent discount will entice a consumer to buy, how traffic will flow if a carpool lane is added, where a hurricane will make landfall, or whether an individual's DNA shows an increased likelihood of cancer.

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88 Moore's law, first described by Intel cofounder Gordon Moore, states that the number of transistors that can be placed on an integrated circuit doubles approximately every two years. In other words, the amount of computing power that can be purchased for the same amount of money doubles about every two years.

THE BENEFITS FOR INDIVIDUAL BUSINESSES CAN HAVE SUBSTANTIAL SPILLOVER EFFECTS FOR THE WIDER ECONOMY

Big data and advanced analytics offer the ability to quantify, track, and predict economic activity, the operation of complex systems, and customer behavior. The resulting insights can create transparency around company performance, expose variability to enable experimentation, augment human decision making, segment populations to customize action, and, in some cases, inspire new products and services. Individual businesses can exploit these capabilities to gain a competitive advantage, become more efficient, and create new sources of value. When the adoption of big data reaches critical mass, productivity rises within entire sectors, thereby spurring GDP growth.

Big data creates macroeconomic impact via three major routes

- **Cost efficiencies and productivity gains.** Big data analytics allow organizations to raise their efficiency by optimizing labor, equipment, and processes. Research has shown a correlation between companies' adoption of data-driven decision making and a subsequent increase in their output and productivity.[89] In this chapter, we focus mainly on this type of macroeconomic impact because of its clear link to GDP growth (although we also discuss two additional types of economic impact as described below). We estimate that the retail, health-care, manufacturing, and government sectors could realize up to $610 billion in annual cost reductions by 2020. However, these cost savings can result in higher sector productivity and GDP growth only in retail and manufacturing. (In health care and government services, cost savings do not translate neatly into GDP growth because of deficiencies in the way productivity is calculated in these sectors; see Box 5, "Measuring GDP and productivity in public and quasi-public sectors"). However, the cost savings in these sectors are very real and will benefit the economy by constraining the growth of health-care spending and making government services more efficient.

- **Shifts in market share.** At the individual firm level, big data analytics can reveal insights that cut time to market, drive sales, and reinforce critical branding messages. Data sharing among marketing, R&D, and customer service functions, for example, can create products that better match consumer preferences. Gaining visibility into product reviews and call logs can enhance customer service. The companies that are most adept at identifying these insights and translating them into business strategies are likely to gain market share. These dynamics will change the competitive landscape within individual sectors, creating new winners and losers. If the most productive firms gain market share, this will eventually raise productivity within entire sectors and the broader economy, thereby raising GDP growth. We do not attempt to quantify this effect in our calculation of the economic impact of big data, as it would occur over many years, and in some cases big data may simply shift profits among players rather than raise overall efficiency in a given sector.[90]

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89 Erik Brynjolfsson, Lorin M. Hitt, and Heekyung Hellen Kim, *Strength in numbers: How does data-driven decision making affect firm performance?* April 2011.

90 For an interesting analysis on how Walmart forced its competitors to use IT to become more efficient, thereby raising the productivity of the entire retail sector, see *US productivity growth: 1995–2000*, McKinsey Global Institute, October 2001.

Box 5. Measuring GDP and productivity in public and quasi-public sectors

Big data could have a potentially very large impact on government services and health care due to the size of these sectors in the US economy. Total government spending is $6.25 trillion (nearly 40 percent of US GDP), of which $1.3 trillion is health-care related.[1] Total public and private health-care expenditure is estimated at $2.5 trillion, or 17.9 percent of GDP.[2] Our analysis finds that big data could lead to $190 billion in annual cost savings in the health-care sector. In government services, it could produce up to $95 billion annually in operational efficiencies—and reduce expenditures and increase revenue by even greater sums. But these savings cannot be translated directly into GDP gains because of the way GDP is measured for public and quasi-public sectors in the national accounts. There are two issues at work.

First is the way that GDP is measured. In the private sectors of the economy, like manufacturing, GDP is measured as the value added that is produced by the sector, or revenue minus the cost of inputs. The GDP of the government and health-care sectors, however, is based on the amount of spending—not the value of output. When sector spending is used as the baseline, it follows that any productivity-driven cost reductions will reduce spending in the sector, and hence the measured GDP of the sector. For example, consider the potential use of big data analytics to streamline the processing of tax returns, the approval of visas, or the issuance of permits. Such changes might reduce the labor required and improve customer service. But this would paradoxically reduce the measured GDP of the government sector rather than increasing it, since government GDP is counted as the cost of the labor and other inputs in the sector.

Furthermore, GDP measurement in quasi-public sectors ignores the impact of productivity gains from raising the quality of services provided. For example, a hospital may use labor optimization techniques to free time for its nursing staff, but then opt to reallocate the nurses to activities that increase patient comfort. This would be a clear improvement, but one that is not always captured by GDP statistics. The economic benefits of improved health outcomes—which include more productive workers who can stay longer in the labor force—are likewise not measured in health-care GDP. Similarly, a government agency focusing on the environment may use big data analytics to more strictly monitor polluters, thereby reducing emissions. Because the national economic accounts do not consider environmental quality, the benefits from such activities will not be captured in GDP. The same situation is found in education, where big data analytics could support better tailoring and monitoring of individualized learning, resulting in better student achievement and higher-quality education—but this quality improvement will not be measured as an increase in the GDP of the education sector.

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1 Based on OECD statistics of government expenditure by function, 2011.

2 Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, National health care expenditures data, January 2012.

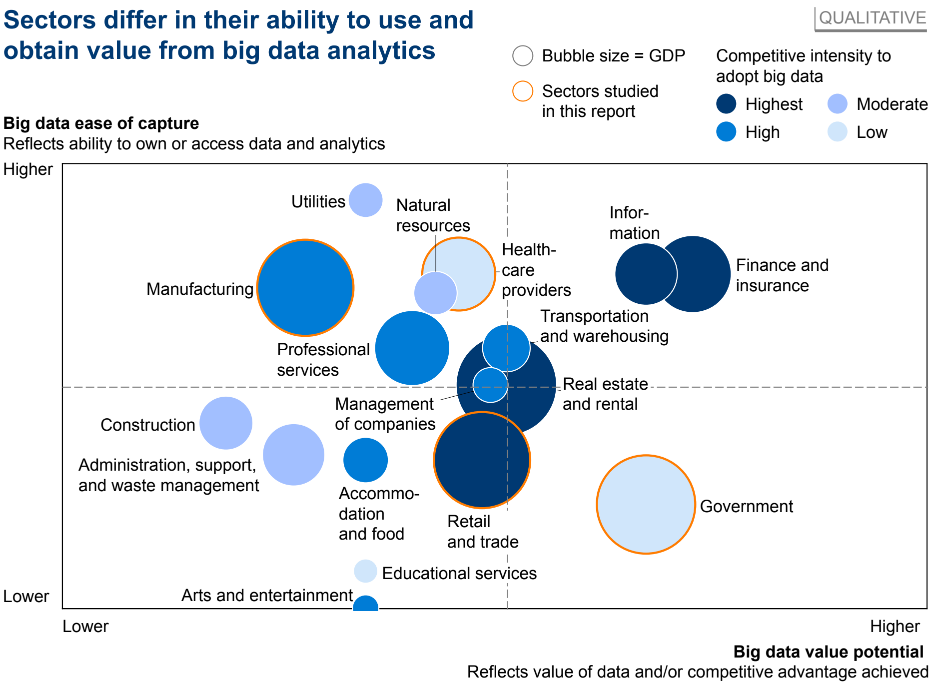
- **Consumer surplus.** Finally, big data creates value for consumers in ways that cannot necessarily be quantified and are not captured in GDP. Consumers generate much of the information that is allowing companies to hone their business models, but they are also reaping rewards. New applications such as parking finders, traffic monitors, and personal health trackers—all based on innovative uses of big data—can reduce search time and make life more convenient. Promotions and offerings can now be custom-tailored to individuals based on their purchasing history, preferences, and habits. Above all, consumers now have the tools to instantly find the best prices for goods and services, and they have access to niche products and services that better suit their needs.[91]

THE ADOPTION OF BIG DATA VARIES BY SECTOR

While certain sectors (such as natural resources and construction) today generate relatively little data, big data has potential across much of the economy. The ownership, availability, and competitive pressures within a sector all influence the rate of adoption and, therefore, the need for policy changes to capture the potential economic value of big data (Exhibit 15).

Exhibit 15

Sectors differ in their ability to use and obtain value from big data analytics



SOURCE: US Bureau of Economic Analysis; McKinsey Global Institute analysis

91 See Erik Brynjolfsson, Yu Jeffrey Hu, and Michael D. Smith, *The longer tail: The changing shape of Amazon's sales distribution curve*, September 2010.

In competitive and consumer-facing sectors, big data is a tool for gaining market share and improving profitability, and there is likely little need for policy intervention. Companies at the forefront of utilizing big data are typically in sectors in which data are readily generated, and they own or can obtain much of the information themselves (whether through individual transactions or markets for purchasing information). For highly competitive, consumer-facing industries, using data to gain insight is becoming an imperative. Sectors such as retail, financial services, information (e.g., publishing and data processing), and manufacturing are among the largest contributors to GDP within this group.

Although companies in these sectors are at the forefront of utilizing big data analytics, there is still considerable room for adoption. Competitive dynamics will push companies toward even wider and more sophisticated use of big data without any new incentives or policy changes.

Public and quasi-public sectors lacking competitive dynamics or with barriers to data sharing will be less likely to adopt big data without additional incentives or actions. The public sector generates an enormous amount of data—and in some of the areas regulated by the government, it could utilize and share even more. This information may be generated in the course of transacting with citizens (e.g., permitting or Medicare claims) and with the environment itself (e.g., traffic lights, public transit, snow plows, parking, and police deployment). But government employees may lack the training, tools, or incentives to share and make use of data. It will require concerted efforts and policy decisions to apply big data to improve government services. Making public-sector data available to the private sector could additionally have significant economic impact (see Box 6, "Open access to government data").

Similarly, quasi-public sectors such as health care and education could create tremendous economic and social benefit through the use of big data analytics, but in many cases the value is not captured because stakeholders' interests are not aligned (e.g., payors and providers or competing providers). Incentives will have to be fundamentally redrawn for these entities to fully exploit the potential of big data.

Box 6. Open access to government data

Private-sector companies are already making use of existing public data to create innovative new products and services. Walkscore.com, for example, uses government data to assess pedestrian-friendly neighborhoods, creating a metric that facilitates both urban planning and real estate deals. Real estate is similarly the focus of web-based services Zillow, Redfin, and Trulia, which draw on local property records data, crime and education statistics, and demographic information. The Weather Channel's offerings are enhanced by satellite data from the National Oceanic and Atmospheric Administration (NOAA). Multiple products and services have been created from the data collected by government GPS satellites. Additional value and efficiency could be unlocked if even more public data were shared and standardized (in fact, open data will be the subject of an upcoming report from MGI).

More open sharing of appropriately "anonymized" data by government with civil society, social entrepreneurs, and the private sector can also create transparency that inspires action in areas of relevance to citizens. Asthmapolis, for example, maps asthma attacks in real time to identify sources of pollution; this can be of benefit not just in health care but also in real estate and city planning.

Government scientific research and data are another tremendous source of potential value to the private sector. NASA findings inform scientific research and aerospace innovation, for example, and the sharing of research data from the National Institutes of Health (NIH) facilitates product development in the biotechnology and pharmaceutical industries. These spillover effects could be amplified and expanded into other areas with more open and efficient data sharing.

However, most government agencies have no formal record of the extent of their data, what is publicly shared and available, and what is not. Data.gov is beginning the effort to catalog the existing stores of data housed in various agencies and is working with the private sector to create new avenues for consumers to access and use this information.

BIG DATA COULD CREATE UP TO $610 BILLION OF ECONOMIC VALUE FOR THE US ECONOMY IN FOUR SECTORS

While it is impossible to predict the full effects of this rapidly evolving technology across the entire economy, we have analyzed its economic impact on four large and markedly different sectors: retail, manufacturing, health care, and government services.

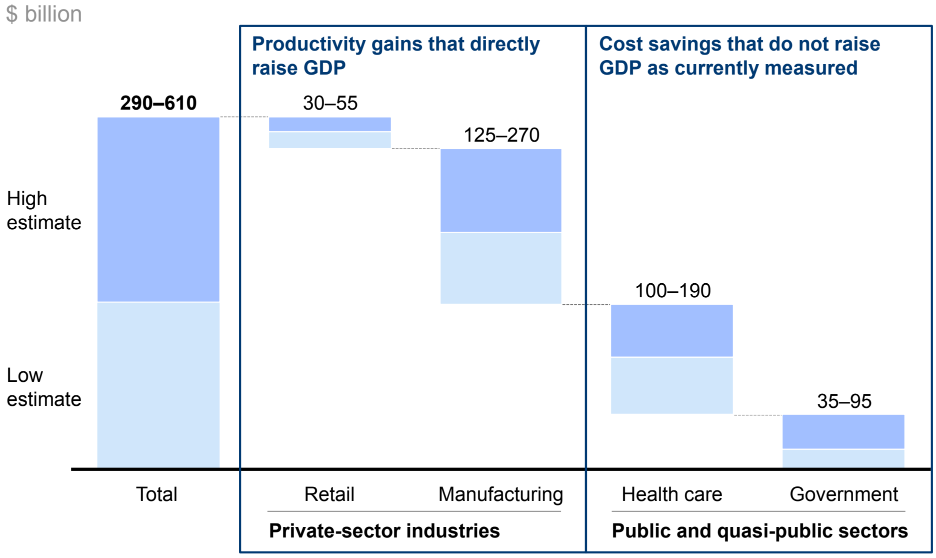
In these sectors, big data could produce up to $610 billion in annual productivity gains (Exhibit 16). In retail and manufacturing, these productivity increases translate into an additional $155 billion to $325 billion of annual GDP. As explained above, the productivity gains in health care and government will not raise GDP due to limitations in how GDP is calculated, but big data could generate as much as $285 billion of cost savings in these sectors.[92] If these savings were redeployed elsewhere in the economy, our estimate of the GDP impact of big data would be even larger.

Exhibit 16

Big data analytics can raise US GDP by up to $325 billion in retail and manufacturing, and create up to $285 billion in cost savings in health care and government

Projected annual productivity gains and cost savings by 2020

$ billion



SOURCE: McKinsey Global Institute analysis

We now discuss in detail how big data and advanced analytics could create economic value in these four sectors. But it is also important to note that this is only an illustration of big data's potential impact across the entire US economy. Sectors such as financial services, real estate, professional services, transportation, and information are likely to generate additional value on a par with those explored here.

Retail: Using big data insights to connect with customers and transform operations

Retailers have been recording every transaction for decades, but now they have new tools for analyzing a greatly expanded volume of data more effectively. They can gain new insights from radio-frequency identification chips embedded within products, location-based smartphone tracking, in-store customer behavior analysis captured on video and via sensors, and customer online searches and reviews.[93]

92 Measured as a share of projected 2020 output or spending, these productivity gains and cost savings vary between 1.5 percent and 5 percent in each sector. Productivity gains are 1.5 percent of projected sales in retail and 4 percent of projected output in manufacturing. Cost savings are 2 percent of projected outlays in government and 5 percent of projected spending in health care.

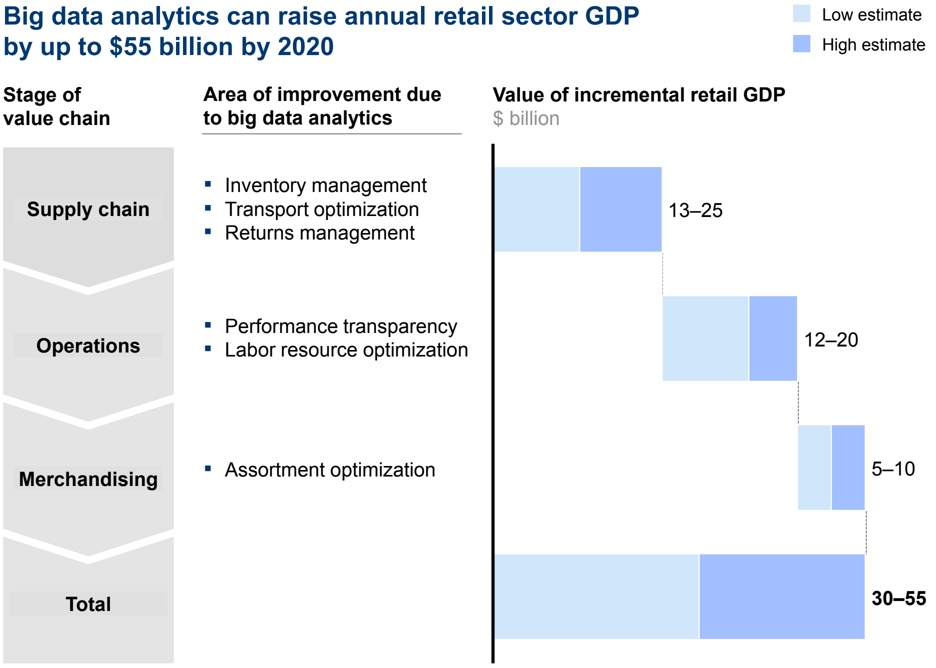
93 See Robert F. Byrne, *New math*, *big data*, Institute for Operations Research and the Management Sciences (INFORMS), July/August 2011; N. Srinivasan and Rajeev Nayar, *Harnessing the power of big data: Big opportunity for retailers to win customers*, Infosys Limited, 2012; and *Big data's impact on the data supply chain*, Cognizant 20–20 Insights, May 2012.

Some industry leaders (including Walmart, Kroger, and Target, and most notably Amazon in the e-commerce space) are already at the cutting edge of devising new applications for big data. For example, Amazon has taken cross-selling to a new level with sophisticated predictive algorithms that prompt customers with recommendations for related products, services, bundled promotions, and even dynamic pricing; its recommendation engine reportedly drives 30 percent of sales.[94] But most retailers are still in the earliest stages of implementing these technologies and have achieved best-in-class performance only in narrow functions, such as merchandising or promotions.

We estimate that wider adoption of big data tools could generate $30 billion to $55 billion in annual savings from productivity gains in the retail sector (Exhibit 17). These productivity gains are realized within the retail supply chain (through better inventory management, logistics optimization, and returns management) and in overall operations, through labor resource optimization and performance transparency. The major areas of impact within retail are summarized below.

Exhibit 17

Big data analytics can raise annual retail sector GDP by up to $55 billion by 2020



SOURCE: McKinsey Global Institute analysis

- **Supply chain.** Big data analytics can improve productivity in the supply chain through tighter inventory and returns management, better sourcing, and streamlined transportation and logistics. For example, detailed, real-time data on inventory can be combined with demand forecasting to reduce excess ordering and stockouts. Detailed information about consumer preferences, price sensitivity, and the availability of additional products and suppliers can be powerful tools to drive cost optimization. Returns data can generate insights on product improvements, and retailers can also minimize excess returns by working with suppliers to improve defective or high-variability products. We estimate that improvements in the supply chain can add up to

94 *Big data: The next frontier for innovation, competition, and productivity*, McKinsey Global Institute, May 2011.

$25 billion in cost-driven productivity gains annually, with additional benefits of speed and availability to both consumers and industrial customers.

- **Operations.** The operational improvements made possible by big data are mainly through optimizing labor inputs and creating performance transparency. For example, by conducting analysis on individual store, product, and employee performance, retail managers can identify best practices and take steps to continuously improve performance and transparency. Analytics can make more accurate predictions of store traffic and associated staffing needs to optimize labor scheduling. These improvements can add up to $20 billion in cost-driven productivity gains.

- **Merchandising.** Big data can guide decision making to optimize pricing, product assortment, and product placement within a store. Data on customer movement (whether collected via video surveillance, smartphone tracking, or sensors) and point-of-sale information can be used to create a store layout and merchandise assortment that is more convenient and appealing for shoppers and more profitable for the retailer. Online retailers can even adjust web design and placement based on how consumers interact with each page. Gains in merchandising can lead to small productivity gains ($5 billion to $10 billion) through optimization of product assortment.

In addition to productivity gains, big data analytics can drive large shifts in market share and profit pools in favor of the most adept retailers. In addition to productivity gains discussed above, we estimate that shifts in retailers' market share and profit pools can total more than $600 billion as the most effective companies capture consumer spending that would have gone to competitors. For example, data-driven analytics allow retailers to implement more targeted merchandising and marketing strategies, including improved cross-selling, location-based marketing, customer segmentation, in-store behavior data, sentiment analysis, and enhanced customer life-cycle management. The availability of more granular customer data from transaction histories and social media can produce sophisticated customer segmentation; discount offers, for example, can be personalized based on demographics, purchasing history, and other factors.[95] Location-based marketing, which relies on the tracking functions in smartphones and other devices, can send timely customized offers to consumers who are in or near stores. And by scanning social media in real time, retailers can gauge the effectiveness of marketing campaigns and respond to public feedback.

Manufacturing: Big data analytics can streamline R&D, production, and supply-chain management

Manufacturers have large troves of data in their possession. In fact, the US manufacturing sector is estimated to store nearly 2,000 exabytes of data, among the highest of any sector of the economy. Much of the data is generated by sensors in equipment owned and operated by manufacturers themselves. If this information is synthesized and acted upon, companies can substantially improve how they run their machinery and operations, design products, and respond to customer needs.[96]

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95 *The social economy: Unlocking value and productivity through social technologies*, McKinsey Global Institute, July 2012.

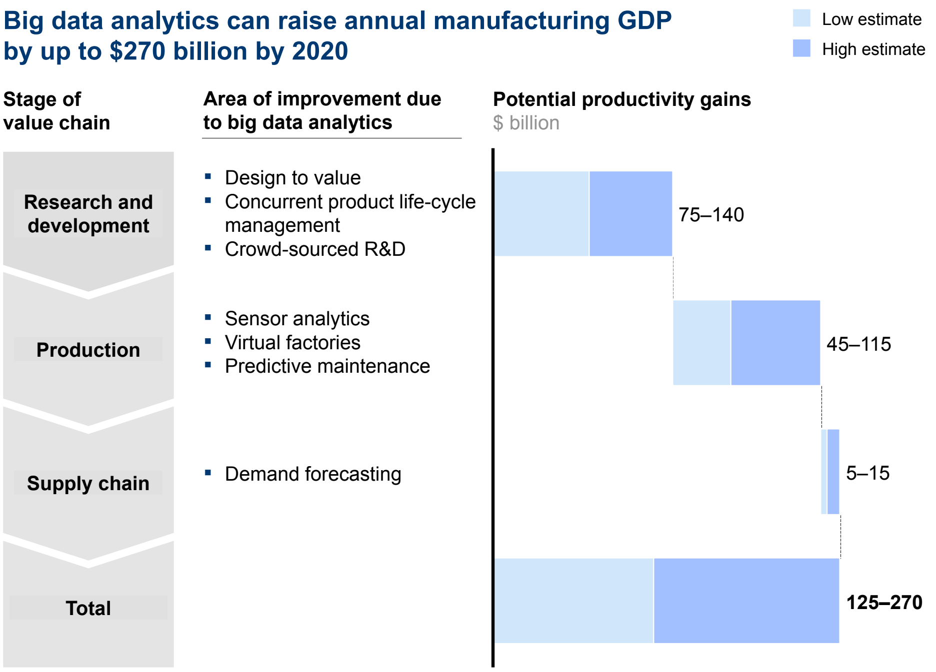
96 *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute and McKinsey Operations Practice, November 2012.

Data is not new to the manufacturing sector.[97] But the sector that pioneered innovations from the assembly line to advanced robotics has been slow to utilize big data analytics. Extensive interviews with industry experts reveal that only a small number of firms are actively cultivating these capabilities today. Most modern equipment generates data, but these experts report that many of the advanced analytic tools available to them are not user friendly and do not easily translate to changes that can be implemented by workers on the front line. Many feel that there is room to make process improvements across their operations without investing in big data—and until this "low-hanging fruit" is harvested, advanced analytics will remain the provenance of cutting-edge firms. Big data–driven gains in the manufacturing sector are largely waiting to be captured, although certain subsectors like semiconductors are already moving forward.

Despite this slow start, change is coming, and momentum may accelerate as companies witness the results achieved by early adopters. We estimate that adoption of big data tools could generate up to $270 billion in annual productivity gains in manufacturing by 2020 (Exhibit 18). These productivity gains are realized both in product development (through more effective R&D, design to value, and concurrent product life-cycle management) and in operations (through better demand forecasting, sensor analytics, virtual factories, and predictive maintenance). The uses of big data to improve productivity in various stages of manufacturing are summarized below.

Exhibit 18

Big data analytics can raise annual manufacturing GDP by up to $270 billion by 2020



SOURCE: McKinsey Global Institute analysis

97 See J. A. Harding et al., "Data mining in manufacturing: A review," *Journal of Manufacturing Science and Engineering*, volume 128, number 4, December 2005. For more recent work, also see A. K. Choudhary, J. A. Harding, and M. K. Tiwari, "Data mining in manufacturing: A review based on the kind of knowledge," *Journal of Intelligent Manufacturing*, volume 20, number 5, October 2009.

- **Product development.** Big data creates new efficiencies in product development and design that represent $140 billion in productivity gains. In the design stage, where decisions are made that can drive 80 percent of manufacturing costs, product life-cycle management (PLM) systems can combine the large data sets generated by computer-aided design, engineering, and production systems, enabling more effective collaboration, even with outside suppliers. PLM platforms can allow designers and engineers to test different designs and choices of parts and suppliers, saving 20 to 50 percent on development costs. Customer data can also guide the design-to-value process. The features and functionalities that are known to be of highest value can be enhanced, while superfluous elements can be removed, saving 10 to 15 percent in materials costs.[98] In heavy industrial and capital-intensive sectors, manufacturers can work with their customers to collect data about postsales usage patterns and functionality, leading to design improvements and reduced costs for all parties. Finally, companies are also using crowdsourcing to tap the ideas of a large community (whether internal or external), with big data analytics helping to extract the best ideas.

- **Production and operations.** Big data can create $115 billion in annual productivity gains in this area. Most of that potential can be realized through sensor analytics, which can produce significant savings in the cost of energy and raw materials. They can also minimize disruptions in production by monitoring wear on production equipment such as industrial motors and drill bits, allowing for preventive maintenance and saving 10 to 40 percent of maintenance and repair costs.[99] Biosensors on packaged food can even detect contamination and spoilage, reducing waste. Data about machine and labor productivity can be centralized in a “performance dashboard” that tracks the efficiency of each stage. One mineral products manufacturer installed sensors in a kiln’s midzone to monitor lime mud temperature, a leading indicator of calcination. Based on the heat profile, the shape and intensity of the flame that generated heat through the kiln could be optimized; as a result, the manufacturer obtained a 5 percent increase in production. Companies can also use advanced simulation techniques to create 3D models of new processes, new factory floors, and even entire plants before physically building them, reducing the time and cost of construction. In the automobile manufacturing industry, a major new US assembly plant that was built using a 3D model took into account space requirements of systems that were yet to be installed. The simulation enabled the project to be delivered about five weeks ahead of schedule with virtually no field overtime.

- **Supply chain.** Big data makes it possible to seamlessly aggregate information from across the supply chain and coordinate all players to minimize disruptions, realizing $15 billion in measurable annual productivity gains. After experiencing costly delays from the multitude of suppliers providing components for its 787 Dreamliner aircraft, Boeing moved to address the problems by setting up a centralized production integration center with dozens of data and live video feeds from suppliers around the globe. Advanced analytics synthesize these inputs, monitoring their impact on production schedules and costs. Another critical area of supply-chain management is advanced demand forecasting. Rather than using historical data to forecast

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98 Ibid. (J. A. Harding et al., “Data mining in manufacturing,” December 2005.)

99 Ibid.

future demand (knowing that tire sales typically increase in June, for example), manufacturers can use real-time inputs from customers (such as auto telematics, breakdown information, road conditions, and the mileage and routes of trucks on the road). This allows for more accurate estimates of not only the quantity of demand but also exactly where products will be needed. This is a key capability as demand shifts and becomes more segmented.

Health care: Big data can raise productivity while improving patient outcomes

Although the rise in US health-care expenditures has slowed, they have been growing unsustainably for years, rising from 13.8 percent of GDP in 2000 to 17.9 percent in 2011.[100] The United States spends more on health care than any other nation in the world; adjusted for wealth, the nation spends as much as 23 percent more than peer countries in the OECD, without producing better outcomes on average.[101] A recent report found that Americans have shorter life expectancies and experience more illness than people in other high-income countries.[102] As the population ages, reversing this trend will be crucial to relieving the pressure of health-care costs on public deficits, companies' labor costs, and workers' wages.[103]

Big data analytics could play a role in constraining the growth of US health-care costs by optimizing efficiency and cost-effectiveness, as well as improving patient outcomes and providing tools for preventive care and wellness.[104] The three major areas of impact are in clinical operations, R&D, and public health. We estimate that adopting big data in the health-care sector could produce $100 billion to $190 billion in annual cost reductions and higher productivity by 2020 (Exhibit 19).[105] As discussed earlier in this chapter, these gains do not translate directly into higher GDP as they do in retail and manufacturing because health-care GDP measures the amount of national spending on health-care

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100 Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, National health care expenditures data, January 2012.

101 See *Health at a glance 2011*, OECD Indicators. Also see Christian Hagist and Laurence Kotlikoff, *Who's going broke? Comparing growth in health-care costs in ten OECD countries*, NBER working paper number 11833, December 2005; *Accounting for the cost of health care in the United States*, McKinsey Global Institute, January 2007; and a recent update from the McKinsey Center for US Health Reform, *Accounting for the cost of US health care: Pre-recession trends and the impact of the recession*, December 2011.

102 *US health in international perspective: Shorter lives, poorer health*, National Research Council and Institute of Medicine of the National Academies, National Academies Press, 2013.

103 See Michael E. Chernew, Richard A. Hirth, and David M. Cutler, "Increased spending on health care: How much can the United States afford?" *Health Affairs*, volume 22, number 4, July 2003.

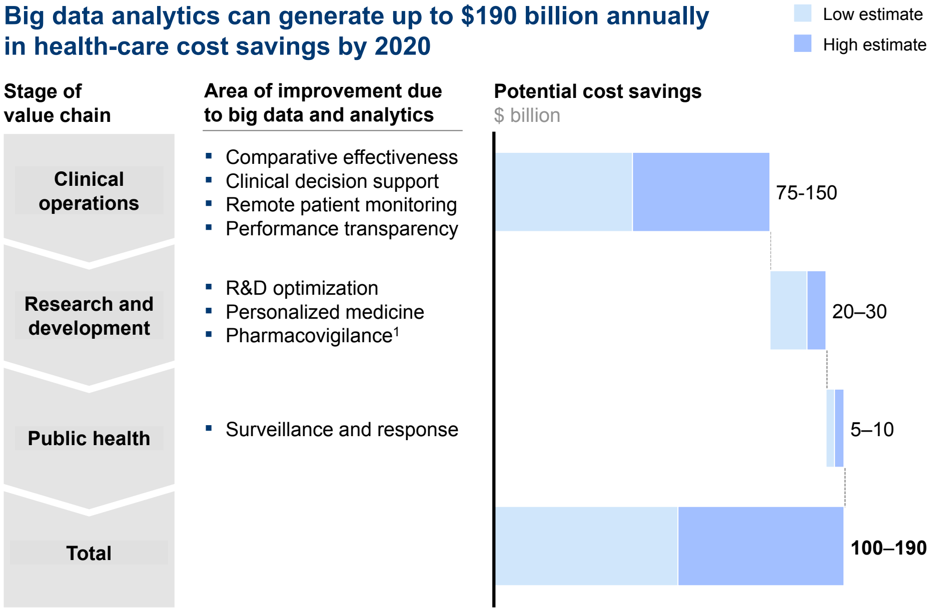
104 *The "big data" revolution in healthcare: Accelerating value and innovation*, McKinsey & Company Center for US Health System Reform and Business Technology Office, January 2013.

105 An earlier MGI report, *Big data: The next frontier for innovation, competition, and productivity* (May 2011), calculated the value of big data in US health care to be $333 billion, including $226 billion in reductions to national health-care expenditures. The approach used in this report is consistent with this earlier work (in health care as well as in retail, manufacturing, and government services), but our estimate of a $100 billion to $190 billion impact in health care is smaller because we have reclassified items such as pricing and accounting changes as shifts in market share or consumer surplus within the overall payor-provider landscape; we do not consider them to be true operational cost savings as measured in the other game changers. Furthermore, in this research we do not estimate the impact of big data beyond cost savings.

services, not the sector's "output." Many of these cost savings (e.g., opting for more cost-effective treatments) could in fact reduce spending and thus would reduce measured GDP despite the benefits. In addition, better health outcomes could lead to productivity gains through fewer sick days and longer productive life spans of the labor force; this has a significant but unquantifiable long-term impact on GDP.

Exhibit 19

Big data analytics can generate up to $190 billion annually in health-care cost savings by 2020



1 Also known as drug safety, "pharmacovigilance" is defined by the World Health Organization as the science and activities relating to the detection, assessment, understanding, and prevention of adverse effects or any other drug-related problem.

SOURCE: World Health Organization; McKinsey Global Institute analysis

- **Clinical operations.** An array of big data tools can reduce inefficiencies in the delivery of patient care. The first of these, with the largest economic impact, is comparative effectiveness research, which analyzes the relative efficacy and cost effectiveness of various treatments for specific patient profiles.[106] It may reveal, for example, that a certain type of treatment yields a 10 percent lower complication rate, or that two drugs with radically different price points produce comparable outcomes. Clinical decision support systems are another valuable tool; when physicians enter orders into a computerized system, they can receive updated medical guidelines and warnings against adverse drug reactions. The same kind of "performance dashboard" used by high-tech manufacturers can be deployed in a clinical setting to track the "patient journey" through a hospital; the Centers for Medicare and Medicaid Services is piloting these systems. As the incidence of complex chronic diseases such as diabetes continues to rise in the United States, remote patient monitoring can be deployed as a means to reduce hospitalizations and improve outcomes. Together these various systems can drive $75 billion to $150 billion in direct

106 See Anirban Basu, Anupam B. Jena, and Tomas J. Philipson, "The impact of comparative effectiveness research on health and health-care spending," *Journal of Health Economics*, volume 30, number 4, July 2011. Also see Harold C. Sox and Sheldon Greenfield, "Comparative effectiveness research: A report from the Institute of Medicine," *Annals of Internal Medicine*, volume 151, number 3, August 2009; and Daniella J. Perlroth, Dana P. Goldman, and Alan M. Garber, "The potential impact of comparative effectiveness research on US health care expenditures," *Demography*, volume 47, number 1 supplement, March 2010.

productivity gains annually. The shift to electronic medical records, now under way, will be critical to enabling these gains.[107]

- **Research and development.** One of the most exciting applications of big data is in R&D, which could produce $20 billion to $30 billion in direct productivity gains annually by 2020. Scientists have the computational power to process massive amounts of data and test molecules using simulations. Predictive models can help pharmaceutical companies determine which early-stage drugs are most promising, reducing failure rates. Statistical tools and algorithms can improve recruitment and protocol design in clinical trials; they can also analyze the results and spot potential side effects earlier on. If the right organizational models are put in place, big data tools can support open innovation and crowdsourcing to speed the development of new treatments. Organizations such as 23andme are harnessing social media and big data analytics to increase patient engagement in research. With the price decline in sequencing genomes actually outpacing Moore's law, these efforts can quickly scale up the size of data sets, moving personalized medicine closer to reality.[108]

- **Public health.** Big data is well suited to the task of monitoring outbreaks of disease and mobilizing local health-care providers to contain outbreaks. For example, the US Centers for Disease Control and Prevention (CDC) uses big data in its FluView surveillance. We estimate that the productivity gains from big data analytics in public health monitoring and mobilization amount to $5 billion to $10 billion annually.

Realizing this transformation in health care will require major IT investment, structural changes, and a willingness to embrace greater transparency. It may also call for policy interventions, as health care is a quasi-public sector with real barriers to data sharing; provisions of the Health Insurance Portability and Accountability Act (HIPAA), for example, can make it difficult to share data for certain kinds of medical research. Intellectual property issues around research discoveries and drug development will have to be resolved in order to forge more collaborative and multidisciplinary research partnerships. Providers may require new incentives to overcome concerns over losing revenue to payors and competing providers as well as malpractice and liability issues. Doctors will need to accept a more data-driven approach, and employees across all provider systems will have to more fully integrate these technologies into day-to-day patient care. We discuss these challenges further in the last section of this chapter.

In addition to productivity gains, big data and analytics can generate shifts in revenue and profit pools among the various stakeholders in the health-care sector, for instance through changes in accounting and pricing. These changes can occur via two primary applications for payors: fraud prevention (through automated systems for claims checking) and performance-based drug

107 In 2005, only about 30 percent of US physicians and hospitals used even basic electronic medical records, but by the end of 2011, usage was up to 50 percent for doctors and 75 percent for hospitals. However, significant investments are still needed, as many of these systems cannot connect with each other.

108 According to data from the National Human Genome Research Institute (part of NIH), the cost of sequencing a genome has dropped from approximately $100 million in 2001 to less than $10,000 today.

pricing (which utilizes patient outcomes data to negotiate with pharmaceutical companies). Clinical data sets that link outcomes to savings for payors can be used to enable performance-based pricing and risk-sharing/incentive schemes that reward high-performance drugs and reduce cost or usage for those that do not lead to beneficial outcomes. There is an entrepreneurial opportunity for companies to provide data management and analysis services to the health-care sector.

Government services: Big data can lead to cost efficiencies

With governments at every level facing both deficits and rising obligations, creating leaner processes has become an urgent imperative.[109] Big data can play an important role, but capabilities vary widely: the National Institutes of Health, for example, is making a concerted push to use big data tools to advance medical research, and the US Department of Transportation has an initiative to develop intelligent transportation systems. In contrast, the US Department of Veterans Affairs is only now computerizing its paper claims process, and many local governments lack even basic systems for data analysis. Redundancy and lack of compatibility between IT systems, as well as proprietary attitudes over data ownership, are challenges that will have to be overcome.

The federal government has taken some initial steps toward embracing big data. Information currently resides in myriad separate (and sometimes duplicative) data centers, with no central catalog and in differing formats. In response, the Federal Data Center Consolidation Initiative was launched in 2010 to consolidate some 800 of the government's 2,000 data centers by 2015. In May 2013, the administration issued an executive order establishing a new "open data" policy stating that all newly generated federal data will be made publicly available in open, machine-readable formats with the appropriate safeguards; the goal is to make large stores of data more available to businesses and researchers.

We estimate that big data analytics could produce administrative efficiencies that generate productivity gains of $35 billion to $95 billion annually by 2020. In addition, we estimate $280 billion to $460 billion in reduced expenditures though minimizing erroneous government payments and making procurement more efficient as well as revenue increases through making tax collection more effective (Exhibit 20).

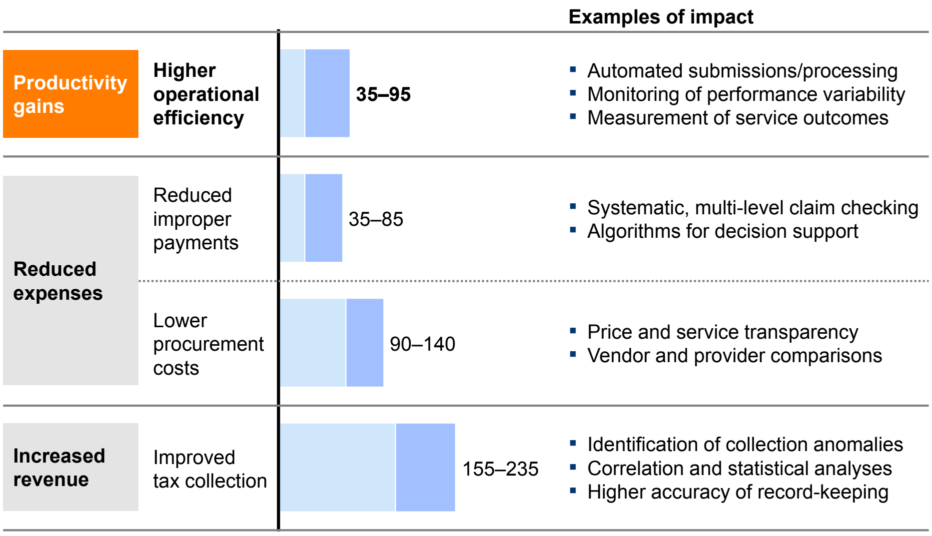
109 See *The public-sector productivity imperative*, McKinsey & Company, March 2011.

Exhibit 20

Big data analytics can generate up to $95 billion in productivity gains for government services by 2020—and additional savings and revenue

Impact of big data analytics in government services
$ billion

Low estimate
High estimate



SOURCE: McKinsey Global Institute analysis

- **Operational efficiency.** Direct productivity gains in government services are generated through the use of big data analytics to increase operational efficiency. Enhanced data systems and sharing, combined with greater automation (such as automatic form population, which allows administrative workers to process data 20 percent faster), could produce operational efficiencies and reduce administrative expense and errors, saving federal and local governments up to $95 billion a year by 2020. Streamlining cumbersome back-office functions can free federal, state, and local employees to provide better customer service to citizens, reducing wait times for all manner of services.

- **Fraud detection and error reduction in entitlement programs.** The Government Accountability Office estimates that improper payments from ten major federal programs, including Medicare and Medicaid, total up to $115 billion; similarly, estimates by the FBI suggest that 3 to 10 percent of medical payments may be fraudulent.[110] The right big data tools could detect fraud and prevent erroneous payments, saving up to $85 billion annually by 2020.

- **Government procurement.** Big data has applications for bringing transparency to government purchasing, lowering federal procurement costs by up to $140 billion annually by 2020. Better sourcing systems and the sharing of information on pricing and vendor performance across agencies can reduce inefficiencies and create economies of scale. By providing the general public and other potential suppliers with cost requirements and performance data pertaining to contracts, the government may be able to more easily procure quality products and services at competitive prices.

110 *Improper payments: Remaining challenges and strategies for governmentwide reduction efforts*, US Government Accountability Office report, March 28, 2012; FBI financial crimes report to the public (fiscal years 2010–2011).

- **Tax collection.** The federal tax gap (the amount of taxpayer liability that is not paid on time) was approximately $385 billion in 2006, the last year for which analysis is available.[111] Big data analytics could use algorithms to pinpoint and reduce tax fraud and underpayment, increasing revenue by up to $235 billion a year by 2020.

CAPTURING THE FULL ECONOMIC VALUE OF BIG DATA WILL REQUIRE CONCERTED STEPS

Several overarching factors could determine how quickly the public and private sectors adopt big data.

Privacy, cybersecurity, and data ownership issues will have to be resolved

Big data's reach is growing—but new data collection approaches have created significant new privacy and security issues. Data security and identity theft are growing dangers, and many people are simply unaware of how much of their personal information is captured, stored, and shared. Surveys have suggested that a majority of Americans are not interested in relatively "benign" uses of data such as tailored advertising.[112] Retailers, in particular, have been successful at using consumer data but are also encountering pushback over privacy issues in marketing. The use of dynamic pricing and the protection of "personally identifiable information" have legal implications that need to be addressed at a public policy level.

Privacy and intellectual property laws will have to be reevaluated and updated to address the uses of big data; at present there are many gray areas. In some cases, privacy laws hamper the free flow or use of data for potentially beneficial uses. Regulations restrict the types of information government agencies can share with one another or require onerous approvals for transmitting data. In addition, there is a great degree of variability in the data policies and restrictions imposed by state and local school districts, making it harder for education researchers and policy makers to understand trends and develop innovative tools that could improve school quality. But parents and privacy advocates have expressed reservations about implementation of new databases that track student records, especially since new federal regulations allow the information to be shared with private companies without parental consent.

In other areas, the lack of explicit regulation affords consumers little or no protection. In 2010, the Federal Trade Commission recommended the establishment of a "do not track" registry to provide privacy protections online, and two years later, the White House proposed a "Consumer Privacy Bill of Rights." Both proposals remain stalled.

Policy makers and many large companies are increasingly concerned about cybersecurity, as data breaches can threaten national security as well as economic and business activity. As digital data becomes more pervasive, mobile

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111 Tax gap calculations are made available only longitudinally, after the IRS has had ample time and opportunity to assess the missing taxes. See Internal Revenue Service, http://www.irs.gov/uac/The-Tax-Gap.

112 Joseph Turow et al., *Americans reject tailored marketing and three activities that enable it*, Annenberg School of Communication at the University of Pennsylvania and Berkeley Center for Law and Technology at UC–Berkeley School of Law, September 2009.

devices and sensors proliferate, and valuable intellectual property is created "in the cloud," new targets could emerge. As more firms seek to improve productivity by sharing data and more tightly integrating with partners in their supply chains, they will have to confront all-new security risks. Information security requires a continuously evolving response to stay ahead of increasingly sophisticated threats. For example, leading firms are reorienting their security architecture from protecting devices to identifying and protecting critical data instead.[113] On the regulatory front, a policy framework is being debated as lawmakers seek to address concerns over privacy, liability, and other issues connected with cybersecurity.

It is often unclear to what extent users own their own data and how it can be shared. A smartphone user, for example, may create data on a device made by the phone manufacturer, transmit it over a network owned by the carrier on an operating system created by an independent software firm, and ultimately send it to a website or app created and owned by another party. The companies along the chain operate independently and capture different pieces of the user experience, with or without the user's knowledge. (And many privacy policies required to use a cellphone suggest that data flowing through the phone is property of the phone manufacturer.) In these situations, the owner of the data is not clear or is determined on a one-off basis by the user's acceptance of terms of use, which may be conflicting or may generate a complex cascade of data ownership. These legal issues have yet to be fully resolved.

By seeking public input on expectations and norms and then establishing clear guidelines, policy makers can balance the need to liberate data with citizens' right to privacy. An efficient, clear, and up-to-date framework would remove uncertainty and facilitate more rapid adoption.

Major IT investments and new organizational models are needed to realize big data's potential across sectors

Taking advantage of big data requires organizations to make significant investments in IT systems and human capital. At present, many senior leaders see big data as a trend that may be overhyped, and they worry (correctly, in some cases) that big data projects may lead to budget overruns with little to show in the way of tangible business outcomes. These concerns are causing some companies to postpone investment.

New business models are emerging to assist firms that do not capture and generate data on their own. The fledgling data-broker/data-aggregation industry will have to establish standards and build trust regarding the storage, use, and security of data to maintain the integrity of the overall system.

In some areas, the cost of collecting data may be too high for any individual entity, but multiple stakeholders could use the data profitably to the benefit of the overall sector. Some of these situations can be addressed by appropriately opening up government data to the public. Others may call for new collaborative models that bring together stakeholders that hold different pieces of the overall data.

The US health-care system is a prime example of a sector that will need a fundamentally new model of data sharing. Its data assets currently exist in

113 *Meeting the cybersecurity challenge*, McKinsey on Business Technology, 2011.

discrete pools held by different (and sometimes adversarial) stakeholders. Physicians and hospitals are still in the early stages of shifting to electronic medical records, while payors have a wealth of claims transactions, and the pharmaceutical sector has vast research data. Integrating these fragmented data sets—and finding a way to include patient behavior and compliance data—to gain valuable insights presents a host of technology and compatibility challenges. The various stakeholders will need a new incentive structure to encourage sharing, and policy interventions may be necessary. But some intriguing new models are emerging: new state health exchanges, health information aggregators, and multidisciplinary research partnerships. The NIH's BD2K initiative seeks to inventory data resources throughout the biomedical community and disseminate tools for analyzing them. As we neared publication, the NIH joined more than 70 medical, research, and advocacy organizations around the world in a new effort to standardize open databases of genetic and clinical information, paving the way to research advances in disease treatment.

The United States needs to develop more specialized talent

Big data promises big things—but only if organizations have the right people in place who know what to do with it. A recurring theme among senior leadership across all sectors is a shortage of professionals trained and experienced at the intersection of disciplines necessary to capture, analyze, and generate meaningful business insights from big data. In addition to deep analytics talent, organizations need management with the right balance of business judgment and statistical skills to translate analysis into action.

The United States is already ahead of other countries in deploying big data and developing the expertise needed to harness this information and create value. But to maintain its lead, it will need to focus on building a pipeline of talent. Previous MGI research has estimated that by 2018, the United States will face a shortage of up to 190,000 data scientists with advanced training in statistics and machine learning—and this specialty requires years of study. More broadly, an additional 1.5 million managers and analysts will need enough proficiency in statistics to ask the right questions and consume the results of the analysis of big data effectively. A significant amount of retraining may be necessary to develop the skills of those already in the workforce.[114] Many industries are engaged in a war for top analytical talent; this shortage is likely to be one of the central challenges to wider public-sector adoption, since government limits on compensation make it difficult to lure highly sought-after candidates away from the private sector.

Integrating big data into an organization's daily operations requires new operating models and a new mindset

The unique value proposition of big data may require companies to redraw organizational charts so that analytics are not simply slotted into the IT department but are part of cross-functional execution teams. In the private sector and the quasi-public sector alike, many entities (including silos within organizations) will have to overcome old instincts to closely guard their data.

Big data will require not just talented data analysts and sophisticated IT systems but also a fundamental shift in thinking about data use and decision making. Where professionals once relied heavily on intuition, they will have to integrate

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114 *Big data: The next frontier for innovation*, *competition*, *and productivity*, McKinsey Global Institute, May 2011.

data-driven insights into the equation. It will be critically important that managers know how to interpret data and not confuse statistical correlations with physical reality. Experimentation and modeling are fundamental aspects of big data and analytics, and these tools require flexibility and creativity.

Experimentation may reduce risk and help clarify benefits before implementing this technology at scale. To maximize the value, organizations should let the business case guide the analytics and minimize cost by targeting analyses that will inform tangible business results.

In 2012, the Obama administration announced the Big Data Research and Development Initiative, spanning projects across the National Science Foundation; the NIH; the CDC; the Departments of Defense, Energy, and Homeland Security; and the US Geological Survey. The intent is to build the government's big data capabilities and train new analytical talent. The adoption of big data tools in the federal government may provide additional momentum in academia, the biomedical research community, and the private sector.

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It takes a concerted productivity push to sustain long-term growth in a mature economy, especially in the face of demographic headwinds. This is particularly true in the United States, where a large and inefficient health-care system and public sector represent a growing share of the economy. Enhancing the performance of these sectors will be critical if the United States is to improve the delivery of vital services and relieve some of the bureaucratic burdens and costs that can hinder industry. As big data technologies come of age, the next decade could spark a productivity revolution in the United States, much as the adoption of information and communications technologies did 15 years ago. But this hinges on creating the right incentives, establishing a clear legal framework around data and privacy, and training highly specialized human capital. The United States has led the development of this technology and owns a disproportionate share of the world's data assets. Many US companies are already at the cutting edge of pushing forward new applications based on data-driven insights. Big data is a prime example of the US capacity for innovation—and this game changer holds the promise of delivering tools that help to meet the current productivity imperative.

Infrastructure: Building a foundation for long-term growth

More than 50 years ago, the United States undertook one of the most ambitious public works projects in history: the Interstate Highway System, which paved the way for a new era of commerce and mobility. After the New Deal and postwar building booms, the United States could lay claim to world-leading infrastructure.

In recent decades, however, US investment in infrastructure has lagged while investment in other countries has surged. Years of chronic underinvestment in specific areas such as transportation and water treatment are now catching up with the United States, as is resource misallocation in many past projects. The Great Recession and the ensuing years of lower economic activity eased some of the demand on the nation's strained infrastructure systems, but that merely bought time. With the recovery continuing, capacity and quality constraints are once again starting to bite. Maintenance, upgrades, and even expansion in some areas must be addressed.

The combination of high unemployment in the construction sector and the large multiplier effects associated with these projects makes a compelling case for taking action now. The current low borrowing rates present a unique window of opportunity—but that window will not stay open indefinitely. Our analysis, consistent with other estimates, shows that the United States will need to increase infrastructure spending by 1 percentage point of GDP in the coming years, with particular attention to transportation and water systems, to compensate for past underinvestment and provide the foundation for future growth. This equates to additional investment of $150 billion to $180 billion annually.

Such investment would have a significantly positive economic benefit in the next five years, boosting what has been a relatively tepid economic recovery. We estimate that this increase in infrastructure investment could add 1.4 to 1.7 percent (or $270 billion to $320 billion) to annual GDP between now and 2020. It would also create 1.5 million to 1.8 million jobs for the duration of the investment, easing unemployment in the construction sector.

In addition, the United States can place new emphasis on the productivity of infrastructure spending. In an era of funding constraints, the nation cannot afford to have major projects run over budget and behind schedule, as has too often been the case historically.[115] Nor can it afford to invest in projects with negative or low net benefits compared to alternative opportunities. In fact, many cost overruns are driven by inaccurate initial cost projections rather than expensive

115 See Bent Flyvbjerg, M. K. Skamris Holm, and S. L. Buhl, "How common and large are cost overruns in transport infrastructure projects?" *Transport Reviews*, volume 23, number 1, 2003, which shows nearly 25 percent cost escalation for transportation infrastructure projects in North America. Also see US Government Accountability Office testimony to Congress in *Federal-aid highways: Cost and oversight of major highway and bridge projects—issues and options*, May 8, 2003; and *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013.

execution. Poor planning can lead governments to undertake projects that should never have been built.

A relentless focus on making the most of every dollar spent could either reduce the investment required for necessary upgrades or deliver more infrastructure for the same money spent. Beyond the jobs created, this yields economic impact in myriad ways, such as relieving congestion, enhancing competitiveness, and reducing logistics and supply-chain costs. Over time, taking a more efficient approach to project selection, delivery, and operation would build the nation's infrastructure backbone, enabling growth in other sectors. We estimate this could increase annual GDP by $600 billion by 2030, through the combined effect of a higher and more productive national infrastructure stock.

The actions discussed in this chapter would bring the nation's infrastructure up to the level of peer countries such as Germany by 2030, erasing a competitive disadvantage and enhancing the overall attractiveness of the United States as a place to do business. It is also essential for capturing the other opportunities in this report, including domestic shale gas and oil production and increased trade in knowledge-intensive goods.

By delivering a combination of short-term job creation plus a long-term, sustained impact on economy-wide productivity, we believe that reinvesting in the nation's infrastructure could be a game changer.[116] Throughout the nation's history, visionary infrastructure projects have helped propel the next era of economic growth. These represent something much more profound than just short-term construction projects; strategic, forward-looking investments are the foundation for future growth and competitiveness.

THE UNITED STATES HAS UNDERINVESTED IN INFRASTRUCTURE CAPACITY AND MANAGEMENT

Many reports have sounded the alarm about the inadequate state of US infrastructure. Most notably, the American Society of Civil Engineers bestowed a grade of D+ on the nation's infrastructure. Public attention tends to focus on the issue only after a major incident, such as the Northeast blackout of 2003, the failure of the New Orleans levee system after Hurricane Katrina, or the recent collapse of an Interstate 5 bridge in the state of Washington.

But these high-profile failures are only symptoms of a deeper and more subtle problem: the gradual erosion of the nation's infrastructure quality. The cost of the maintenance backlog is steadily increasing, as are the costs to business. Infrastructure deterioration creates delay and congestion on US highways, clogs the nation's waterways, and results in frequent power outages—all of which reduce the attractiveness of business investment in the United States.

In 2012, the World Economic Forum (WEF) ranked US infrastructure behind that of other advanced economies such as Canada, Germany, France, Singapore, and South Korea. The performance of different assets varies in the WEF rankings. For example, while overall infrastructure in the United States ranks 14th in the world, the nation's ports came in at number 19 and its roads at number 20 (Exhibit 21). Closing this gap will require additional investment in capacity as well as clear improvements in how infrastructure assets are managed.

116 *A new economic analysis of infrastructure investment*, US Department of the Treasury and Council of Economic Advisers, March 2012.

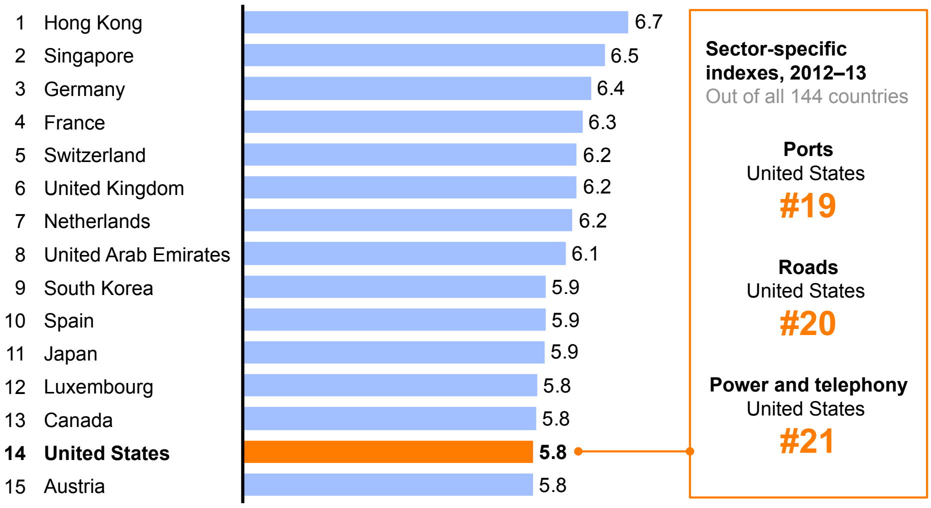
Exhibit 21

The World Economic Forum ranks US infrastructure behind that of most other comparable advanced nations

Overall infrastructure quality index, 2012–13

Top 15 of 144 countries

Scale: 1 = Extremely underdeveloped; 7 = Extensive and efficient by international standards



SOURCE: World Economic Forum; McKinsey Global Institute analysis

In addition, preparing to meet the challenge of climate change is heightening the urgency of infrastructure investment—and raising the level of investment that will be required. How much this will add to the nation's infrastructure needs is unknown. But in the aftermath of Hurricane Sandy, New York City recently unveiled a $20 billion infrastructure plan that includes building coastal defenses, protecting the power grid, and retrofitting large buildings. Half of the funding will come from previous federal and city allocations, and $5 billion will come from disaster aid. The city will have to raise financing for the balance.[117] Climate change mitigation is a global issue, however, and it will also create opportunities for US engineering and construction firms to become leading international players in this field.

The United States needs to increase annual infrastructure investment by 1 percent of GDP and focus on transportation

The United States has been underinvesting in infrastructure for the past two decades. Since the early 1990s, annual infrastructure investment has totaled roughly 2.6 percent of GDP, and the gap between investment and projected need is becoming a competitive disadvantage (Exhibit 22). We estimate that this level will have to increase to 3.6 percent of GDP annually in order to support current projections for US GDP growth and reverse the decline in the US infrastructure stock. This translates to $150 billion to $180 billion in additional investment each year.

But improving US infrastructure is not a simple matter of adding more capacity across the board. A closer examination reveals substantial differences in the quality of different types of US infrastructure assets. Close to three-quarters of the shortfall in infrastructure investment is in transportation; roads, highways, and bridges alone account for more than half of the total gap (Exhibit 23). In

117 *A stronger, more resilient New York*, The City of New York, June 2013.

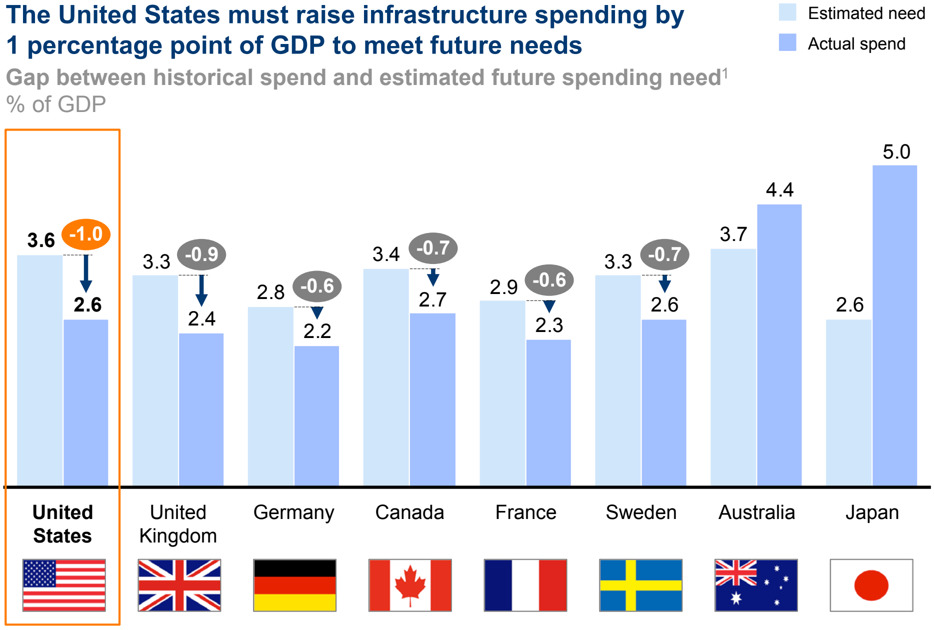
2008, federal, state, and local governments spent $182 billion on roads alone, with $91 billion of this representing capital investment. But the Federal Highway Administration notes that $170 billion in capital investment would be needed annually for 20 years to significantly improve conditions and performance.[118]

Exhibit 22

The United States must raise infrastructure spending by 1 percentage point of GDP to meet future needs

Gap between historical spend and estimated future spending need[1]

% of GDP



1 Actual spend calculated as weighted average annual expenditure over years of available data, 1992–2011. Estimated need based on projected growth, 2013–30.

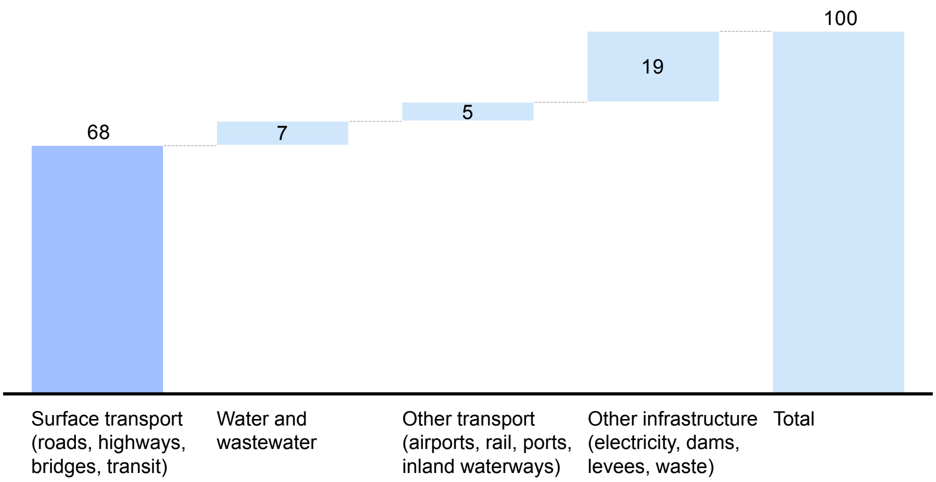
SOURCE: McKinsey Global Institute analysis

Exhibit 23

The shortfall in US infrastructure investment is felt most acutely in surface transportation systems

Estimated infrastructure investment shortfall for the United States

100% = $1.2 trillion by 2020[1]



1 Does not include additional infrastructure items in ASCE report such as schools, public parks, and recreation.

NOTE: Numbers may not sum due to rounding.

SOURCE: American Society of Civil Engineers; US Department of Transportation; McKinsey Global Institute analysis

118 *2010 status of the nation's highways, bridges, and transit: Conditions and performance, report to Congress*, US Department of Transportation (Federal Highway Administration and Federal Transit Administration), 2010.

The Federal Transit Administration reports that one-third of the nation's transit assets are in marginal or poor condition, meaning they are nearing or have exceeded their expected life span. The agency estimates that there is a $78 billion backlog to bring all public transit systems into a state of good repair; subsequently, $14 billion of replacement expenditures will be needed each year.[119] In the inland waterways system, a critical component of the US industrial transport system, the investment required simply to maintain current service levels is estimated to be $13 billion by 2020, nearly twice the expected funding.[120]

Underinvestment in transportation infrastructure erodes the competitiveness of many US industries. Manufacturers and retailers, for example, suffer from less reliable supply and distribution networks, and they hold more inventories as a result. This raises their cost of doing business. Mining and materials industries face increased shipping costs and delays and find it less profitable to supply new markets for exports. Congestion on US roads and highways was also estimated to cost commuters more than $120 billion in wasted gasoline and lost time in 2011.[121]

Of the remaining funding gap for other infrastructure, which accounts for 19 percent of the total shortfall, almost half (9 percent) is for power generation, transmission, and distribution. By 2020, the American Society of Civil Engineers projects an investment gap of $107 billion, mostly in transmission and distribution. While the electric power system is generally reliable in most states and meets its reserve margin targets, aging transmission and distribution infrastructure will need to be modernized. The decline in the price of natural gas is causing a shift to gas power generation, however, and this could create an opening to invest in a modern power grid without causing large rate increases for consumers and commercial users.

Freight rail networks, airports (with some notable exceptions), and telecom infrastructure, in contrast, are generally in good condition across the United States. The deregulation of railroads has allowed for increased return on investment, improved efficiency, and the entrance of more private capital. American freight rail carriers doubled their capital investment in the past two decades; they have also increased the overall productivity of rail transport, in part by shedding underutilized lines and rationalizing networks. Freight rail is twice as expensive in Germany, France, and Japan as it is in the United States, according to the American Association of Railroads. Some US airports do have poor reputations, largely due to small and aging terminals or the frequency of delays.[122] But most fare well in terms of runway capacity, particularly for freight handling. They also offer markedly lower landing charges than those in Europe and Asia. In telecommunications, fixed-line coverage is expensive due to the nation's geographical scale and low population density, but the United States has made great recent strides in establishing itself as a world leader in wireless broadband

119 *2010 national state of good repair assessment*, Federal Transit Administration, June 2010.

120 *Failure to act: The economic impact of current investment trends in electricity infrastructure* and *Failure to act: The economic impact of current investment trends in airports*, *inland waterways*, *and marine ports*, American Society of Civil Engineers, 2012.

121 *Urban mobility report 2012*, Texas A&M Transportation Institute, December 2012.

122 US Department of Transportation statistics list Newark, San Francisco, Chicago Midway, Chicago O'Hare, and Houston as the five worst-performing major airports for on-time departures in 2012.

and 4G/LTE deployment.[123] The United States has the second-lowest entry-level pricing for broadband in the OECD (behind only Israel), and more than 80 percent of US households have access to broadband speeds exceeding 100 megabits per second.[124]

Even in these areas of relative strength, however, there is room for further investment. In passenger rail, Amtrak's Northeast Corridor service is straining to meet demand, and California's plan to link Los Angeles and San Francisco by high-speed rail will take years to realize. The goal in both of these areas is to create alternative transportation that relieves road and airport congestion, increasing mobility. In telecom, some 19 million Americans do not have access to fixed broadband networks at home, and some 32 percent of households have yet to adopt broadband.[125] The Federal Communications Commission has launched a National Broadband Plan to expand infrastructure and promote adoption in homes, schools, and libraries. Expanding broadband will create opportunities for increased economic activity, and connecting all schools will enable the deployment of new digital learning tools in the nation's classrooms, as we discuss in the next chapter of this report.

Addressing operational inefficiencies is as important as expanding capacity

Not all US infrastructure underperformance can be attributed to underinvestment in capacity. Some is due to productivity and operational issues. US ports are a clear example. Ports receive investment from port authorities, private investors, and the federal government; nearly $50 billion in capital investment is planned for port infrastructure through 2016.[126] Yet despite this investment, US ports suffer from productivity and operational issues caused in part by complex organizational and management models that limit the benefits of automation and reduce overall performance accountability. As a result, US ports lag leading international ports on productivity.[127]

Another cause of operational inefficiencies is inadequate investment in maintenance, refurbishment, and renewal of existing assets, which increases future repair costs. The US inland waterway system, made up of 12,000 miles of commercially navigable channels, has seen rising delays despite relatively stable traffic volumes, in part due to inadequate maintenance of aging locks. The US Army Corps of Engineers estimates that hours lost to both scheduled and unscheduled delays in the waterways have increased threefold, from 50,000 hours of delays in 1993 to more than 160,000 hours in 2011.[128]

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123 Richard Bennett, Luke A. Stewart, and Robert D. Atkinson, *The whole picture: Where America's broadband networks really stand*, Information Technology and Innovation Foundation, February 2013.

124 *Eighth Broadband Progress Report*, Federal Communications Commission, August 2012.

125 *Exploring the digital nation: Computer and Internet use at home*, Economics and Statistics Administration and the National Telecommunications and Information Administration, November 2011.

126 *Failure to act: The economic impact of current investment trends in airports*, *inland waterways*, *and marine ports*, American Society of Civil Engineers, 2012.

127 "Introducing JOC port productivity," *Journal of Commerce*, February 2013.

128 *Inland waterways and export opportunities*, US Army Corps of Engineers Institute for Water Resources, May 2012.

The 2008 recession temporarily reduced strains on infrastructure capacity—but demand is on the rise again

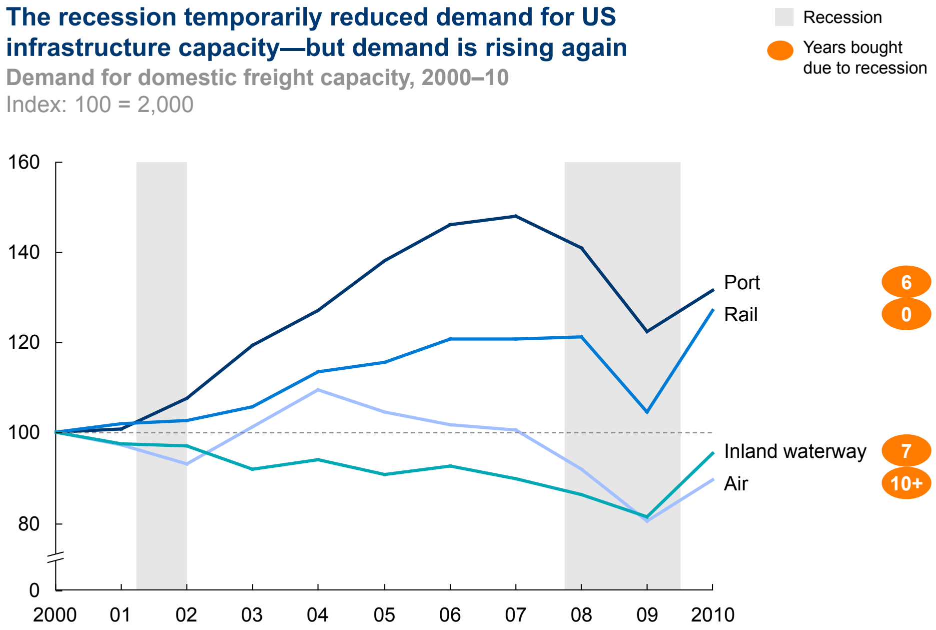
During the Great Recession and its immediate aftermath, lower economic activity in the United States relieved some of the pressure on the nation's freight infrastructure and provided a respite from rising freight costs at ports, airports, and waterways. But freight loads are once again trending up toward pre-crisis levels (Exhibit 24).

Exhibit 24

The recession temporarily reduced demand for US infrastructure capacity—but demand is rising again

Demand for domestic freight capacity, 2000–10

Index: 100 = 2,000



SOURCE: US Department of Transportation; American Society of Civil Engineers; Federal Highway Administration; NBER; McKinsey Global Institute analysis

There is a strong case to be made that now is the time to invest in infrastructure projects, particularly in the crucial area of transportation. First, there is an array of projects that would generate high returns on investment that are currently not being funded. Second, there is an opportunity to lock in financing at historically low borrowing costs. Third, unemployment in the construction sector is improving but remains stubbornly high (as of May 2013, it stood at 10.8 percent, above the overall national unemployment rate of 7.6 percent). While infrastructure projects involve more than construction jobs (they also include architecture, design, engineering, project management, and other high-skilled roles), projects would benefit from an ample supply of labor and would create jobs in a hard-hit sector. And last but not least, the high multiplier effect associated with infrastructure spending would have beneficial ripple effects at a time when the US economy is operating below full potential and the recovery needs to build momentum. (See Box 8, "Estimates of the infrastructure spending multiplier," later in this chapter.)

THE UNITED STATES MUST ALSO RAISE THE PRODUCTIVITY OF INFRASTRUCTURE INVESTMENT

To effectively deploy additional investment in infrastructure, the United States will have to improve its performance on project selection, timely delivery and execution, and maintenance and renewal. This could raise the overall productivity of US infrastructure by as much as 40 percent and generate more economic impact for every dollar spent. And there is added pressure to raise infrastructure productivity today: as commodity prices rise, input costs are going up as well. In extreme circumstances, this can even lead to spot shortages of asphalt and other critical materials, making productive use of such assets even more important.

Making the most of infrastructure investment starts with selecting the right portfolio of projects

One of the most effective ways to make infrastructure investment more productive is to choose the right mix of projects from the outset. Too often, the primary approval criteria for project selection in the United States are political support and visibility rather than comprehensive cost-benefit analysis.[129] Even when economic analysis is used, it is not always rigorous, or it may be disregarded in actual decision making. When state and local governments choose suboptimal projects, the cost of financing rises, so focusing on those projects with the clearest returns is a crucial part of taking a more cost-effective approach for the nation as a whole.

In addition, planners at all levels of US government tend to have a bias toward addressing congestion and bottlenecks by building new capacity. But rather than immediately jumping to build new infrastructure projects to solve problems, planners and project sponsors might first consider refurbishing existing assets or using technology to get more out of them. (See "Better maintenance, optimization, and demand management can extend the life of existing infrastructure assets" later in this chapter.)

A more effective planning process takes a systematic portfolio approach—one that considers how each project fits into broader policy priorities and what the network effects will be. It then uses a rigorous economic analysis to prioritize and select projects. Taking a broader perspective can have major impact. Chile, for example, has created an Infrastructure Master Plan. Its National Public Investment System evaluates proposed projects using standard forms, procedures, and metrics, including cost-benefit analyses that consider factors such as opportunity cost and the cost of travel time. Final approval rests with Chile's Finance Ministry, which allocates funding based on a combination of these cost-benefit analyses and national goals. South Korea's infrastructure planning process was once plagued by routine cost underestimation and benefit overestimation, but the creation of a single national entity, the Public and Private Infrastructure Investment Management Center (PIMAC), in 2005, has improved performance. PIMAC assesses projects using a detailed "preliminary feasibility study" methodology, assembling a multidisciplinary team from three or more organizations to examine the project from all angles and ensure transparency. It now rejects 46 percent of reviewed projects where once only 3 percent of reviewed projects were rejected.[130]

In the United States, fragmented local or regional control over investment decisions lowers national effectiveness. While creating a single national infrastructure agency may not be feasible, a greater level of coordination is

129 In 2010, for example, the Government Accountability Office reported that state transportation departments often assign greater importance to political and public support than the cost-benefit analysis when selecting projects. See *Statewide transportation planning: Opportunities exist to transition to performance-based planning and federal oversight*, GAO, December 2010.

130 *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013.

possible, and the type of rigorous cost-benefit analysis illustrated in these examples could also be replicated at the regional or state level.

Major savings are possible in the delivery and execution stages

Delays and cost overruns are a familiar refrain in infrastructure projects. Boston's Big Dig, for example, remains the costliest highway project in US history and was plagued by years of delay and shoddy construction. Originally estimated at $2.6 billion, it now has a final price tag estimated by the Massachusetts Department of Transportation at $24.3 billion, including interest on borrowing. More recently, the San Francisco–Oakland Bay Bridge is being completed almost a decade late, and its original budget of $1.3 billion has grown to more than $6 billion.

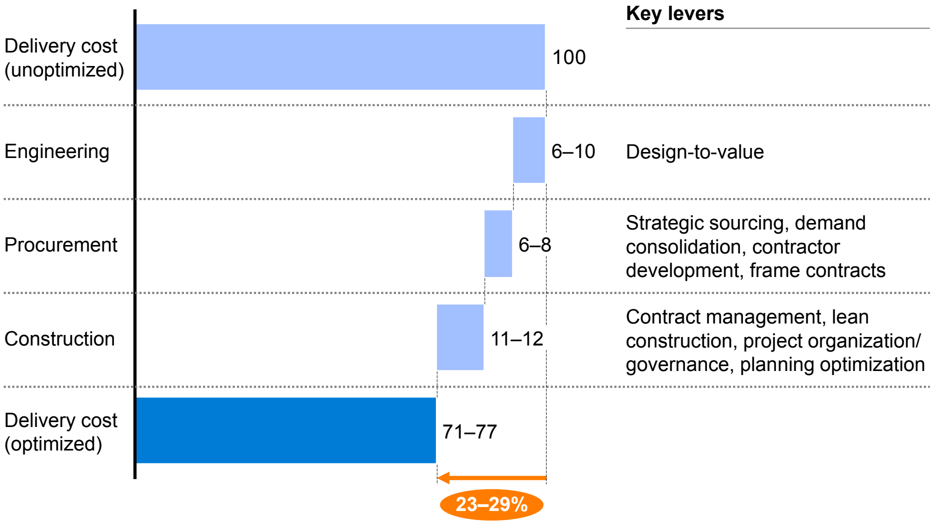
With multiple infrastructure needs competing for scarce public funding, governments cannot afford to risk such spiraling costs. A new approach that incorporates greater accountability and tighter management of the delivery and execution stages can protect the public interest and produce large efficiencies. Based on nearly 40 capital productivity studies from 1994 to 2012, previous McKinsey Global Institute research has found that it is possible to reduce typical delivery costs in infrastructure projects by up to 29 percent (Exhibit 25).[131]

Exhibit 25

Productivity improvements can reduce the cost of infrastructure projects by up to 29 percent

Sample project cost, indexed[1]

%



1 Based on nearly 40 capital productivity studies, 1994–2012.
NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

This can start even before ground is broken on a project by speeding the approval processes, which can drag on for years in the United States. Other countries have taken successful steps to accelerate project reviews: Australia, for example, has developed mechanisms to expedite decisions for complex projects without compromising environmental protection standards. In 2010, an application for building a cruise passenger terminal in New South Wales was approved in just nine months, while the state of Victoria approved a large desalination plant in 2009, after only 18 months of consideration.

131 Ibid.

International best practices for streamlining the permitting stage include smart prioritization of projects and public accountability for agency delays. Multigovernment and multiagency reviews can be coordinated in a much more harmonized "one-stop-shop" approval process, and "tiebreaker" entities with credibility across a broad range of disciplines could be empowered to make decisions. Public input and environmental reviews are crucial elements, but they should be framed within reasonable, definite time limits. The current process is particularly costly, complicated, time consuming, and unwelcoming for international investors.

Investing time and resources in the early project planning and design stages can yield major savings. Considering multiple design simulations and materials choices can minimize costly change orders that cause delays during construction; new big data tools can help with this process. Design-to-value and design-to-cost approaches in the engineering process can lower costs. A more strategic approach to sourcing, perhaps including demand consolidation that takes advantage of economies of scale, can hold down costs in the procurement process. Agreements with contractors can be tightened, and accountability for delays and quality issues can be enforced.

Today, new innovations are beginning to revolutionize some types of infrastructure construction and produce large efficiency gains. Consider bridge building, for example. Large sections of a bridge can now be prefabricated and shipped to the actual site for quick installation, reducing construction time significantly and preventing extended traffic disruptions. The Federal Highway Administration reports that states across the country are beginning to adopt these accelerated bridge construction (ABC) techniques. In some cases, overpass bridges have been installed over a single weekend. Utah was an early adopter of these techniques, and Massachusetts now has a statewide ABC program.

Better maintenance, optimization, and demand management can extend the life of existing infrastructure assets

Another major strategy for increasing infrastructure productivity involves maximizing the life span and capacity of existing assets. In many cases, directing more resources to these areas may be a more cost-effective choice for policy makers than new build-outs.

First, there is a need to focus more attention on maintenance, refurbishment, and renewal. This is an increasingly urgent issue for the nation's aging water infrastructure, much of which was built in the years immediately after World War II; some of the nation's oldest pipe systems are now more than a century old. Even more recent water treatment plants will need refurbishment: many built in the 1970s after passage of the Clean Water Act will soon require rehabilitation or replacement. Proactive maintenance to upgrade and extend the life of these aging systems is becoming a more urgent priority. As this report neared publication, the Senate had just passed the Water Resources Development Act of 2013 and sent the bill to the House of Representatives. In addition to providing funding for maintenance and upgrades to the nation's inland waterway system (described earlier in this chapter), the legislation includes a financing program to provide local governments with loans and loan guarantees for projects such as pipe replacement or rehabilitation and new or upgraded treatment plants.

Second, new technologies can optimize the performance of existing assets so they can better handle demand. Intelligent transportation systems (ITS), for example, use data gathered via sensors and GPS tracking to synthesize real-time information for this purpose. The Information Technology and Innovation Foundation reviewed several impact assessment studies for various ITS pilot projects and identified benefit-to-cost ratios ranging anywhere from 6.3-to-1 to 38-to-1, far above the benefit-cost ratio of adding conventional highway capacity, which was 2.7-to-1.[132] (See Box 7, "The rise of intelligent transportation infrastructure.") Further, the radar systems that were used for US air traffic control for decades are being replaced with upgraded, next-generation systems that use GPS data. This will allow airports to tighten the spacing of takeoffs and landings, maximizing the use of existing runways and reducing delays. Airlines will also benefit through shortened flight times and reduced fuel costs. And the applications are not limited to transportation infrastructure; sensors and smart meters can also play an important role in optimizing the timely maintenance, efficiency, and reliability of water and power networks.[133]

Third, demand management can avoid costly investments in new capacity. In transportation infrastructure, it can be used to regulate the amount of wear and tear on roads and bridges. Tolls can be imposed on roads and bridges not only to raise revenue but also to discourage driving and encourage a shift toward carpooling or the use of public transportation.

Congestion pricing, which was pioneered by Singapore in 1975, is one form of demand management, and it has the important benefit of introducing usage-related funding streams for infrastructure. Singapore's scheme initially required drivers to purchase physical permits for driving into the central business district during the morning rush hour; enforcement officials monitored each car to check that the required sticker was properly displayed. The system was later digitized using transponder technology and automated payment systems. It has produced a significant decrease in daily traffic and a shift toward greater use of public transportation. Other cities around the world—including London and Stockholm—have followed suit. Toll roads and bridges are common across the United States, and new models of dynamic congestion pricing are being introduced (see Box 9, "The Capital Beltway public-private partnership," later in this chapter). But congestion pricing for entry into dense urban cores has yet to be attempted. A proposal to implement this strategy in New York City attracted national notice but was not taken up by the State Assembly.

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132 Stephen Ezell, *Intelligent transportation systems*, Information Technology and Innovation Foundation, January 2010.

133 "Intelligent water management," *American Water Intelligence*, volume 3, number 7, July 2012.

Box 7. The rise of intelligent transportation infrastructure

The United States is one of the world's leaders in broadband and 4G/LTE wireless Internet coverage, and this widespread connectivity could enable the deployment of intelligent transportation systems (ITS), particularly in and around congested urban areas. These technologies monitor traffic and asset performance data in real time and enable communication between the various elements of the transportation network (including vehicles, roads, traffic lights, and message boards). This can be used to achieve better demand management, reduced congestion, improved road safety, and more effective planning of investment in new capacity. ITS can be considered in five categories.

- **Real-time traveler information systems** can deliver live information to drivers, such as directions, weather updates, and alternative routes to avoid congestion, accidents, or repair work. These systems can also broadcast the location of parking spaces in urban settings and potentially allow users to reserve a spot in advance.
- **Transportation network management systems** enable remote monitoring and traffic redirection from computerized central operations centers through light signals, highway on-ramp meters, automated gates, and electronic message signs. These systems can improve the flow of vehicles by synchronizing the operation of intersection signals with the presence of waiting cars or spacing out vehicles entering highways.
- **Transportation pricing and demand-management systems** enable automated congestion pricing systems, electronic toll collection, fee-based express or high-occupancy lanes, and pricing systems based on road usage. The US E-ZPass system is an example of electronic toll collection, although it is not as sophisticated as systems in other countries.
- **Real-time public transportation systems** report the position of trains and buses to provide information about route and schedule adjustments at stops and stations as well as within vehicles. This continuous and comprehensive overview of status and location also enables operations managers to dispatch support in case of breakdowns or unexpected demand.
- **Fully integrated intelligent transportation systems** can enable communication between different assets on the network. For instance, such systems can link communication from vehicles to roadside sensors, traffic lights, and other vehicles to enable intersection collision avoidance and intelligent speed adaptation systems. This could help drivers in navigating unprotected left turns by providing information about gaps in oncoming traffic and dangers related to other users such as pedestrians or cyclists.

In 2010, the Federal Highway Administration announced plans to make real-time traffic information available to drivers in all US states and the nation's 50 largest metropolitan areas by late 2016, and the US Department of Transportation has established an ITS office to lead research in this area. The US Government Accountability Office evaluated the program, estimating that its cost of $1.2 billion would generate $30.2 billion in mobility, environmental, and safety savings over eight years. The savings identified included about 321 million hours annually in avoided incident delays, an 11 percent annual reduction of fuel use, and a 10 to 16 percent reduction of annual emissions.[1]

1 Both of these figures are in net present value. *Surface transportation: Efforts to address highway congestion through real-time traffic information systems are expanding but face implementation challenges*, US Government Accountability Office, GAO-10-121R, November 2009.

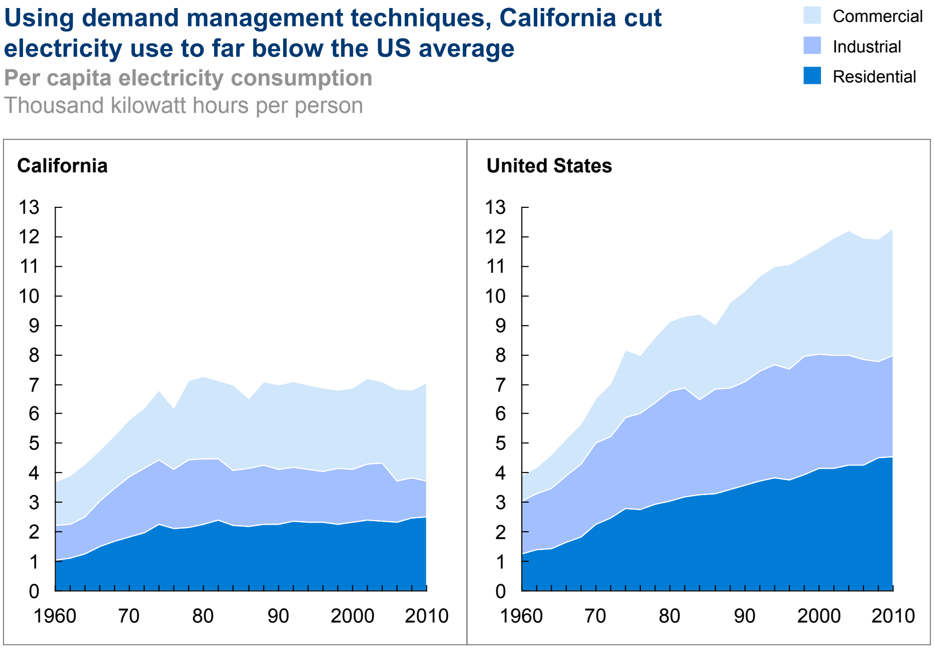
Demand management has been used successfully in other infrastructure assets, such as energy. For example, in the 1970s California introduced pricing mechanisms and efficiency standards for buildings and electrical appliances to reduce energy use, and it has periodically updated regulations to keep pace with new technologies. The results have been striking, as California has been able to sustain the same level of electricity consumption over four decades even as the state's economy has grown more than tenfold since 1975, reducing the need for additional power plants (Exhibit 26).

Exhibit 26

Using demand management techniques, California cut electricity use to far below the US average

Per capita electricity consumption

Thousand kilowatt hours per person



SOURCE: Kandel, Sheridan, and McAuliffe, *A comparison of per capita electricity consumption in the United States and California*, California Energy Commission paper, 2008; McKinsey Global Institute analysis

INFRASTRUCTURE INVESTMENT COULD ADD $320 BILLION TO ANNUAL GDP AND CREATE 1.8 MILLION JOBS BY 2020

Closing the US infrastructure investment gap and raising infrastructure productivity will have short-term impacts on GDP over the next five to seven years by providing new demand when the economy is operating at less than full potential. It will have important longer-term impacts as well by increasing the capital stock in the US economy and raising infrastructure productivity. We discuss each of these effects separately.

Additional infrastructure investment could raise GDP by up to $320 billion annually between 2014 and 2020

To address growing deficiencies, the United States would need to increase infrastructure investment by 1 percentage point of GDP. Because the US economy is operating at less than full potential, this will provide short-term stimulus and add to aggregate demand, thereby raising GDP. Based on projections for US GDP growth between now and 2020, this amounts to spending an additional $150 billion to $180 billion per year by 2020.[134] We estimate that the associated multiplier effect would raise GDP by $270 billion to $320 billion

134 According to the US Congressional Budget Office's baseline projection for real GDP growth, US GDP in 2020 (real terms) is roughly $18 trillion.

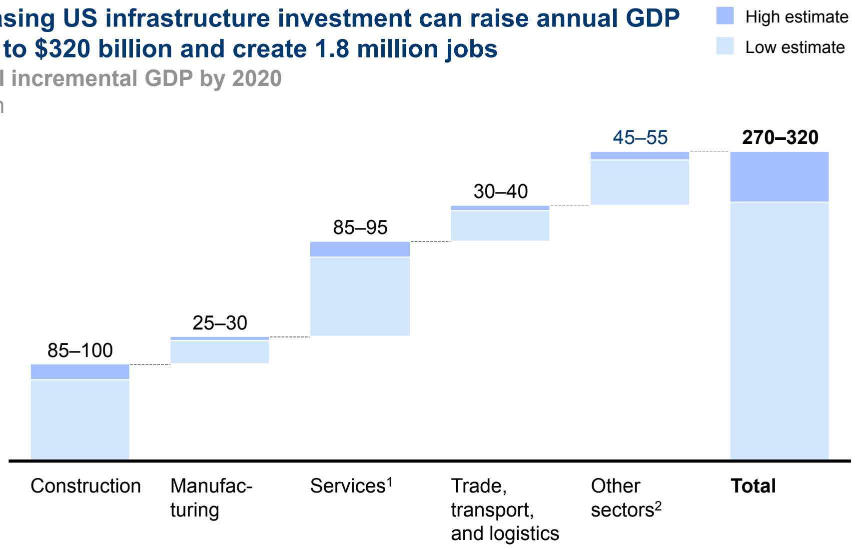
annually through 2020 (Exhibit 27). Box 8 discusses different estimates for the multiplier effect of infrastructure spending.

Exhibit 27

Increasing US infrastructure investment can raise annual GDP by up to $320 billion and create 1.8 million jobs

Annual incremental GDP by 2020

$ billion



	Construction	Manufacturing	Services	Trade, transport, and logistics	Other sectors	Total
Jobs impact	1.1 million–1.3 million	100,000–120,000	160,000–190,000	100,000–120,000	25,000–30,000	**1.5 million–1.8 million**

1 Includes financial, legal, and professional services; management, health care, and education; and leisure and hospitality.
2 Includes real estate; agriculture and forestry; mining; and government.
SOURCE: US Bureau of Economic Analysis; American Society of Civil Engineers; McKinsey Global Institute analysis

During this period, this level of increased infrastructure investment could raise employment by 1.5 million to 1.8 million new jobs (1.1 million to 1.3 million directly in the construction sector and around 500,000 indirectly in other sectors such as manufacturing and professional services). The direct jobs are generally referred to as construction jobs, but they require greater skills than residential construction work and also pay higher wages. Of the 5.8 million jobs in the construction sector as of April 2013, only 15 percent are heavy and civil engineering jobs related to infrastructure. The rest are divided between residential/commercial buildings (22 percent) and specialty trade contractors (63 percent, most of which is electrical, plumbing, and HVAC work related to buildings).[135]

135 An analysis of 30-year trends in residential/commercial building investment and specialty trade contractor employment shows a close relationship, with a correlation coefficient of 0.9; HVAC here refers to heating, ventilation, and air conditioning.

Box 8. Estimates of the infrastructure spending multiplier

The idea of increasing investment in infrastructure to stimulate economic activity has been discussed extensively in recent years. But the ultimate stimulus effect depends on the size of the multiplier, and results vary in the studies that have assessed the impact of additional infrastructure spending on GDP.

In a May 2013 draft paper, DeLong and Tyson review the recent academic literature on multipliers and find that they are significantly larger during downturns than when the economy runs at capacity. They also observe more generally that multipliers appear to be larger than previously thought.[1]

A recent analysis of fiscal stimulus multipliers by Moody's Analytics found that every dollar of infrastructure spending produced a $1.44 increase in GDP, higher than general aid to states ($1.34), lump-sum tax rebates ($1.22), and making income tax cuts permanent ($0.35).[2] For their part, Leduc and Wilson (2012) estimate that "each dollar of federal highway grants received by a state raises that state's annual economic output by at least two dollars," implying a multiplier for road infrastructure of at least 2.[3]

In February 2013, the Congressional Budget Office released its impact assessment of the American Recovery and Reinvestment Act for 2012. In that report, the CBO estimates the multiplier effect for transfer payments to state and local governments for infrastructure to range from 0.4 to 2.2. The multiplier for infrastructure is second only to direct purchases by the federal government.

To be consistent with the approach used throughout this report, we rely on data from the US Bureau of Economic Analysis (BEA). It shows that the GDP effect is higher in infrastructure-related sectors such as construction, logistics, and some manufacturing than in most other sectors. For example, every $1 in higher output from the construction sector produces $1.77 in GDP; in storage and warehousing, $1.99; in transportation, $1.69; and in the manufacturing of fabricated metals, cement, and ceramics, as well as wood, rubber, and plastics products, $1.45 to $1.68. Our analysis in this chapter uses the BEA multiplier of 1.77 for the construction sector.

1 J. Bradford DeLong and Laura D. Tyson, *Discretionary fiscal policy as a stabilization policy tool: What do we think now that we did not think in 2007?* University of California, Berkeley, draft 1.3, May 2013.

2 See *Global policy prescriptions: How another recession can be avoided*, Moody's Analytics special report, August 26, 2011; analysis on fiscal policy multipliers updated to first quarter of 2012.

3 Sylvain Leduc and Daniel Wilson, "Highway grants: Roads to prosperity?" *Federal Reserve Bank of San Francisco Economic Letters*, volume 35, November 26, 2012.

Beyond 2020, infrastructure investment can further raise US GDP through its effect on productivity and capital deepening

The short-run impact of infrastructure investment on GDP would fade when the economy returns to its full potential. At that point, additional infrastructure investment simply reallocates resources from other sectors, and the GDP impact will depend on what those sectors might be. Given the difficulty in projecting this, we do not assume any additional annual increase in GDP from this primary effect after the economy returns to full capacity. For the sake of simplicity, we assume this is sometime around 2020.

However, after 2020, infrastructure investment may raise GDP growth through a different channel: by increasing overall productivity. Well-targeted investments in physical infrastructure increase the economy's capital stock as well as improving the efficiency of other factors of production. Investing an additional 1 percentage point of GDP each year will also yield competitive benefits, gradually raising the US infrastructure stock to the peer-country average: from 64 percent of GDP today to 70 percent by 2030.

Beyond these gains, it is possible to create even greater GDP impact by maximizing the capital productivity of infrastructure investment through the strategies outlined above: improved project selection, enhanced design and delivery models, and optimization of existing infrastructure. The impact of these productivity mechanisms is similar to the effect of increasing capital investment by 60 percent. If this is achieved, the total impact of capital deepening and greater productivity would increase to $600 billion in additional annual GDP by 2030.

NEW FINANCING MODELS CAN INCREASE INFRASTRUCTURE INVESTMENT

Given concerns about the fiscal debt and deficit, the cost of increasing infrastructure investment and the question of how to pay for it are increasingly important. Federal, state, and local governments have typically been the primary investors in roads, transit systems, water systems, and airports, but the traditional funding sources are showing strains. For example, the US Highway Trust Fund relies on an 18.4-cent-per-gallon federal gas tax that has not been raised since 1993 and is not indexed to inflation. In an age of fiscal consolidation, when there is considerable opposition to tax increases to fund new build-outs, governments will need to rely on creative new funding sources to capture the infrastructure opportunity.

Innovative public financing models: Moving beyond budget allocations

In the past, infrastructure investment by all levels of government was almost exclusively executed through straightforward budget allocations (relying on general tax revenue) or bond issuance backed by project revenue. Bonds offer the advantage of low borrowing costs (state and local borrowing is subsidized through a federal tax exemption on interest received), but they leave the government in question saddled with most or all of the risk and rarely have a mechanism linking financing to performance.

In road transportation, the dominant model is the "design-bid-build" approach, in which a public manager contracts with an outside firm to design the project, then invites bids from competing construction firms to build the project. Recently state governments have begun to try "design-build" projects, hiring one firm for both design and delivery; this can accelerate timetables and save transaction costs. Examples include the Mineta San Jose International Airport in California, the Intercounty Connector highway in Maryland, and the Interstate 35W bridge in Minnesota that was rebuilt after its collapse in August 2007.[136]

New funding models are also possible, including variations on traditional municipal bond offerings. Private activity bonds, for example, are issued by state and local governments for projects such as inland ports, highway toll lanes, and airports that benefit private-sector companies but are in the public interest; these may qualify for tax-exempt status, lowering borrowing costs. Build America Bonds were created by the American Recovery and Reinvestment Act; they allowed state and local governments to sell taxable bonds and receive reimbursement from the federal government for a portion of the interest costs. This program supported the municipal bond market in the aftermath of the financial crisis, but it expired at the end of 2010. The Obama administration recently proposed a similar option, called America Fast Forward Bonds. If approved by Congress, these could be sold to public pension funds and foreign investors that do not receive a tax benefit from traditional tax-exempt bonds.

Established in 1998, the Transportation Infrastructure Finance and Innovation Act (TIFIA) is administered by the US Department of Transportation. It offers direct loans, loan guarantees, and lines of credit to regionally or nationally significant transportation projects such as highways, transit systems, railroads, and ports. These may benefit private developers as well as state and local governments and other public entities. Each dollar of federal funding can provide up to $10 in credit assistance, leveraging additional private capital.

State revolving funds date back to the 1987 Clean Water Act. Each of the 50 states now has a Drinking Water State Revolving Fund and a Clean Water State Revolving Fund; both programs are administered by the Environmental Protection Agency. Federal seed funding is supplemented with local matching funds and, in some cases, capital market investment. The funds make low-interest loans to municipalities and organizations, which repay the loans from project revenue or local taxes, recapitalizing the fund. The concept is similarly applied to transportation, through state-level transportation revolving funds.

Infrastructure projects—especially transit projects—can substantially increase private property values in the surrounding area, and "value capture" aims to capture these increases to repay public investment. This can be accomplished through joint property development, the sale of air rights, special tax assessments, tax increment financing, and other mechanisms. Hong Kong is known for utilizing the joint property development approach; it has generated revenue by developing shopping malls near its rail stations.[137] In the United States, a 2010 GAO study of 55 transit agencies found that 32 had used joint development strategies and 19 had used other value capture mechanisms.[138] Tax increment financing designates a special district, measures the tax base at the predevelopment level, and then directs any future incremental gains in taxes derived from increased property values to retire bonds, repay developers,

136 Design-Build Institute of America, Fact sheet on design-build in transportation.

137 *Infrastructure finance reform*, Infrastructure Australia, issues paper, July 2011.

138 *Federal role in value capture strategies for transit in limited, but additional guidance could help clarify policies*, US Government Accountability Office, July 2010.

or fund ongoing infrastructure needs. Chicago has created 162 tax increment financing districts to pay for transit improvements.[139] Similar approaches have helped to finance projects such as the new Atlanta BeltLine network and Denver's refurbished Union Station, which will serve as the hub for a major mass transit expansion.[140]

Public-private partnerships

Governments that own and operate infrastructure directly are increasingly considering options for engaging private investors to bridge the funding gap. Public-private partnerships, or PPPs, are commonly used around the world and are now increasingly being considered as a solution in the United States. They are not without their pitfalls, however, and governments and private investors alike must approach these deals with appropriate caution. PPPs have been difficult to implement in US transportation infrastructure for a variety of reasons, including a lack of transaction sophistication in some public agencies on the tendering/procurement side, a political unwillingness to create sufficient revenue streams (such as tolls) to support an appropriate return on the capital for private investment, unrealistic risk and return expectations in the private sector, and tax subsidies for traditional financing approaches that decrease the popularity of alternatives.

But in an era of fiscal constraints, governments may indeed look to bring in private expertise and capital to build infrastructure. To attract private capital, governments can take steps to reduce the risk for investors that are willing to make long-term investments. Private operators will be more inclined to enter the market if they have confidence that they will be compensated for other government actions that might destroy the value of their investments (such as building adjacent competing facilities) and that the government will not adversely change the rules on how revenue is generated or expropriate the project. To make deals more attractive, governments can offer private investors long-term operating arrangements, an arrangement that allows them to raise money in the capital markets and earn a return.

Private investors need to see a path to earning an appropriate return before they will commit their own capital and bear a project's risk. This introduces incentives to manage costs by increasing efficiency in the design, construction, and operating stages. Besides supplying capital, PPPs may impose more discipline on project selection and delivery, lower completion and operating costs, and increase accountability.

PPPs have been used in transportation projects across Canada, Europe, South America, and Asia. The United States has been slower to adopt this model, but a notable recent example is the Capital Beltway outside Washington, DC (see Box 9, "The Capital Beltway public-private partnership"). Other recent PPP projects include light rail expansion in Denver, a courthouse in Long Beach, and multiple toll roads in Texas. While the terms and conditions of each of these transactions is different, the general idea of shifting risk exposure to the private sector for project development and operations is gaining popularity across the United States.

139 *Findings and recommendations for reforming the use of tax increment financing in Chicago: Creating greater efficiency, transparency and accountability*, TIF Reform Panel report, August 2011.

140 Chicago Metropolitan Planning Commission, value capture case studies, 2012.

A high-profile contrast of PPPs and traditional government financing can be seen in the ongoing Ohio River Bridges project, which aims to open two new bridges by 2016: a Downtown bridge to Louisville, built by Kentucky using traditional government procurement, and an East End bridge, built by Indiana using an integrated PPP procurement contract that covers design, construction, and financing. The private contractor on the Indiana project was able to offer a 23 percent cost reduction relative to the previous estimates, and proposed to accelerate the timeline for delivery by eight months. It is too early to directly compare the cost and efficiency of the two approaches, but this project will provide an interesting case study and will be an important indicator of the effectiveness of PPPs in the United States.

Box 9. The Capital Beltway public-private partnership

One of the most heavily traveled roads in the country, the Interstate 495 Beltway around Washington, DC, has long been synonymous with gridlock. To alleviate this congestion, Virginia officials opted to expand the road's capacity by adding high-occupancy/toll (HOT) lanes alongside the existing lanes for a 14-mile stretch on the Virginia side of the Beltway. The resulting project has been closely watched around the country not only for its financing model but also for its implementation of dynamic congestion pricing.

The HOT lanes project was completed through a public-private partnership that enlisted two private-sector infrastructure firms: Fluor Enterprises and Transurban. Fluor designed and built the lanes, while Transurban will operate them and provide routine maintenance. The Virginia Department of Transportation will retain ownership. The lanes (two northbound and two southbound) opened in November 2012 along with additional carpool ramps and access points. The project also included more than $260 million of upgrades to aging bridges, overpasses, and soundwalls.

The $2 billion express lanes project combined state funding, private equity capital, tax-exempt private activity bonds, and a federal TIFIA loan. The private-sector participants provided approximately 75 percent of the capital and will receive the toll revenue for the next seven decades. It remains to be seen whether the completed project can achieve its goals of simultaneously providing congestion relief and turning a profit for the private-sector participants.

The HOT lanes put the principle of congestion pricing into action. They can be accessed for free by buses and vehicles with three or more occupants, thus encouraging the use of public transit and carpools. Single- and double-occupancy vehicles can also access the lanes to cut down on their travel time if the driver pays a toll. Dynamic pricing raises the tolls when traffic is heavy, based on real-time demand monitoring, and electronic toll capabilities run on E-ZPass transponder technology. If tolls exceed expectations, the state will share the revenue—but if the incentive to carpool proves to be too successful, the state will owe Transurban subsidies.

Infrastructure banks

Infrastructure banks, which can operate on a self-sustaining model similar to revolving funds, are quite common in other parts of the world (the European Investment Bank is one example). Proposals for a national infrastructure bank have not gone very far in the United States, but these institutions do exist at the state level (including institutions in Florida, Pennsylvania, and Texas, among others), although most operate on a relatively small scale. Using federal, state, and local funding, often complemented by private investment, these institutions issue low-cost revolving loans, which can act as catalysts to "crowd in" private investment for complex or expensive projects with regional or national significance. South Carolina's state infrastructure bank, the most active in the nation, has leveraged its initial funding by issuing debt backed by dedicated state revenue; it has provided nearly $3 billion in grants and loans during its lifetime, mostly to highway and bridge projects.[141]

Beyond simplifying financing, these institutions can offer other benefits. By bringing a more holistic regional or national perspective to project selection, they can add more coherence in addressing bottlenecks at a systemic level and mitigate the influence of local politics. Infrastructure banks can also act to plan, contract, and oversee complex, large-scale projects such as PPPs.

CAPTURING THE INFRASTRUCTURE OPPORTUNITY

This chapter has outlined the potentially game-changing impact that could come from significantly raising US infrastructure investment and productivity. At stake is $270 billion to $320 billion of GDP annually between now and 2020, along with the creation of up to 1.8 million jobs—and nearly $600 billion of annual GDP by 2030. Other countries—including Australia, Chile, South Korea, and Singapore—have successfully revamped their approaches to infrastructure planning and management, and their best practices can be employed at the federal, state, and local levels in the United States.

But capturing this opportunity requires overcoming institutional and organizational barriers, especially where infrastructure projects cross jurisdictional boundaries. In many cases, the planning, funding, and approval of infrastructure projects are handled by different parties, often with very different objectives. Even within a region, different levels of government may be charged with overseeing competing or complementary infrastructure. Overlaying this are the forces of public and political opinion that underpin any government action. These issues can add substantial delays and inefficiencies to the process.

Streamlining approval processes, especially when multiple agencies and layers of government are involved, will be essential. It can take four to five years for a large infrastructure project to complete environmental reviews, for instance. The federal government has announced plans to streamline federal approval processes, including the simultaneous review and approval of projects by multiple agencies. To expedite permitting, it also launched a new online "performance dashboard" that tracks the approval status of selected high-priority federal infrastructure projects. This pilot effort is currently limited to 14 pre-selected projects, but it is intended to add transparency and urgency to the process. These efforts are a

141 Robert Puentes and Jennifer Thompson, *Banking on infrastructure: Enhancing state revolving funds for transportation*, Brookings-Rockefeller Project on State and Metropolitan Innovation, September 2012.

step in the right direction, but they will have to be scaled up if the United States is to successfully transform its infrastructure assets and management.

The growing acceptance of PPPs allows governments to tap into new sources of capital for infrastructure funding and, potentially, to execute projects more quickly and efficiently. Where public infrastructure suffers from the accountability problem of many owners and competing objectives, private infrastructure networks have the singular purpose of improving business performance. But PPPs are not a panacea that can erase the need for increased public funding. There are risks inherent in the private-sector provision of public goods, and governments will have to structure agreements carefully to ensure transparency, accountability, and protection of the public interest.

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Today the United States has a historic opportunity to take aggressive action to address its aging infrastructure. The price of deferring hard decisions is becoming more apparent with each passing year, as deficiencies continue to grow. Infrastructure is a necessary foundation underpinning all the other game changers described in this report. The United States cannot move gas and oil to refineries, export liquid natural gas, or pursue increased trade of manufactured goods without high-quality roads, freight rail, and ports. Big data servers use tremendous amounts of electricity and need to run on a reliable grid. Schools cannot deploy new educational technologies without the broadband to run them. In addition, infrastructure investment is a powerful generator of middle-class jobs and economic stimulus in the short term, and a source of productivity gains and competitiveness for the entire economy in the years that follow. Labor is available, and borrowing costs are currently near all-time lows, creating the right conditions to seize the moment and rebuild the foundational systems that will support economic growth and productivity for decades to come.

Talent: Investing in America's human capital

The US labor market is under increasing strain—and cracks were becoming apparent well before the Great Recession hit. Today 11.8 million people are unemployed in the United States, and another 8 million are in part-time employment because of lack of opportunity. The labor force participation rate is at its lowest level since 1979, and even before the downturn, job creation was far weaker than in previous decades.[142] Better pathways into the job market are needed for new workers; for those displaced by recession, automation, or competition; and for those who aspire to acquire new skills.

Building the skills that lead to readiness for employment, career progress, and the ability to innovate is critical to America's economic future. The United States must build a more cohesive and effective system of education and talent development in order to cultivate a productive workforce that can meet the challenges of a technology-driven global economy. As President Obama notes, "It is an undeniable fact that countries who out-educate us today are going to out-compete us tomorrow."[143]

A holistic and sustainable approach to addressing the nation's human capital pipeline can improve outcomes from K–12 all the way through post-secondary education. It also can preserve the diversity of US institutions while overcoming the fragmentation that limits their effectiveness. An exciting degree of experimentation and innovation is under way, and many promising examples are emerging across the country. There are also lessons to be drawn from other advanced economies that have successfully improved their human capital systems and reaped the economic benefits. Implementing some of these approaches at larger scale and as part of a more systemic strategy could have a profound impact on the health of the US labor market and national competitiveness.

In the first part of this chapter, we highlight several initiatives that could have significant impact on workforce development: creating non-degree training programs to give workers the specific skills needed by employers; improving learning and labor market outcomes for some graduates of two- and four-year colleges; expanding the number of graduates in science, technology, engineering, and math (STEM); and incorporating a greater focus on skills in targeted areas of immigration policy.

But no comprehensive workforce development solution can succeed without a parallel focus on achievement in primary and secondary school, which lays the groundwork for future productivity and innovation and is closely linked to GDP

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142 *An economy that works: Job creation and America's future*, McKinsey Global Institute, June 2011.

143 Remarks by the president on No Child Left Behind Flexibility, White House Office of the Press Secretary, September 23, 2011.

growth.[144] A strong educational foundation during the K–12 years confers the ability to learn new skills and adapt to changing work environments later in life.[145] The second half of this chapter, which focuses on this crucial stage of the human capital pipeline, offers reason for optimism, pointing to other nations (and US states) that have made large strides over the course of a decade. It highlights successful programs, new technologies, and emerging evidence on best practices yielded from decades of school reform efforts.

Scaling up efforts to create a more cohesive and effective system of skills development could produce significant economic returns. By taking action at both the K–12 and post-secondary levels, the United States could add between $165 billion and $265 billion to annual GDP by 2020. But even more striking effects would follow as better-educated students continue to filter into the workforce in the years ahead. This could produce a large “liftoff” effect, raising annual GDP by up to $1.7 trillion by 2030.

Transforming education has been attempted on a local level for many years, but today real improvements to the broader system are within reach. If the United States can rise to the challenge, it will emerge as a more prosperous, innovative, and cohesive society—one that is capable of delivering on its promise of economic opportunity.

THE US POST-SECONDARY EDUCATION SYSTEM IS FALLING BEHIND

In advanced economies, those with post-secondary degrees fare much better in the labor market than those with less education. But the United States, which once had the best-educated workforce in the world, has lost its competitive advantage in this area. The United States long led the world in its share of older workers with tertiary degrees, at 41 percent.[146] However, its rate of education attainment has not increased substantially for decades, while other countries have made strides (Exhibit 28). The share of US workers ages 25 to 34 with tertiary degrees is also 41 percent, but today that is barely above OECD average and far behind leading countries such as South Korea (63 percent), Canada (56 percent), and Japan (56 percent).

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144 The link between K–12 achievement gains and GDP growth is well documented in academic research. See, for example, Eric A. Hanushek and Ludger Woessmann, “How much do educational outcomes matter in OECD countries?” *Economic Policy*, volume 26, number 67, July 2011; Simon Appleton, Paul Atherton, and Michael Bleany, *International school test scores and economic growth*, Centre for Research in Economic Development and International Trade, University of Nottingham No. 08/04, 2008; Robert Barro, “Human capital and economic growth,” *The American Economic Review*, volume 91, number 2, May 2001; and *The economic costs of the achievement gap in America’s schools*, McKinsey & Company, April 2009.

145 James Heckman and Alan Krueger, *Inequality in America: What role for human capital policies?* The MIT Press, 2005.

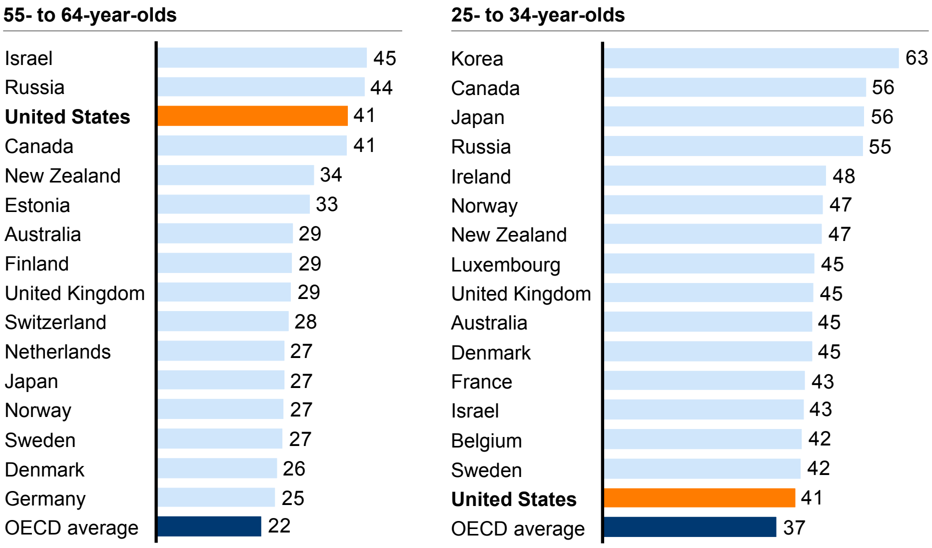
146 Tertiary education refers to all post-secondary (that is, post–high school) education. The World Bank, for instance, defines tertiary institutions as including universities, colleges, technical training institutes, community colleges, nursing schools, and research laboratories.

Exhibit 28

The United States no longer leads the world in tertiary education attainment

Share of population with tertiary degrees, older vs. younger cohort, 2009

%



SOURCE: Organisation for Economic Co-operation and Development (OECD), *Education at a glance 2011* statistical annex; McKinsey Global Institute analysis

Recent evidence shows some positive momentum in college education; only one-quarter of young US workers ages 25 to 29 had college degrees in 1995, but today that share is up to one-third.[147] But other indicators are more worrisome, including the number of young Americans who enter college but struggle to complete their degrees. Just 38 percent of those earning bachelor's degrees graduate within four years, and less than 30 percent of community college students earn a two-year associate degree within three years.[148] This is a costly outcome for students, given that tuition now averages $8,655 a year at public universities and $29,000 at private colleges.[149] US student loan debt has grown to nearly $1 trillion, dampening consumption and household formation by young Americans.[150]

Even some graduates who do earn degrees are struggling in the workforce. More than one-quarter of those holding bachelor's or advanced degrees earn less than the median annual wage for two-year associate degree holders. Similarly, one-third of those with associate degrees earn less than the median wage for high school graduates.

Of course, the low wages earned by some graduates reflect many factors beyond the quality of education. Some very capable workers select professions that pay modestly (such as some creative fields) by choice, and others live in regions with

147 This positive momentum is also reflected in the recently released 2013 OECD *Education at a glance* report. The United States rose from 16th to 12th in the OECD for its share of 25- to 34-year-olds with tertiary degrees.

148 *Digest of education statistics*, National Center for Education Statistics, 2011; and National Center for Education Statistics/IPEDS Graduation Survey, in *Pathways to prosperity: Meeting the challenge of preparing young Americans for the 21st century*, Harvard Graduate School of Education, February 2011.

149 *Trends in college pricing 2012*, The College Board.

150 *Household debt and credit report 2013*, The Federal Reserve Bank of New York.

lower costs of living and lower wages. We attempt to adjust for these effects, and find that geographical cost-of-living differences for four-year graduates account for only 16 percent of low graduate earnings, and the choice of students to enter low-paying fields accounts for only 29 percent of the shortfall. The remaining 55 percent of the earnings gap may reflect lack of jobs and high unemployment, but a combination of low learning quality and a lack of workplace relevance associated with some degrees is also likely a factor. (See the appendix for details of this analysis.)

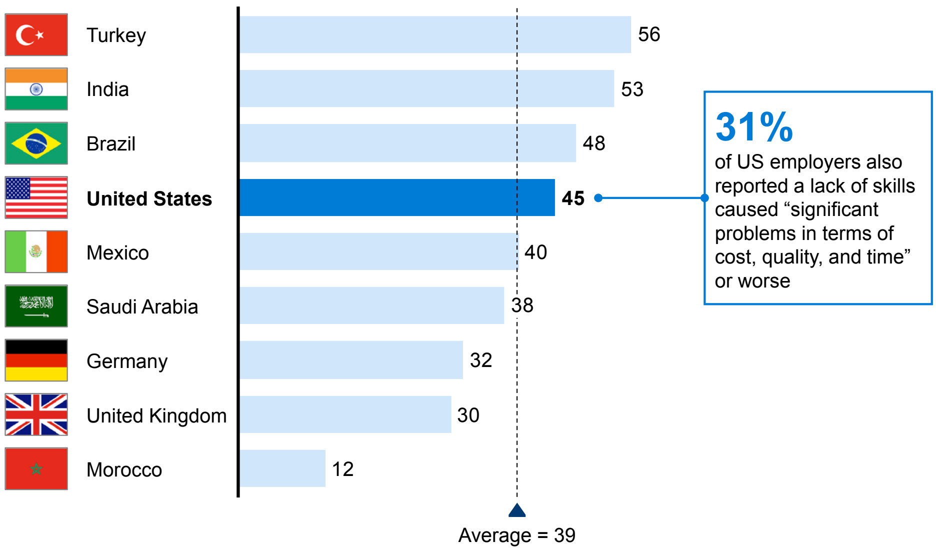
With unemployment remaining high, companies should be able to fill vacant positions with ease—and yet, there is a disconnect (Exhibit 29). A 2011 McKinsey Global Institute survey of 2,000 US companies found that two-thirds of employers had difficulty finding qualified applicants in a range of high- and low-skill positions in management, science and engineering, sales and marketing, customer service, transportation, skilled trades, and production. Moreover, 30 percent reported having positions open for six months or longer that they could not fill.[151] In 2012, 45 percent of employers surveyed said the lack of worker skills is the main reason for entry-level job vacancies.[152]

Exhibit 29

Nearly half of US employers say skills shortages are a leading driver of entry-level vacancies

Lack of skills as common reason for entry-level vacancies

% of employers responding



SOURCE: *Education to employment: Designing a system that works*, McKinsey & Company, 2012

FOUR ACTIONS COULD HELP BUILD A MORE COMPETITIVE US WORKFORCE

Building a more competitive workforce and creating opportunity for a greater share of the population will require reshaping post-secondary training and education. We discuss four initiatives that could play a role in this effort: dramatically expanding non-degree training programs to build skills and

151 *An economy that works: Job creation and America's future*, McKinsey Global Institute, June 2011.

152 *Education to employment: Designing a system that works*, McKinsey Center for Government, December 2012.

credentials in the existing workforce (and especially among the unemployed); making two- and four-year degree programs more effective; increasing the number of STEM graduates; and incorporating a greater focus on skills in portions of immigration policy, as other countries have done.

Developing more effective non-degree worker training programs

Conventional wisdom in the United States is that students need a two-year or four-year degree to enter the workforce—and indeed, workers with degrees earn a wage premium. However, many jobs that employers are struggling to fill do not require college degrees.[153] Short-term training options such as industry-specific technical programs and certificate programs can provide workers with the skills needed for these positions. These vary in duration from a few weeks to several months, but are generally shorter than a two-year college degree program. Although these programs are not as extensive in the United States as in other advanced economies, they are becoming more widely available: more than one million certificates were awarded in 2010, more than three times the number awarded in 1994.[154]

Training programs are most effective when they teach industry-specific skills and result in credentials that are meaningful in the labor market. Employment outcomes can be further improved when these programs engage with potential employers and provide hands-on learning. Depending on the program, some participants can eventually earn more than two- and four-year college graduates. For example, metalworking certificate holders can earn annual wages of nearly $45,000, which is the median wage of 25- to 34-year-old bachelor's degree holders.[155] Because many of these credentials are nationally administered (e.g., by the National Institute for Metalworking Skills or the American Welding Society), students who obtain certificates can obtain both marketable skills and mobility.

Most short-term training programs are offered by community colleges or other educational institutions that impart very specific skills, but other models exist. Larger companies can offer their own in-house training or partner directly with local schools, or a consortium of employers in the same industry can develop a joint program with agreements to protect participants from talent poaching. A successful example of this approach is AMTEC, a consortium of automotive manufacturers that has teamed up with community colleges to train skilled automotive workers. Courses are jointly designed by educators and employers, and the program, funded by a National Science Foundation grant, includes modules of three to eight weeks in duration.

Other countries have created extensive training programs as a viable educational pathway. Many (but not all) of these programs feature apprenticeships as part of the practical training. (See Box 10, "Apprenticeships: Learning on the job," for more details on Germany's apprenticeship system, which aligns with both

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153 According to the ManpowerGroup's *Talent shortage survey 2012*, the jobs that are hardest to fill include skilled tradesmen, commercial drivers, mechanics, and machine operators. Many of these jobs do not require a college degree and can be filled by workers who complete short-term, targeted training programs.

154 Anthony Carnevale, Stephen J. Rose, and Andrew R. Hanson, *Certificates*, Georgetown University Center on Education and the Workforce, June 2012.

155 Ibid., as well as analysis based on data from US Census Survey of Income and Program Participation. Median wage for bachelor degree holders ages 25 to 34 obtained from National Center for Education Statistics.

secondary and post-secondary schools.) Some 26 percent of high school graduates in Finland opted for post-secondary non-degree training in 2010.[156] Sweden has expanded enrollment in these types of programs from 10 percent of high school graduates in 2005 to 21 percent in 2010 to address high unemployment among young workers.

Box 10. Apprenticeships: Learning on the job

Apprenticeships can be an effective way to immerse new workers in a job that requires specialized skills, providing an opportunity for hands-on learning under the mentorship of more experienced professionals. There is no standard definition of what constitutes an apprenticeship; programs vary widely in duration, implementation, intensity, and outcome. But the common thread is practical workplace training that imparts job-ready skills and can complement or replace classroom training. Some of the most successful models in the United States are administered by labor unions and geared to workers who aspire to become skilled tradesmen. Another approach involves programs jointly provided by schools and employers, incorporating both classroom credits and job-specific competencies that are evaluated by the employer. These programs can vary in length and may or may not result in degrees or professional credentials.

Apprenticeships can provide a stepping-stone into a wide range of positions. The Virginia Department of Labor and Industry, for example, offers the Virginia Registered Apprenticeship program, in which some 2,000 employers provide apprenticeships for trainees to learn skills as electricians, machinists, surveyors, opticians, barbers, and a wide range of other jobs. The program combines at least 2,000 hours of supervised on-the-job training with a minimum of 144 hours of classroom instruction, and participants receive credentials upon completion.

Other advanced economies have embraced the apprenticeship model more fully than the United States. Fewer than 400,000 Americans joined apprenticeship programs in 2011, less than one-quarter the number in Germany.[1] Germany's dual system of education combines high-quality vocational training with apprenticeships in one of nearly 350 nationally recognized occupations. These programs are longer-term (two to three years) and closely aligned with the broader secondary and post-secondary education system. They are widely available as early as the tenth grade, with an enrollment rate of roughly 60 percent.[2] Although the German approach has been successful, apprenticeships are a flexible concept and other models could be scaled up in the US context.

1 US Department of Labor Employment and Training Administration; *The state of apprenticeship in 2010*, London School of Economics and Political Science.

2 Ibid., *The state of apprenticeship in 2010.*

156 OECD education statistics. We use the OECD definition of non-degree programs to compare between countries. The OECD uses the term "post-secondary, non-tertiary education" for such programs, and bases its classification on the International Standard Classification of Education (ISCED) 4 category. In the OECD definition, these programs are between six months and two years in duration.

Making non-degree training programs more widely available to US high school graduates could have a substantial impact—and it need not require a revamp of the secondary school system. Today roughly 16 percent of US high school graduates enroll in non-degree training programs, up from 13.5 percent in 2007.[157] If today's enrollment rates and completion rates are maintained, 1.2 million high school graduates will receive training by 2020. Building on recent momentum and matching Sweden's benchmark of 21 percent enrollment would translate to roughly 350,000 more participants by 2020, an increase of 30 percent. Matching the benchmark set by Finland (26 percent) would produce 700,000 more high school graduates trained in these programs cumulatively by 2020.

To get to these numbers, the United States will need to expand these training programs on a large scale—an effort that will require significant private-sector participation. Most of the dual system training in countries such as Germany, Austria, and Switzerland, for example, is run by companies. Government has a role to play in convening, highlighting, and supporting these partnerships (and in some cases, commissioning the design of employer-based skills standards that can provide a framework for programs and educational institutions). The US Department of Veterans Affairs, for instance, is attempting to mobilize private-sector hiring of returning veterans by launching an On-the-Job Training program as part of the GI Bill.

While the United States spends considerably less per capita on vocational training than other advanced economies, funding is not the only barrier to achieving effective scale. One of the key issues is an information gap. Lacking enough data on the precise skills required for most jobs, the organizations designing training programs may not be teaching the right skills. Creating more direct partnerships between employers and educators to design worker training is a helpful start to tackling this issue. Industries could work together to develop standard skill taxonomies and competency maps so that thousands of educational institutions and training providers could develop more tailored programs; new online, open-source, and employer-led programs could also emerge. Big data could assist this effort and also help greater numbers of workers access information on skill requirements, training opportunities, and job openings.

Improving labor market outcomes for graduates of two- and four-year programs

We have identified three potential routes toward making higher education more effective for all students: helping students choose the most appropriate and effective post-secondary options for their goals through counseling and better information; improving student learning outcomes, particularly for workplace-related competencies; and raising completion rates.

First, reforms are needed to help students determine the degree program that is best suited to their needs. Students could make more informed choices if they were armed with better knowledge of the job market realities that await various majors, including typical salaries, prospects for advancement, and skill requirements, as well as more transparent information about the performance of individual educational institutions. Institutions can also be more proactive in providing students with financial counseling on repayment requirements as they relate to job and salary prospects *before* they take out large loans.

157 Ibid.

Policies requiring data reporting, investments in longitudinal data systems, and commercial or non-profit platforms for self-reporting outcomes could increase transparency.

A key part of helping students identify the right post-secondary program involves creating greater awareness of the value of two-year associate degree programs that emphasize vocational skills. The US bias against such programs is evident in OECD data. Thirty-one percent of 25- to 64-year-old workers in the United States have four-year or advanced degrees, but only 10 percent have two-year associate or equivalent degrees. In contrast, countries such as Canada, Japan, and Finland have a more balanced distribution between associate/vocational degrees and four-year or other advanced degrees.[158] Some US students choose a four-year degree program even when a two-year degree might produce better job prospects. In a recent survey, 73 percent of US students believed that academic programs were more valued by society, even though half acknowledged that they personally preferred vocational training.[159] Another survey found that 42 percent of recent graduates from bachelor's degree programs in the United States are in jobs that do not require a four-year degree.[160]

Second, colleges and universities can adopt a greater focus on teaching skills and competencies that can tangibly improve graduates' job prospects. Some institutions have incorporated learning methods such as experiential projects, internships, seminars, capstone projects, and service- or community-based learning. Others have changed traditional coursework to incorporate more emphasis on problem solving, critical thinking, communication, teamwork, analysis, and inquiry. Some institutions are working directly with employers to craft programs of study based on the competencies students will need for workforce success.

Many community colleges are already at the core of creative new models that are focused on labor market outcomes. Apprenticeship 2000, for example, is a collaborative effort between eight non-competitive manufacturing companies and Central Piedmont Community College in Charlotte, North Carolina. Employers and the college designed a three- to five-year curriculum in "mechatronics" (an emerging discipline that combines mechanical engineering and electronics), specifically targeting the skills and knowledge needed in regional factories. Students accepted into the program receive a salary, hands-on experience, and upon graduation, an associate degree and journeyman's certificate. In California, PG&E is working with community colleges to train students for careers as utility technicians. Such models show the effective role that community colleges can play when they are fully attuned to the needs of the local economy.

Finally, improving retention and completion rates at two- and four-year institutions is becoming an increasing concern. This may entail a fundamental rethink of retention strategies, support programs, and course requirements. Institutions can create a clearer path to graduation by adopting a stackable curriculum—that

158 This comparison is based on *OECD Education at a glance* data comparing tertiary type-B education programs, which include US two-year associate degree programs. While such programs are mostly associated with vocational education and training, they can also be academic in nature, preparing students for four-year degrees or advanced research.

159 *Education to employment: Designing a system that works*, McKinsey Center for Government, December 2012.

160 *Voice of the graduate*, McKinsey & Company in collaboration with Chegg, Inc., April 2013.

is, the opportunity to earn a series of credentials or degrees by adding courses onto a degree or credential that the student has already obtained without losing any credits. In addition, students need earlier interventions when they begin to fall behind. Some institutions, such as Arizona State University and Austin Peay State University, have begun employing big data tools to help guide individual students on the path to a degree, monitoring their progress toward requirements for their major, recommending courses, and identifying students who might need mentoring. Such targeted guidance can significantly improve completion rates.[161] Furthermore, the introduction of online classes can help students who need greater flexibility due to work or personal issues complete their degrees rather than dropping out; it can also provide remedial help for certain courses and ease waiting lists for popular and required classes.[162]

Increasing the number of two- and four-year STEM graduates

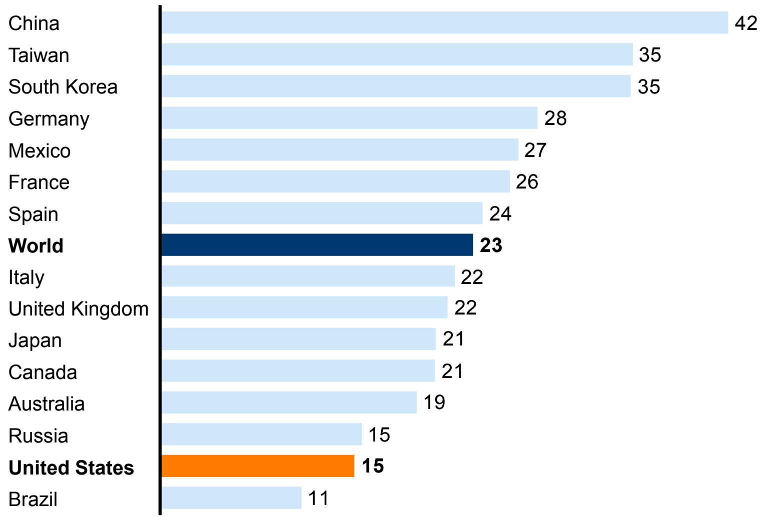
Maintaining the ability to innovate, especially in medicine, energy, and technology, will be crucial to US growth in the decades ahead—and maintaining US competitiveness in these fields depends on cultivating highly educated workers (see Box 11, "Does the United States need more STEM graduates?"). But among countries with large numbers of college graduates, the United States ranks in the bottom quartile for STEM graduation. Among 2008 college graduates, 42 percent of Chinese students received STEM degrees, compared with only 15 percent of US students (Exhibit 30).[163]

Exhibit 30

The US STEM graduation rate is very low compared with other countries

College graduates with STEM degrees

% of 2008 graduating class[1]



1 Only includes countries with more than 100,000 college graduates in 2008 or most recent year. STEM fields are defined as physical and biological sciences, mathematics, computer sciences, architecture, and engineering.

SOURCE: National Science Foundation, *Science and Engineering Indicators 2012*, First University Degrees by selected region and country/economy: 2008 or most recent; McKinsey Global Institute analysis

161 "Big data on campus," *The New York Times* (with *The Chronicle of Higher Education)*, July 18, 2012.

162 *Winning by degrees: The strategies of highly productive higher-education institutions*, McKinsey & Company, November 2010.

163 National Science Foundation, *Science and Engineering Indicators, 2012*.

Box 11. Does the United States need more STEM graduates?

Recent research has raised the question of whether the United States really needs more graduates with science, technology, engineering, and math degrees.[1] Our analysis shows that there is indeed a current shortage of STEM graduates with two- and four-year degrees relative to the economic need and opportunity, and the gap will be even wider by 2020.

We estimate that there are currently 10.4 million jobs in the US economy that require STEM training, based on a broad definition that includes jobs in computer and mathematical fields, architecture and engineering, life and physical sciences, high-tech manufacturing, and STEM management positions. These cover a wide range of positions, including health-care lab technicians, machine assemblers, and power plant operators. Against that need, there are 10.1 million STEM graduates in the workforce.

At first glance, this would appear to indicate little shortage of STEM workers. But this is misleading. First, 43 percent of STEM graduates choose jobs in other fields, and that diversion is largely voluntary.[2] Applying this diversion rate to the current economy indicates that there is already a shortfall of skilled workers to fill today's STEM jobs, and the gap is likely to widen in the future. Based on employment projections from the Bureau of Labor Statistics, we expect 1.2 million more STEM jobs to be created by 2020. Projections from the National Center for Education Statistics indicate that by 2020, 1.5 million students will graduate from two- and four-year colleges with STEM degrees. Assuming the diversion of STEM graduates into non-STEM fields continues at today's rate, this will lead to a gap of nearly 400,000 unfilled STEM jobs.

1 Hal Salzman, Daniel Kuehn, and B. Lindsay Lowell, *Guestworkers in the high-skill US labor market*, Economic Policy Institute, April 2013.

2 Anthony Carnevale, Nicole Smith, and Michelle Melton, *STEM*, Georgetown Center on Education and the Workforce, 2011.

Increasing STEM graduation rates to the global average of 23 percent requires addressing two issues: raising the enrollment rate of freshmen into STEM programs, and reducing the attrition rate of enrolled students out of STEM programs. Only 14 percent of incoming freshmen choose STEM fields to begin with, and nearly 50 percent will change majors or drop out before graduation. In comparison, the attrition rate for non-STEM majors is around 25 percent.

Reducing the attrition rate requires reexamining the curricula and approaches used in "gateway" STEM classes like advanced algebra and first-year calculus. Many students never consider STEM majors because they are discouraged by their experiences in these introductory courses. Other approaches include clear learning and career paths, exposure to industry and cutting-edge research through internships, and better connections to the broader STEM community through campus organizations, research competitions, and mentoring programs. Funding and grants for undergraduate research, particularly during the summers, can also provide continuous engagement.

Several successful examples show that STEM attrition can be reduced by injecting research, real-world projects, and creativity into the standard curriculum. The EXPRESS program at the University of Missouri, for example, provides research experience to freshmen and sophomores; those in the program have a 90 percent retention rate, higher than the university mean. Other universities are trying different approaches, from replacing large section classes with courses on creative problem solving to designing an engineering course on numerical methods around a racing simulation. And outside the university setting, the RoboAcad program—a partnership of NASA, academics, and industry—challenges summer interns to create highly technical engineering deliverables.

Policy makers have long recognized the importance of STEM education, and for years, the United States has directed considerable resources toward building these vital skills. The federal government spent $2.9 billion in 2012 on more than 200 STEM education programs run by multiple agencies, and the president's 2014 budget calls for $3.1 billion in funding for programs designed to train effective STEM teachers, bolster high school programs, improve STEM retention, and drive research. But the efforts made to date have not yet produced strong results on a national level. Greater momentum can be achieved by stepping up private-sector participation to help integrate real-world application of STEM skills into the classroom.

Attracting high-skilled immigrants to the US workforce

The United States is a nation of immigrants, and yet there are missed opportunities to attract and retain international talent. The nation could generate tremendous impact on productivity in the near term and beyond 2020 by increasing the annual flow of high-skilled immigrants. This can be done by increasing the number of skilled H-1B visa holders, giving preference to visas for extended relatives of permanent residents who have specialized skills or tertiary degrees, and streamlining the visa process for skilled workers and entrepreneurs.[164]

The role of immigration in the economy continues to be debated, and as we near publication, a comprehensive immigration bill is pending in the US Congress. Many US companies are seeking more high-skilled workers, particularly those with STEM backgrounds. Recent research has focused on the links between skilled H-1B visa holders, productivity, and talent shortages.[165]

We estimate that the US foreign-born population will grow by 7.4 million from 2012 to 2020.[166] Encouraging higher-skilled immigrants in specific categories can bolster the talent pool and fill immediate shortages in innovative industries. Of the 42 million foreign-born residents in the United States today, 12.5 million are permanent residents and three million are temporary visa holders. These two groups constitute the immigrant labor force in the country. Within these

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164 Volker Grossman and David Stadelmann, *Wage effects of high-skilled migration: International evidence*, May 2010; and Giovanni Peri, "The effect of immigration on productivity: Evidence from US states," *The Review of Economics and Statistics*, MIT Press, volume 94, number 1, 2012.

165 Jonathan T. Rothwell and Neil G. Ruiz, *H-1B visas and the STEM shortage: A research brief*, Brookings Institution, May 2013; and Giovanni Peri, Kevin Shih, and Chad Sparber, *STEM workers, H-1B visas and productivity in US cities*, January 2013.

166 Based on US Census projections of annual net international migration, 2015 through 2020, extended backward to 2012 through 2015.

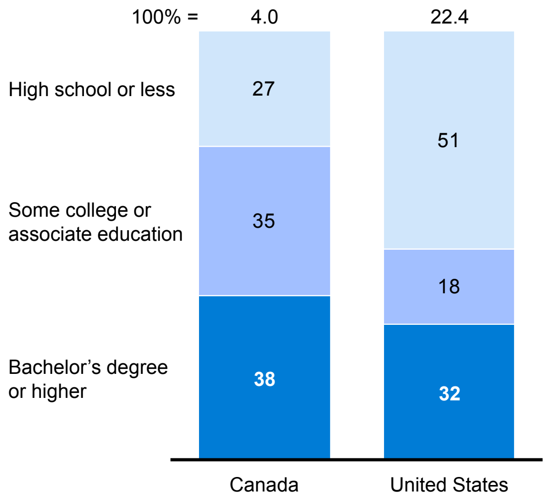
two subgroups, only 32 percent of permanent residents and visa holders are employed and have tertiary degrees, while 51 percent have high school diplomas or less. In Canada, by contrast, 38 percent of permanent residents and visa holders are employed and have tertiary degrees, while only 27 percent of the immigrant labor force have high school diplomas or less (Exhibit 31).[167]

Exhibit 31

US immigrants have lower educational attainment than Canadian immigrants

Immigrant labor force by highest educational attainment, 2011

%; million



NOTE: Numbers may not sum due to rounding.
SOURCE: Statistics Canada; US Bureau of Labor Statistics; McKinsey Global institute analysis

Increasing the number of immigrants with tertiary degrees could be accomplished through several actions. First would be an increase in the number of H-1B visas. The average number of H-1B visas allowed over the past three years has been 125,000; the peak in the last decade was in 2001, when the US quota was 161,000. Increasingly the current quota to the 2001 peak would immediately expand the pool of highly skilled and specialized workers.

Second, changing the mix in one subcategory of permanent residency visas could have a large impact. In 2012, only 4 percent of permanent residency permits ("immigrant visas") issued were employment-based, and most of those recipients were highly skilled workers.[168] The rest were issued to family members: 49 percent to immediate family members of citizens (spouses, children, and parents) and an additional 39 percent to extended relatives of both citizens and permanent residents. To expand the pool of skilled workers, the United States could give preference to extended relatives with specialized skills or tertiary degrees. Such a preference for skills need not apply to immediate family or to those who would not be in the labor force, such as retirees or children.

Third, the visa process can be streamlined for skilled workers and entrepreneurs. Skilled immigrants arriving in the United States typically need to first obtain H-1B visas and then apply for permanent residency. But the Canadian model is worth considering. Canada, which already has the highest share of foreign workers with

167 *OECD regions at a glance 2011*, OECD.

168 VISA statistics 2012, Table II, US Department of State.

tertiary degrees in the OECD, has updated its Federal Skilled Workers Program to accelerate review of visa applications in 24 target occupations. Once accepted, an applicant immediately receives a permanent resident visa. Furthermore, Canada recently launched the Entrepreneur Start-up Visa program, which grants permanent residency to qualified entrepreneurs and connects them with Canadian business partners.[169] Together, these initiatives attract and capitalize on foreign talent.

IMPROVING WORKER TRAINING AND HIGHER EDUCATION CAN ADD NEARLY $165 BILLION TO ANNUAL GDP BY 2020

There is no shortage of innovative programs for improving workforce skills, with many of the most exciting ideas emanating from the local level or from individual institutions. But in order to maximize the potential benefits across the economy, the United States will need to move beyond fragmented solutions and begin to shape a more cohesive and systemic approach to workforce development. While the contours of this system are still under debate, the initiatives described above are potential components that could have a significant impact on GDP and create employment opportunities for millions of workers by 2020.

- **Non-degree training programs.** Raising the number of high school graduates receiving post-secondary, non-degree training directly translates to GDP gains. Participants often achieve better labor market outcomes than graduates of associate degree programs.[170] We assume that instead of facing the job prospects typical of high school graduates, this population will exhibit the labor force participation, employment, and wage characteristics of associate degree holders.[171] In addition to making this path more widely available to new high school graduates, training can benefit currently unemployed workers who lack college degrees. The historical rate of unemployment among this group is 6 percent, but today there are 1.3 million more unemployed in this group than would be expected—and they are prime candidates for these types of programs. Altogether, expanding industry-specific training programs could add $7 billion to nearly $15 billion to annual GDP by 2020.

- **Improving learning and employment outcomes for college graduates.** If current trends persist, we estimate that by 2020, roughly one-quarter of workers with bachelor's degrees will earn less than the median full-time annual earnings of associate degree holders. Similarly, one-third of workers with associate degrees will earn less than the median wages of high school graduates. Adjusting for factors such as cost-of-living differences and voluntary choices of lower-paying careers, we find that improving labor market outcomes of these bachelor's degree holders to match the median wage of associate degree holders and lifting these associate degree holders to the

169 Citizenship and Immigration Canada. The United States does offer an EB-5 visa for foreign investors, but it is typically undersubscribed each year. A proposal to streamline and improve an entrepreneurial visa is being debated as part of the immigration reform legislation currently pending in Congress.

170 This is based on Carnevale et al., *Certificates*, June 2012, and on evidence from various US states. For example, see Florida College System 2010–11, graduates' average employment rates and full-time earnings by award type. Also see *Employment outcomes report 2012*, Oklahoma State System of Higher Education.

171 Reliable estimates of completion rates in these short-term programs are not available. For sizing purposes, we assume that given the short duration and employment-focused nature of these programs, all new enrollees will complete their programs.

median high school graduate wage would raise annual GDP by $45 billion by 2020. Improving bachelor's and associate degree outcomes even further—to match the median wages associated with their actual educational attainment—would add $95 billion to annual GDP by 2020.

- **Increasing the number of STEM graduates.** By reducing attrition rates in STEM fields to levels comparable with other majors, the United States can improve the persistence rate of STEM majors from 53 percent to 76 percent. In combination with increasing the enrollment rate in STEM programs from 14 percent to 24 percent, the share of US four-year-college graduates with STEM degrees can grow from 15 percent today to 23 percent by 2020, bringing the United States in line with peer countries. Increasing the number of STEM graduates can raise annual GDP by $25 billion in 2020 because of the lower unemployment rate and higher wage premium for STEM graduates over non-STEM graduates.[172]

- **High-skill immigration.** Increasing the skill level of the net additional 7.4 million immigrants that are likely to arrive between 2012 and 2020 will also have tremendous impact on GDP. Increasing H-1B visa issuance to match the 2001 peak—that is, issuing an additional 37,000 H-1B visas each year—would increase the 2020 population of H-1B visa holders by nearly 130,000 above the baseline 2020 projection. Assuming these additional H-1B workers earn the average wage for workers with tertiary-level STEM education, this shift would add $8.5 billion to annual GDP by 2020.[173] Even more significantly, the educational profile of incoming family-sponsored permanent resident workers can be shifted to give preference to those with specialized skills or tertiary degrees. (This would apply only to extended family members who would be in the labor force, not to the immediate families of citizens and permanent residents.) Applying this change only to this specific group would generate an annual GDP impact of $22 billion by 2020.

Taken together, all of these initiatives can increase annual GDP by $105 billion to $165 billion in 2020 (Exhibit 32). Furthermore, the cumulative impact of these strategies will continue to grow in the years that follow as more workers gain skills and attract higher wages for the duration of their careers. This would add an incremental gain of $350 billion to annual GDP by 2030 and cultivate a more competitive workforce.

172 Based on the US Census Bureau's Annual Community Survey (2011) and the US Bureau of Labor Statistics Occupational Employment Survey, we calculate the average wage for young (25–34 age group) STEM workers to be $52,000, about 24 percent higher than the non-STEM workers in this age cohort. To calculate the GDP impact, we assume that the historical STEM wage premium remains at current level. See Jonathan Rothwell, *The hidden STEM economy*, Brookings Institution, June 2013; and David Langdon et al., *STEM: Good jobs now and for the future*, US Department of Commerce, July 2011.

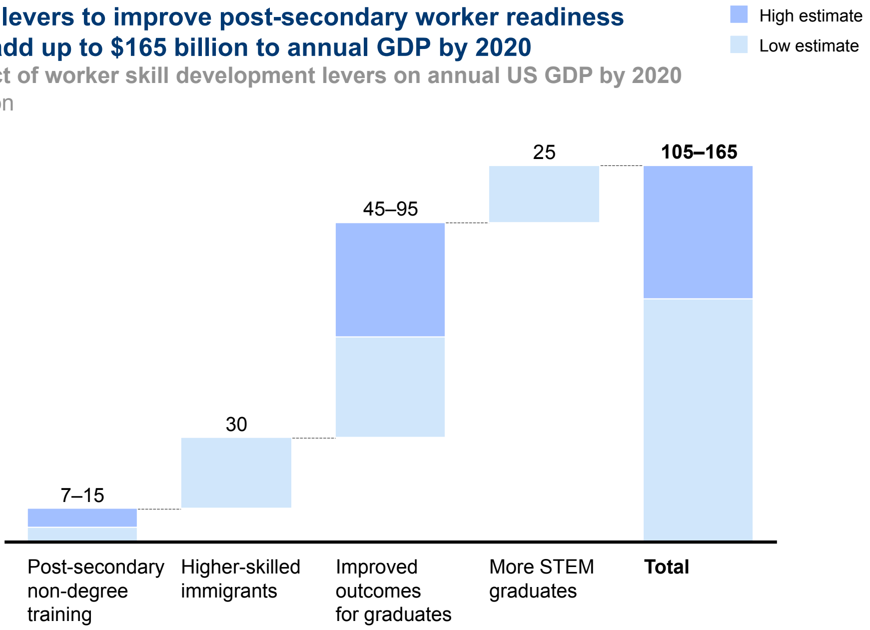
173 We assume the STEM premium applies to these additional H-1B visas because the majority of currently issued H-1Bs go to workers in STEM fields such as computer systems analysts and software developers.

Exhibit 32

Four levers to improve post-secondary worker readiness can add up to $165 billion to annual GDP by 2020

Impact of worker skill development levers on annual US GDP by 2020

$ billion



SOURCE: National Center for Education Statistics (NCES); American Community Survey (US Census); US Bureau of Labor Statistics; Congressional Budget Office; McKinsey Global Institute analysis

RAISING K–12 STUDENT ACHIEVEMENT IS CRUCIAL TO ECONOMIC GROWTH AND COMPETITIVENESS

The strategies described above would go a long way toward improving outcomes in the worker training and higher education components of the human capital pipeline. But another growing challenge has to be addressed: many of the students entering higher education need remedial help before they can progress to more advanced subject matter or reach their full potential in the workplace.[174] The United States led the world in expanding education for the entire population for many decades, an accomplishment that resulted in rising wages, productivity gains, and a growing middle class.[175] Today, however, that competitive advantage is eroding.

Peer countries are outperforming the United States

Low student achievement today will translate into a less productive workforce in the future, and the trends are troubling for the United States. On the 2009 Programme for International Student Assessment (PISA) test, a widely used benchmark for global performance, the United States placed 17th out of 65 countries for reading and ranked 23rd for science. Its scores in these two areas roughly match the OECD average. But US math performance was especially weak: the United States ranked only 31st, with a mean score of 487 (Exhibit 33). By comparison, students in Germany averaged 513; in Finland, 541; in Singapore,

174 Twenty percent of first-year undergraduates reported taking remedial courses in a January 2013 Statistics Briefing from the National Center for Education Statistics. Rates may be much higher in large state university systems; the California State University System, for example, launched an Early Assessment Program to address the fact that 60 percent of incoming freshmen needed remedial education in math, English, or both (see *California's early assessment program*, Policy Analysis for California Education, March 2012).

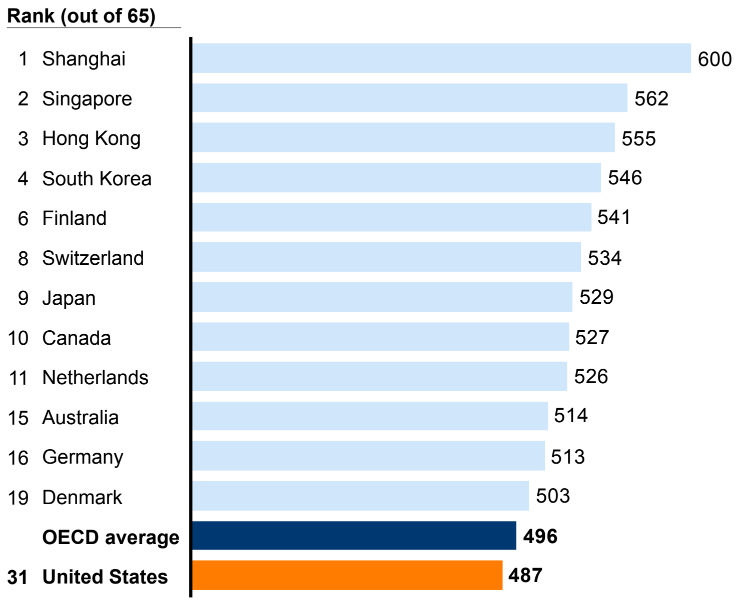
175 Claudia Goldin and Lawrence F. Katz, *The race between education and technology*, Belknap Press/Harvard University Press, 2008.

562; and in Shanghai, 600.[176] Low math scores today will eventually translate into a shortage of workers capable of doing the calculations needed for modern manufacturing processes or adept at interpreting the data that drives the economy.

Exhibit 33

US student achievement in international tests falls below the OECD average

PISA 2009 math (mean score)



SOURCE: OECD; PISA; McKinsey Global Institute analysis

Other nations—including Italy, Poland, and Germany—show that it is possible to significantly raise student achievement, as measured by PISA scores, within a decade or less. Over ten years, each of these countries pursued reforms and added 20 to 30 points to PISA math scores, the equivalent of one-half to almost one school year of attainment.

Although the United States will need to tailor its own solutions, Germany's success suggests that dramatic gains are possible. After that country's students placed in the bottom half of the 2000 PISA rankings, education leaders confronted a system that was manifestly underserving immigrants and economically disadvantaged students. Germany built first on model reforms from its leading states, then gradually scaled them nationally, using common standards and assessments to understand how students learn and how to target interventions. Germany also closed many low-performing schools and gave school leaders more autonomy on decisions ranging from staffing and curriculum to lengthening the school day. As the existing teaching workforce aged and retired, the quality bar was raised for new teachers. From 2000 to 2009, Germany's PISA math scores rose from 490 to 513, the equivalent of more than half a grade level.

176 For the full rankings of all PISA test results, see the OECD website: http://www.oecd.org/pisa/46643496.pdf.

Successful models are emerging from recent US experimentation in school reform

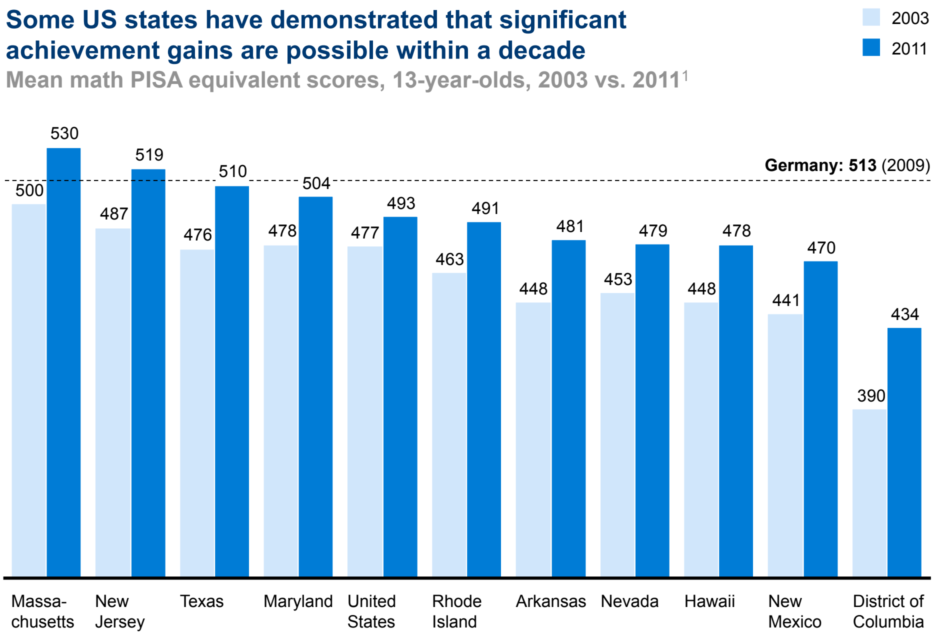
After decades of experimentation in school reform, the United States has now produced a number of successful models, many of which can be replicated at scale. Three broad lessons that have emerged show particular promise as springboards for change: the quality of classroom instruction is vital; there is potential to transform some of the lowest-performing schools through robust turnaround efforts; and technology-enabled personalized learning can amplify the impact of highly effective teachers, accelerating achievement gains.

Many individual US states have made remarkable strides over the past decade as measured by the results of national achievement tests (the National Assessment of Educational Progress, or NAEP). We converted US NAEP test scores into PISA scores to compare how US states have performed in relation to other countries. We find that nine states—Arkansas, Hawaii, Maryland, Massachusetts, Nevada, New Jersey, New Mexico, Rhode Island, and Texas—and the District of Columbia made comparable or even larger strides than Germany's 23-point gain from 2000 to 2009 (Exhibit 34). For some states, this meant bringing low average test scores up to the national average. Texas, Massachusetts, and New Jersey, in contrast, have managed to surpass the national benchmark. In fact, some US states have already achieved PISA-equivalent scores comparable to the PISA performance of leading countries.[177]

Exhibit 34

Some US states have demonstrated that significant achievement gains are possible within a decade

Mean math PISA equivalent scores, 13-year-olds, 2003 vs. 2011[1]



1 Analysis converts NAEP scores to PISA equivalents using mean and standard deviation conversion.
SOURCE: OECD; PISA; National Center for Education Statistics; NAEP; McKinsey Global Institute analysis

National and state policy innovations have built considerable momentum for education reform efforts. For example, as part of the 2009–10 Race to the Top initiative, 38 states implemented changes such as data systems to track student performance and turnaround strategies for low-performing schools. Additionally, 45 states and the District of Columbia have adopted the Common Core State

177 We use the term "equivalent" to distinguish PISA scores reported for the United States from state-specific scores that are converted from NAEP results.

Standards put forth by the National Governors Association and the Council of Chief State School Officers; these standards attempt to create consistency in curricula and expectations. From variations across 50 states and 15,000 districts, national standards have emerged. These changes are just the beginning of needed reforms, but they create a foundation for further innovation. Accelerating these efforts to transform K–12 education would strengthen the entire US system of workforce development and could have a game-changing effect on the US economy.

TEACHERS, TURNAROUNDS, AND NEW TECHNOLOGIES ARE CRITICAL TO IMPROVED K–12 STUDENT ACHIEVEMENT

Three broad strategies hold great promise for improving student achievement and accelerating change if they are undertaken on a system-wide level.

Recruiting, retaining, and developing great teachers

A growing body of research shows that teaching quality is one of the most crucial factors within a school's control that determines whether students will excel or fall behind.[178] Great teachers—those in the top fifth of their peers—can add the equivalent of an additional two to three months of learning to their students' progress each year.[179] The reverse is also true: teachers performing in the bottom fifth of their peers can cost students two to three months of learning each year.

The US teaching profession is poised to experience a wave of turnover, and now is the time to step up efforts to retain the best teachers and attract a new generation of top talent. There are currently 3.3 million public school teachers, but some 40 percent are expected to retire over the next decade, and another 400,000 are expected to leave for other reasons. By 2020, more than 50 percent of the current teachers in US schools will have begun their careers after 2012. With a new generation of teachers entering the classroom, this is a unique opportunity to raise the quality of classroom instruction by changing recruitment approaches and providing a new level of coaching, mentoring, and training to build teaching skills in the critical first five years on the job.

Raising the quality of instruction starts with recruiting exceptional students into the teaching profession. Realizing meaningful gains will hinge on addressing the factors that have discouraged many candidates from entering the profession in the past: lack of a career ladder, low respect for the profession, low pay, and variable principal quality. A recent McKinsey survey of 1,600 high-performing college students found that just 9 percent wanted to go into teaching.[180]

US high school teachers are paid 72 percent as much as all college graduates in the workforce, while in other OECD countries, that figure is 90 percent (Exhibit 35).[181] But making teaching more attractive is not simply a matter of money: professional development is also essential (especially for new teachers

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178 Eric Hanushek, "The economic value of higher teacher quality," *Economics of Education Review*, volume 30, number 3, June 2011.

179 See The New Teacher Project's *The irreplaceables: Understanding the real retention crisis in America's urban schools*, 2012. Also see The Education Trust-West's *Learning denied: The case for equitable access to effective teaching in California's largest school district*, January 2012; and the MET project's *Gathering feedback for teaching*, January 2012.

180 *Closing the talent gap: Attracting and retaining the top-third graduates to careers in teaching*, McKinsey & Company, September 2010.

181 *Education at a glance 2012*, OECD.

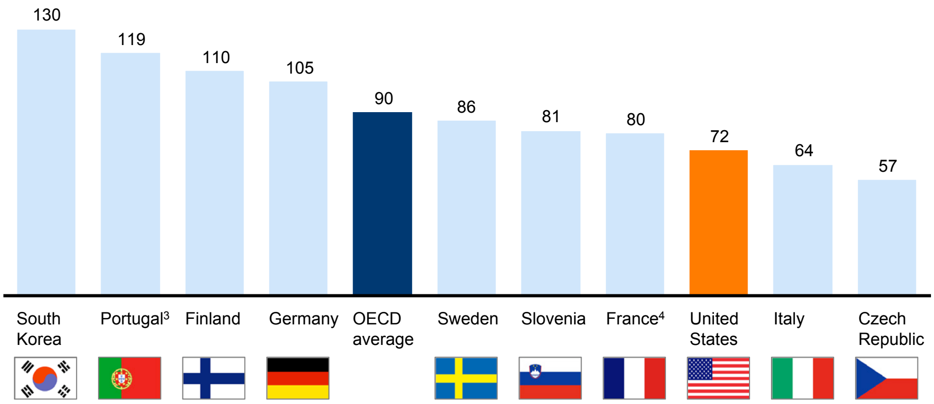
and those who work in troubled schools). A meta-analysis of 1,300 studies found that students scored 21 percentage points higher than average on standardized tests when their instructors received more professional support and training.[182] Studies show that when training is ongoing, collaborative, and driven by relationships with individual coaches, it is most effective at helping teachers raise student achievement.[183]

Exhibit 35

Many countries have higher teaching salaries relative to the average college graduate than the United States

Ratio of upper secondary teachers' salaries[1] to earnings[2] of tertiary-educated workers, 2010

%



1 Figures for Czech Republic, Finland, Italy, Sweden, and the United States are actual salaries. Figures for the other countries are statutory salaries after 15 years of experience.
2 Earnings for full-time, full-year workers (ages 25–64) with a tertiary education.
3 Portugal, 2009.
4 France, 2008.
SOURCE: OECD, *Education at a glance, 2012*; McKinsey Global Institute analysis

Countries with exceptional student achievement treat teaching as a highly selective profession that is accorded tremendous prestige and competitive compensation. Only the very best students are admitted into teaching programs in Singapore, Finland, and South Korea, for example, and standards are especially high for elementary school teachers. Once enrolled, prospective teachers receive rigorous and practical training. The Singapore and Finnish governments pay for teachers' education, and Singapore in particular has designed a path for career advancement and performance pay.[184] The United States could consider options such as college grants for high-performing students who choose teaching, to remove the obstacle of future student loan debt. But regardless of the mechanisms chosen, teachers should be celebrated and respected as skilled professionals who provide a vital public service.

182 See *Reviewing the evidence on how teacher professional development affects student achievement*, Institute of Education Sciences, US Department of Education, October 2007; and Carolyn Hill et al., *Empirical benchmarks for interpreting effect sizes in research*, MRDC working paper, July 2007.

183 Based on numerous reports, including OECD's *The professional development of teachers* and *Teacher professional learning and development* and McKinsey's *How the world's most improved school systems keep getting better.*

184 *Closing the talent gap*, McKinsey & Company, September 2010.

School turnarounds that target "dropout factories"

Seminal research found that approximately 2,000 high schools produced more than half of the nation's high school dropouts. Some 40 percent of students who entered the ninth grade in these schools, dubbed "dropout factories," did not exit the twelfth grade with a diploma in hand, resulting in a waste of potential and bleak future prospects for these young people.[185]

But recent experience shows that despite the multifaceted challenges involved, it is possible to transform the nation's worst-performing schools. The track record on turnarounds has been mixed, but recent data show that more interventionist approaches have tended to be more successful.[186] Ambitious experiments in Rhode Island, Virginia, Los Angeles, Chicago, New York, and Philadelphia are contributing to a growing body of knowledge about what it takes to transform a failing school. There is no one right answer, but examples show that turnarounds are most likely to succeed when they are managed by a lead partner with full autonomy (often an external organization that has experience overseeing successful turnarounds) and when they put a strong school leader and staff in place. Performance standards and instructional improvements, such as an extended school day and year, data-driven instruction, and increased math tutoring, may be effective. Many low-performing schools can also benefit from adding support systems such as social workers and therapists.[187] Not surprisingly, the components of a successful turnaround are very similar to those needed to start a high-performing charter school. These efforts undertaken to date have created an experienced set of school leaders and charter school operators that are adept at transforming school quality.

Examples from US states show that successful school turnarounds can have sustained improvement in educational outcomes. A longitudinal study of turnaround interventions in Virginia showed that 144 turnaround schools closed the gap with their peers in two years and then sustained those gains over a monitored three-year period.[188]

New educational technologies and tools for adaptive learning

New software and online technologies are creating exciting new avenues to engage students, personalize learning, and enable teachers to spend more time on individual instruction. Better use of data on student strengths and

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185 Robert Balfanz and Nettie Legters, *Locating the dropout crisis: Which schools produce the nation's dropouts? Where are they located? Who attends them?* Johns Hopkins University, September 2004. See also Balfanz et al., *Building a grad nation: Progress and challenge in ending the high school dropout epidemic*, 2012 annual update, which cites more recent data to show some progress and classifies only 1,550 high schools as "dropout factories" with graduation rates below 60 percent. Our scenario for school turnarounds does not reflect a 60 percent graduation rate cutoff but instead focuses on directing interventions and increased resources to the nation's 2,000 worst-performing schools.

186 See Craig Hochbein, "Relegation and reversion: Longitudinal analysis of school turnaround and decline," *Journal of Education for Students Placed at Risk*, volume 17, number 1–2, 2012; Andy Smarick, "The turnaround fallacy," *Education Next*, 2010; Joan Herman et al., *Evaluation of Green Dot's Locke transformation project: Findings for cohort 1 and 2 students*, Cresst Report 815, 2012; Thomas Dee, *School turnarounds: Evidence from the 2009 stimulus*, National Bureau of Economic Research, 2012.

187 Based on interviews with turnaround experts as well as research by Roland G. Fryer and Harvard University's Education Innovation Laboratory.

188 Craig Hochbein, "Relegation and reversion: Longitudinal analysis of school turnaround and decline," *Journal of Education for Students Placed at Risk*, 2012.

development needs enables teachers to customize interactive lessons for each student, based on what the students know and how quickly they are learning. There is potential for new technologies to help teachers and parents diagnose exactly what a student has mastered and where there are breakdowns in understanding. And many new tools focus explicitly on helping teachers improve their craft. Finally, a host of device providers are helping schools access these technologies, and a growing number of companies are serving as "integrators," advising schools on how to incorporate a full suite of solutions into the classroom.

Combining technology and classroom instruction to provide blended learning may prove more effective than either traditional or online learning alone. One promising example is found in North Carolina's Mooresville Graded School District, which gives laptops to students in grades 3–12 for use in place of textbooks. Students engage with a range of online content and programming selected by each classroom teacher. Teachers serve as "roaming conductors," orchestrating various working groups and stations spread throughout the classroom. They also engage in continual professional development around technology integration. In addition, parents receive training on laptop use and can access an online portal to track student performance and communicate with teachers. The district has increased graduation rates from 64 percent to 91 percent since implementation of the program in 2007; it now ranks second out of 115 districts in the state.[189]

Long-standing legacy models do not change overnight. The one-teacher/one-room/one-blackboard approach has held sway for decades, and there is hesitation to move toward online and blended learning models. But more dynamic approaches are now establishing track records that make a stronger case for educators to embrace change. Bringing digital learning into the classroom will also entail infrastructure challenges. President Obama recently called on the Federal Communications Commission to bring faster connections to 99 percent of students within five years, using its existing E-Rate program, which would not require congressional action.[190]

IMPROVING K–12 STUDENT ACHIEVEMENT CAN RAISE GDP BY $1.3 TRILLION BY 2030

To calculate the GDP impact of improving K–12 school performance, we chose an approach based on academic research that calculates the impact of academic achievement and cognitive skills on a country's subsequent economic growth rates. The research uses data from OECD countries and finds that one standard deviation improvement in academic achievement (as measured by test scores) translates to nearly a 1 percentage point increase in per capita GDP growth for advanced economies within five years, after controlling for other factors that influence GDP growth.[191] (See the appendix for more detail.)

Using this approach, we find that improvements in US student achievement—for instance, improvements that would match the level of Germany, which places among the top third of countries on PISA scores, or better still Finland, a world leader in mathematics, placing among the top ten countries on PISA

189 Based on interviews with Mooresville Graded School District leadership and the district website (http://www.mgsd.k12.nc.us/MGSD/Home.html).

190 "President Obama unveils ConnectEd initiative to bring America's students into the digital age," White House press release, June 6, 2013.

191 See Hanushek and Woessman (2011) as well as Atherton, Appleton, and Bleaney (2008).

scores—could mean an additional 0.3 to 0.6 percentage point of GDP per capita growth annually.

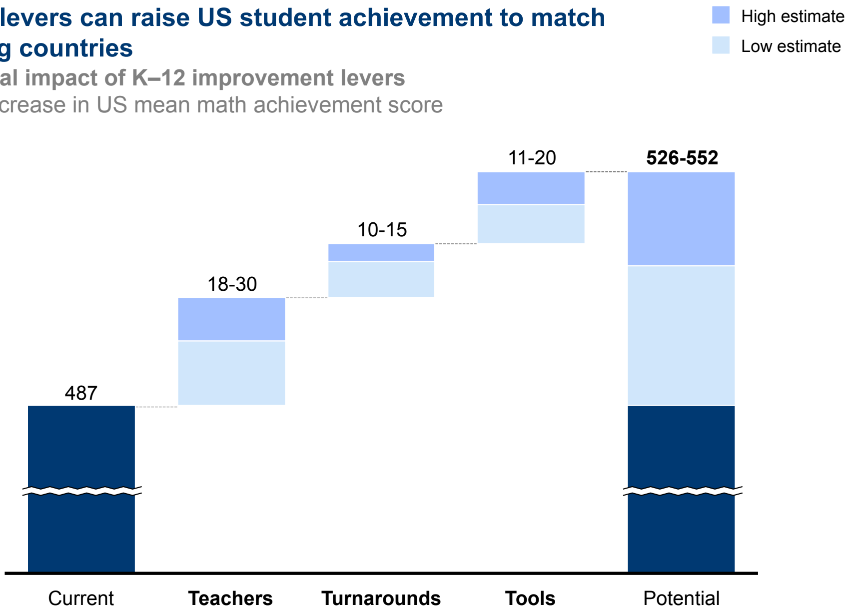
This level of progress seems achievable using the three strategies outlined above: teachers, turnarounds, and digital learning tools (Exhibit 36). To determine the potential impact of these strategies, we used a proprietary, research-based model (described in more detail in the appendix) to determine the student achievement increases that could be expected from improving teacher performance and expanding the impact of an effective teacher through the use of tools and technologies. To model the potential impact from turning around the bottom fifth of US high schools, we determined the achievement gains that could be realized by bringing these schools up to the mean of all US schools. If these gains are achieved, the United States could comfortably reach or even exceed the benchmarks set by Germany or Finland.

Exhibit 36

Three levers can raise US student achievement to match leading countries

Potential impact of K–12 improvement levers

Point increase in US mean math achievement score



SOURCE: OECD; EIU; IHS Global Insight; Hanushek and Woessman, *How much do educational outcomes matter in OECD countries?*; Atherton et al., *International test scores and economic growth*; US Bureau of Economic Analysis; McKinsey Global Institute analysis

These results suggest that improving K–12 education could boost US GDP by $60 billion to $100 billion annually by 2020. These gains are cumulative as more and more students achieve better outcomes, graduate, and join the labor force—and they accelerate in the subsequent decade. The United States would be on course to raise annual GDP by an additional $1.3 trillion by 2030. The "liftoff" effect is even larger if the United States simultaneously develops a more effective system of post-secondary workforce development, for a total impact of $1.7 trillion.

IT WILL TAKE SUBSTANTIAL INVESTMENT TO PRODUCE GAME-CHANGING RESULTS

Reshaping the US system of human capital development will require considerable investment. However, funding is not a panacea—and in fact, a greater focus on creating career ladders and improved professional development for K–12 teachers are two low-cost methods that can yield significant change.

But at the K–12 level, funding will be necessary to raise teacher salaries, adopt new technologies, and transform deteriorating schools. A survey of college students completed by McKinsey found that the minimum base salary required to attract a sufficient number of "top-third" college graduates to a career in teaching is $65,000 a year. Raising pay to that level would require $83 billion a year.[192] The cost of a school turnaround varies greatly: from $600,000 with limited staff replacement to as high as $15 million for a far-reaching turnaround. To size the cost of transforming 2,000 US schools, we have taken a middle-of-the-road estimate of $3 million to $6 million for each school; this requires a total up-front investment of $6 billion to $12 billion.[193] Equipping the nation's schools with broadband, devices, and digital learning tools would also require a multibillion-dollar investment. Estimates vary widely, but a midpoint is $1,000 per student, resulting in a cost of $29 billion to upgrade the technology of half of America's schools.[194]

The cost of reform is significant, but it must be weighed against the sizable long-term gains. The annual investment for K–12 education reform pales against the estimated $1.3 trillion annual GDP gains that could materialize by 2030. Funding for education is not just spending; it is investment that can transform lives, improve economic mobility, and prepare workers for the growing demands of a knowledge-based economy. Given its potential to increase GDP, enhance US competitiveness, and raise living standards for millions of people, this investment would appear to be justified.

Capital can come from both public and private sources. Corporate foundations are one example; GE's Developing Futures in Education program, for instance, has provided funding for seven urban school districts across the country. Companies that depend on highly skilled workers can proactively support STEM education at the K–12 level to build a future talent pipeline, as Intel, AT&T, Pfizer, and many others are doing. Two of the most active philanthropies at the K–12 level are the Bill & Melinda Gates Foundation and the Broad Foundation, both of which invest in school reform and innovation.

One of the most interesting experiments in private-sector involvement is P-TECH, a new six-year high school in New York created through a partnership with IBM, the New York City Department of Education, the New York City College of Technology, and the City University of New York. This creative model features a STEM-intensive curriculum that prepares students for entry-level IT jobs. IBM mentors work directly with students, who graduate with high school diplomas, associate degrees, and good job prospects. P-TECH has attracted wide notice and is already being replicated and scaled up. Chicago is launching five new schools based on this model with participation from IBM, Cisco, Microsoft, Motorola Solutions, and Verizon, and New York State recently announced plans for ten more campuses.

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192 For survey results, see *Closing the talent gap*, McKinsey & Company, September 2010. As a point of comparison, raising salaries to meet the OECD average teacher pay (90 percent of the average salary for tertiary graduates) would cost roughly $60 billion annually.

193 These are funding levels over three years. The $3 million figure is estimated from the Mass Insight report *Turning around the nation's worst schools*, while $6 million is the maximum allowed for school turnarounds under the US Department of Education's School Improvement Grants program.

194 From an estimate by the New Tech Network.

At the post-secondary level, public universities and community college systems alike have seen cuts in state funding since 2008.[195] Many public universities are emulating the fund-raising models used by private institutions and are also opting for debt issuance, taking advantage of the current low interest rate environment. Ohio State University, for example, issued a 100-year "century bond" for $500 million in 2011, and the University of California system followed suit with an $860 million offering in 2012. University bonds have traditionally been tax-exempt, but both of these issuances were taxable, giving the institutions more flexibility in how to use the proceeds.

Because state governments continue to provide the bulk of funding for public universities via budget appropriations, they can demand greater accountability regarding outcomes. Several states are beginning to question the cost-effectiveness of remedial courses that have no vocational context, for example. The federal government, which is the major source of student loans, can similarly tie the availability of funding to institutional performance on measures such as completion rates.

The private sector reaps tremendous benefits from public universities and the community college system in terms of R&D as well as talent development. Public research universities often lie at the heart of the nation's most productive regional industry clusters, and expanded public-private research and educational partnerships can lead to more innovation-based growth as well as greater student engagement.

The current funding crunch is forcing institutions to reassess priorities and look for cost efficiencies. This may set the stage for a fundamental reexamination of their outcomes and models, opening the door to experimentation with online classes and new collaborations with the private sector. Competitive dynamics among individual institutions can also help to drive innovation.

□ □ □

The current wave of innovation in education has produced many local successes and injected new momentum into an area that was once slow to change. Out of these fragmented efforts, it is possible to envision holistic, system-wide solutions that improve outcomes spanning from K–12 through post-secondary education. Human capital is a prerequisite for capturing all the other game changers outlined in this report, and bold action today could set the stage for robust GDP growth in the years ahead. Building a more effective system of talent development is now within the nation's grasp; the challenge will lie in mustering the investment and the political will to make it a reality. This effort will require a long-term commitment as well as a deeper level of collaboration among the public, private, and social sectors. No other undertaking could be more vital to the competitiveness of the United States and the prosperity of its citizens.

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195 See *Recent deep state higher education cuts may harm students and the economy for years to come*, Center for Budget and Policy Priorities, March 2013. The report finds that state funding for higher education has declined by 28 percent per student from 2008 to 2013. Two states—Arizona and New Hampshire—cut higher education spending per student in half during this period.

Appendix: Technical notes

These technical notes provide more detail on some of the definitions and methodologies employed in this report. We address the following points:

1. Overview of approach to estimating GDP and employment impact
2. Shale energy: Methodology for estimating the impact of increased production and capital expenditure
3. Trade: Methodology for estimating the impact of reducing trade deficits in knowledge-intensive goods
4. Big data analytics: Methodology for estimating cost savings, productivity gains, and shifts in profit pools in four sectors
5. Infrastructure: Methodology for estimating the short-term and long-term impacts
6. Talent: Methodology for estimating the impact of improving worker training, post-secondary education, and K–12 education

1. OVERVIEW OF APPROACH TO ESTIMATING GDP AND EMPLOYMENT IMPACT

The specific approach used to size GDP, jobs, productivity, and output impact varies across the five game changers. In some cases, we estimate GDP through a demand-side calculation (as in the energy and trade chapters); in others, we use a supply-side calculation (as with talent). The specific calculations are discussed in each section below. However, we use the same GDP baseline forecast and input-output methodology for assessing impact on GDP and jobs.

Baseline 2020 GDP forecast and labor force against which to measure impact of game changers

To establish a baseline projection of real GDP growth, we average forecasts provided by the Economist Intelligence Unit and IHS Global Insight for 2013–20. Our baseline 2020 GDP is $18,794 billion in real 2011 dollars, which is slightly more conservative than the US Congressional Budget Office (CBO) projection of $19,415 billion (Exhibit A1).[196]

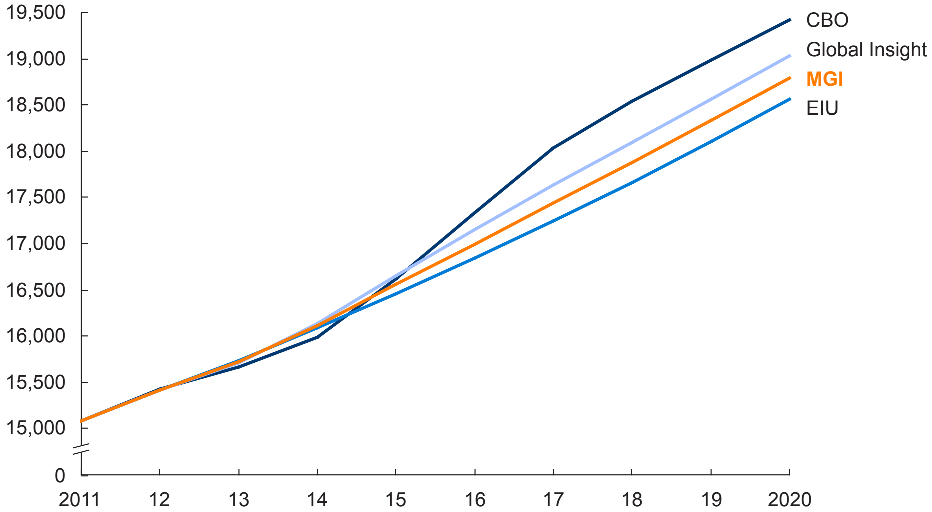
196 The CBO estimate is calculated based on 2011 nominal GDP of $15,075 billion (from US Bureau of Economic Analysis) and the year-on-year real GDP change projected by the CBO through 2020. See *The budget and economic outlook: Fiscal years 2013 to 2023*, Table B-2, Congressional Budget Office, February 2013.

Exhibit A1

Our baseline forecast for GDP growth is in the middle of a range of forecasts

Forecast for real GDP growth through 2020

$ billion (real 2011 $)



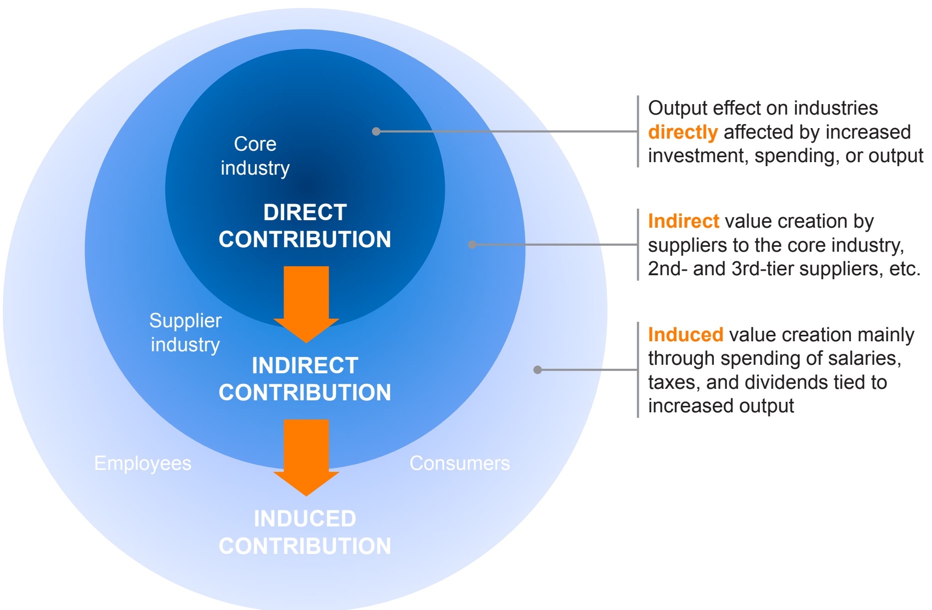
SOURCE: Congressional Budget Office; Economist Intelligence Unit; IHS Global Insight; McKinsey Global Institute analysis

Using input-output tables to calculate GDP and employment impact

To calculate the impact from increasing production in any industry, we use an input-output model that captures not only the direct effects but also the indirect (or secondary) effects on related sectors, as well as the induced effects that ripple through the wider economy (Exhibit A2).

Exhibit A2

Input-output multipliers estimate the economy-wide impact of increased activity in any industry



SOURCE: McKinsey Strategy and Trends Analysis Center; McKinsey Global Institute analysis

The GDP and employment impact for energy and trade competitiveness and the short-term impact of infrastructure are calculated using the 2011 annual input-output "use" table from the US Bureau of Economic Analysis (BEA).[197] This table is a double-entry accounting system in which every industry is entered twice: along the rows as a selling industry and along the columns as a buying industry. Reading down the columns, one sees the industry's supply chain; reading across the rows, one sees its sales distribution or markets.

The "use" table as produced includes imports and exports. Because we want to measure the impact on US GDP alone, we adjust the "use" table by multiplying every entry in a row (i.e., every sale made by an industry) by 1 minus the import share of domestic sales for the industry named at the row where:

$$\text{Import share}_i = \frac{\text{Imports}}{(\text{Domestic output}_i + \text{imports}_i - \text{exports}_i)}$$

For the energy game changer, we make one change to the import adjustment described above. We remove the imports from all industries except the oil and gas extraction industry as well as other key oil-producing and -consuming sectors. We assume that US energy imports would be replaced by domestic production of oil and gas.

The multiplier tables described above give the direct and indirect effects of increasing production in any sector of the economy. A third and quite large effect comes through the change in consumer spending enabled by higher output, called the "induced effect." To create multipliers that include the induced effect, we use a standard approach followed by the BEA, which adds the compensation row and consumer spending column to the "use" table before calculating the multipliers. For the multipliers without induced effect, the compensation row and consumer spending are excluded.

To arrive at jobs multipliers, we adjust every cell of the total requirements table by the ratio of employment to gross output for the row industry and then sum the columns to get the so-called final demand jobs multiplier for the column industry. In this study, which looks at impacts in 2020, we adjust the ratio of employment to gross output to account for productivity changes, assuming that productivity growth from 2011 to 2020 will match growth from 2003 to 2011.

2. SHALE ENERGY: METHODOLOGY FOR ESTIMATING THE IMPACT OF INCREASED PRODUCTION AND CAPITAL EXPENDITURE

To calculate the GDP and employment impact of increased domestic production of shale gas and tight oil, we first estimate the additional annual domestic gross output that can be achieved by 2020 in energy production and manufacturing, and by ongoing capital expenditure. We estimate that US gross domestic output could increase by $285 billion, rising to $515 billion by 2020, driven by higher

197 We do not use the input-output approach in the big data game changer, which measures productivity gains in sectors and so contributes directly to raising GDP. Nor do we use this approach in the talent game changer. We use regression analysis to estimate the impact of K–12 student achievement on GDP growth rates, and for post-secondary education, we measure the impact on wages earned by graduates.

output of US oil and gas production, exports of liquefied natural gas (LNG), and energy-intensive manufacturing industries, and their associated indirect and induced effects on other sectors. We convert this rise in output to GDP using the 2011 output-to-value-added multiplier table and the output-to-jobs multiplier table, both based on the input-output, or I-O, "use" table produced by the BEA.

Estimating the impact of additional production of tight oil

In 2012, the United States produced about 1.5 million barrels per day (mbpd) of light tight oil. We examine two scenarios for future domestic production: the low end assumes an additional 4 mbpd, and the high end assumes an additional 8 mbpd.

In both scenarios, the price of oil used is an average calculated from 2011 US crude oil import statistics. In 2011, the United States imported 8.8 mbpd of crude oil in total. Roughly 20 percent of the imports were light crude, 35 percent were medium crude, and the remaining 45 percent were heavy crude. The total oil import bill in 2011 was $335 billion, or $103.40 per barrel averaged across all assays. The scenarios of 4 mbpd and 8 mbpd of additional production at $103.42 per barrel result in additional output of $150 billion to $300 billion annually by 2020. We then use the input-output multiplier table for the oil and gas extraction sector to estimate the direct, indirect, and induced GDP impact.

The GDP impact also assumes a slight increase in the output of refined products. We assume that no additional refinery capacity is added by 2020, but that utilization of existing US Gulf Coast refineries increases from the current 87–90 percent to 97 percent of nameplate capacity (roughly 7.5 mbpd in 2011). This adds 0.5 to 0.6 mbpd of refined output to 2012 refined product exports of 2.4 mbpd. We presume a 5 percent premium for refined product over the price of crude, which translates to a per-barrel price of $108.60 and additional annual output of $20 billion to $25 billion.

Estimating the impact of additional natural gas production

In 2012, the United States imported nearly three trillion cubic feet (tcf) of natural gas by pipeline, almost all from Canada, as well as 174 billion cubic feet of LNG. We assume that pipeline imports continue to decline, so that by 2020, US imports are 1 tcf lower. The price of Canadian pipeline imports has fallen from $4.09 per thousand cubic feet in 2011 to $2.79 in 2012. We assume that by 2020, import prices will still be in the range of $4 to $6 per thousand cubic feet. The impact of a 1 tcf reduction in LNG imports at this price is $4 billion to $6 billion annually.

Our sizing estimate is based on an assumption of 6 to 15 bcfd of LNG exports by 2020. To calculate export value, we use the 2011 US LNG export price (averaged across all destinations) of $5.02 per thousand cubic feet. This translates to annual LNG exports of $11 billion to $27 billion. Adding these numbers to the expected $4 billion to $6 billion reduction in LNG imports, the total annual output of LNG is estimated at $15 billion to $33 billion.

Estimating the impact of additional production in petrochemical manufacturing

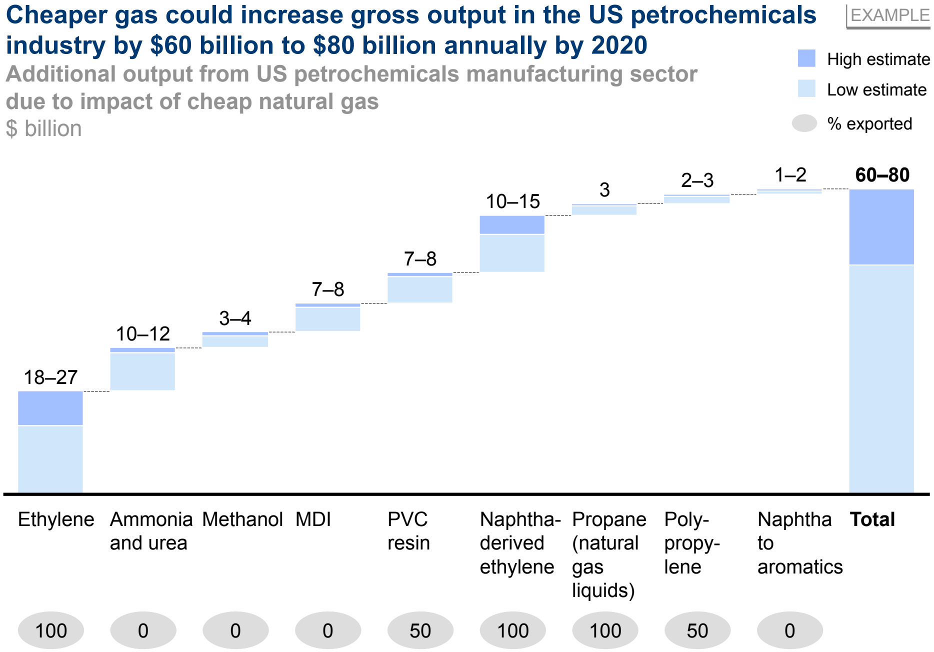
The availability of cheap natural gas is likely to increase production in five categories of petrochemical manufacturing: ethylene; ammonia and methane products; methanol; propane- and naptha-derived compounds; and PVC (Exhibit A3). We estimate the additional domestic production, whether for export or for import substitution, and convert the resulting gross output estimate into GDP impact using output-to-value-added multipliers.

Exhibit A3

Cheaper gas could increase gross output in the US petrochemicals industry by $60 billion to $80 billion annually by 2020

Additional output from US petrochemicals manufacturing sector due to impact of cheap natural gas

$ billion



NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

Estimating the impact of additional production in other manufacturing industries

In addition to petrochemicals, the impact of cheaper gas is likely to be felt in a handful of other energy-intensive industries. These include primary metals, cement, and glass manufacturing, which could produce an additional $6 billion to $20 billion of output, primarily for import substitution. There could also be up to $2 billion in additional output of plastics packaging. Finally, paper and pulp mills could see an additional $2 billion in output that could contribute to small growth in exports to meet growing global demand for paper packaging.

Estimating the impact of additional ongoing capital expenditure

The estimate of annual output by 2020 also includes ongoing capital expenditure, primarily on upstream well drilling and gathering infrastructure. In 2012, North American upstream capital expenditure in unconventional energy (including oil sands, tight oil, shale gas, tight gas, and coalbed methane) was estimated at $128 billion.[198] We estimate that most of this has gone to shale development ($95 billion to $100 billion). By 2020, we assume that total US upstream capital expenditure will rise by $30 billion to $50 billion, for a total of $125 billion to $150 billion.

198 *IHS upstream spending report*, IHS, April 30, 2012.

3. TRADE: METHODOLOGY FOR ESTIMATING THE IMPACT OF REDUCING TRADE DEFICITS IN KNOWLEDGE-INTENSIVE GOODS

We define knowledge-intensive manufacturing to include six industries: motor vehicles, trailers, and parts; other transportation equipment (which includes aerospace); chemicals (including pharmaceuticals); medical, precision, and optical equipment; semiconductors and electronics; and machinery and appliances (which also encompasses computers and office machinery).[199] To calculate the GDP impact of reducing the trade deficit in knowledge-intensive manufacturing industries, we start with the current 2012 trade deficit of $270 billion (in real 2005 dollars). This is 2.0 percent of 2012 GDP (which was $13.593 billion in real 2005 dollars) and was 1.3 percent of 2000 GDP and 0.08 percent of 1990 GDP.[200]

As explained in Section 1 of this appendix, our baseline estimate for 2020 GDP is $18.794 billion in real 2011 dollars. Assuming the trade deficit in 2020 stays unchanged from 2012 at 2 percent of GDP, the 2020 trade deficit would be $375 billion in real 2011 dollars. To reduce the 2020 trade deficit to 1.3 percent of GDP (the same share as in 2000), US gross output must increase by $125 billion (in real 2011 dollars). To reduce the 2020 trade deficit to 0.08 percent of GDP (the same share as in 1990), output must increase by $375 billion (in real 2011 dollars).

The GDP impact of this additional gross output is calculated using the output-to-value-added multiplier based on the 2011 I-O "use" tables described in Section 1. The multiplier varies by industry, ranging from 1.14 for chemicals to 1.60 for computers, electronics, and medical devices. Since we do not project which industries will contribute the additional gross output, we simply use the highest multiplier within the subset of industries that are considered likely to contribute to a surplus; this turns out to be the "other transport equipment" sector, which includes aerospace. The multiplier for this industry is 1.58, close to the high end of the range of multipliers for knowledge-intensive industries. Multiplying the gross output range of $125 billion to $375 billion by 1.58, we get a GDP impact of $200 billion to $590 billion in real 2011 dollars.

The employment impact is calculated using a similar approach, and the output-to-jobs multiplier is based on the 2011 I-O "use" tables. In this case, the jobs multiplier for "other transport equipment" is 4,740 jobs per $1 billion in incremental output. Multiplying the gross output range by this multiplier, we get the jobs impact of 600,000 to 1.8 million annual jobs.

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199 The United Nations International Standard Industrial Classification Rev. 3.1 codes lists these as D34, Manufacture of motor vehicles, trailers, and semi-trailers; D35, Manufacture of other transport equipment; D24, Manufacture of chemicals and chemical products; D33, Manufacture of medical, precision, and optical instruments, watches, and clocks; and D32, Manufacture of radio, television, and communication equipment and apparatus (includes semiconductors). The last industry (machinery and appliances) encompasses D29, Manufacture of machinery and equipment n.e.c.; D30, Manufacture of office, accounting, and computing machinery; and D31, Manufacture of electrical machinery and apparatus n.e.c.

200 Figures for goods trade deficits and surpluses in this chapter, including sector-specific figures, are expressed in real terms (2005 dollars) as the data is typically presented in that form. We make exceptions for two industries, using nominal values for semiconductors and communication and electronic equipment and for computers and office machinery. For these two industries, real values based on the hedonic price index yield unrealistically high growth rates. By using nominal values, we effectively use a price deflator of 1 instead of the hedonic price index. When sizing the GDP impact, we convert the trade deficit and GDP values to real 2011 dollars in order to remain consistent with our treatment of other game changers in this report.

4. BIG DATA ANALYTICS: METHODOLOGY FOR ESTIMATING COST SAVINGS, PRODUCTIVITY GAINS, AND SHIFTS IN PROFIT POOLS IN FOUR SECTORS

In four large sectors of the economy—retail, manufacturing, health care, and government—we estimate that big data analytics can generate $610 billion of annual productivity gains and cost savings. In retail and manufacturing, these gains can translate to $325 billion in additional GDP by 2020. This game changer can also have an impact on profit pools and market share within these sectors. For example, as retailers exploit the opportunities of big data and analytics, nearly $600 billion in profit pools may shift toward these firms.

Sizing the impact in the retail sector

The operational improvements made possible by big data in retail have a direct impact on productivity and GDP, as they focus on maximizing labor inputs and creating performance transparency. Our sizing approach aims to estimate the potential productivity gain on the US retail sector as a whole. This approach builds on previous MGI work that estimated the value potential created in individual firms through a model that focuses on key drivers that include the following: subsector cost structure archetypes, which express various cost categories as a percentage of sales; estimates of impact by individual lever, expressed as a percentage reduction of cost or a percentage increase in volume or price; relative relevance of a lever in a particular subsector; and subsector sales, which allow us to calculate not just the percentage impact on margins but also in absolute dollars.[201] Applying real GDP projections for the retail sector from Moody's Analytics to real 2011 sales for retail subsectors from US Census Bureau data, we estimate baseline 2020 sales forecasts for the various retail subsectors in real 2011 dollars.

Sizing the impact in the manufacturing sector

We estimate a potential impact in both productivity gains and shifts in market share for each lever across the US manufacturing industry as a whole. The approach applies levers to applicable subsectors and sums the impact across subsectors to result in an estimated impact range for each lever. For each lever identified, the estimation of impact uses the following equation for each manufacturing subsector i:

$$\text{Total impact} = \sum_i \text{Applicability}_i \times \text{Spend}_i \times \text{Lever impact}_i$$

- "Spend" refers to the relevant baseline statistic applicable to the lever, such as R&D spending for the R&D efficiency lever. This value is determined by multiplying the relevant statistic from the US Census Annual Survey of Manufactures (e.g., total output) by subsector average weighting factors (e.g., R&D spend as a percent of output) as determined by a sample of outside-in financial statements from subsector-relevant companies and experts with subsector experience.

- The "applicability" of the lever to each particular manufacturing subsector (e.g., chemicals manufacturing, textiles, electronics) as determined by

201 *Big data: The next frontier for innovation, competition, and productivity*, McKinsey Global Institute, May 2011.

the nature of the lever and discussion with experts in those fields. Each subsector is assigned a weight between 0 and 1.0, which accounts for both the applicability of the lever and the likelihood of adoption in an optimistic scenario.

- The typical range of "impacts" of the lever as seen in other case examples, adjusted for any major cross-sector differences. For example, experience with design-to-value cases has shown savings on the order of 15 to 40 percent, depending on subsector.

We project the values forward to 2020 using real projected growth rates for gross output by the manufacturing industry from Moody's Analytics, applied to real 2010 gross output by industry from the US Census Bureau's Annual Survey of Manufactures data.

Sizing the impact in the health-care sector

Big data could generate up to $190 billion per year in productivity improvements for the US health-care sector, primarily through improvement to clinical operations, more targeted R&D, and customizing actions toward specific patient groups. Comparative effectiveness research, for example, utilizes patient and treatment data to determine which treatments are most effective for subpopulations of patients. Our estimate of US productivity improvement potential is based on the notion that the United States could use comparative effectiveness research to reduce state-by-state variability in outpatient care, inpatient care, and drug/non-durable costs. Bringing the four least efficient deciles of US state expenditures into alignment with the US median, for example, would result in up to a 4.2 percent decrease in spending in these areas. The impact of these cost savings alone is estimated at up to $75 billion.

Sizing the impact in government

Automation enabled by big data could drive up to $95 billion in productivity gains in the US public sector by 2020. To estimate this impact, we draw on previous McKinsey & Company research that assessed the amount of time spent on administrative activities in other nations' public sectors as well as discussions with experts on the US public sector.[202] We estimate that big data analytics can increase administrative labor productivity by 15 to 20 percent through mechanisms such as automated form population, improved customer segmentation, improved call-center or caseload support, reduced data search time, and automated decision making.

To estimate the impact, we use baseline spend as derived from BEA measures of compensation for federal, state, and local government workers (excluding educators but including military personnel) in 2011 and triangulate against government outlays by function reported by the Office of Management and Budget that target those areas where administrative reduction levers would be most applicable. The results estimated a total spend in 2011 of approximately $1.2 trillion, which we projected forward to 2020 using the 3 percent increase in discretionary expenditures projected by the CBO. Taking into account an estimate that only 25 to 50 percent of the labor time will be spent on tasks that lend

202 *The road to improved compliance*, McKinsey & Company Public Sector Practice, September 2009.

themselves to automation, we estimate total productivity savings on the order of $35 billion to $95 billion.

5. INFRASTRUCTURE: METHODOLOGY FOR ESTIMATING THE SHORT-TERM AND LONG-TERM IMPACTS

In the infrastructure game changer, we size the economic impact of higher spending in the short term and of greater and more productive capital stock in the long term.

Estimating the short-run GDP and jobs effect of infrastructure investment

Earlier McKinsey Global Institute work has estimated that the optimal infrastructure investment rate for the United States is 3.6 percent of GDP.[203] This assumes that countries should invest annually in infrastructure to maintain stock at 70 percent of GDP growth plus depreciation. This benchmark is the average across a group of large advanced and emerging economies, including the United Kingdom, Canada, the United States, Germany, Spain, Italy, China, India, Poland, and South Africa. It also happens to be Germany's current infrastructure stock. Since the United States currently invests around 2.6 percent of GDP in infrastructure, it will require an additional annual infrastructure investment of 1 percentage point of GDP to close the gap.

Given these numbers, we apply induced output to value-added multipliers from the 2011 I-O "use" table provided by the BEA (using the construction sector as the target sector) to estimate the short-run effect of increasing infrastructure investment for each industry in the US economy. Using this approach, we arrive at a real GDP estimate in the short run of $320 billion by 2020.

In order to triangulate our estimate, we use the American Society of Civil Engineers' "Failure to Act" economic reports, which estimate that an additional $157 billion is needed annually to close the infrastructure investment gap by 2020. Using this number, we again apply the induced construction input-output multipliers to estimate the short-run GDP impact. For this lower estimate of the infrastructure need, we get an annual short-run real GDP impact of $270 billion by 2020. To estimate the jobs impact, we use the direct and indirect output to jobs multipliers from the 2011 I-O "use" tables provided by the BEA, again using construction as the target sector.

Estimating the direct supply-side GDP effect of greater capital stock

For the direct supply-side effect, we assess the effect of expanding the infrastructure stock beyond the baseline (annual infrastructure investments equal to 2.6 percent of GDP). We start by calculating the additional, accumulated new infrastructure stock net of depreciation. Again, we base this on the GDP projection and the additional annual infrastructure investment equal to 1 percent of GDP. We assume a depreciation rate of 2.5 percent annually, and from earlier MGI work, we found the current infrastructure stock in the United States equals 64 percent of GDP. Hence, the additional infrastructure stock in 2020 is given by the depreciated infrastructure stock from 2019 plus the additional 1 percent of

203 *Infrastructure productivity: How to save $1 trillion a year*, McKinsey Global Institute, January 2013.

GDP invested in new infrastructure in 2019. This equals $1.2 trillion in additional infrastructure stock by 2020.

We take the output elasticity of public capital from Bom and Ligthart (2008) as the basis for our calculations.[204] Using this, we estimate the marginal productivity of the infrastructure, or the rate of return on the infrastructure investment, for each year. We assume a non-linear relationship and therefore use the following formula:

$$\Delta GDP_t = \theta \times \Delta \text{Public capital}_t \times \left(\frac{\text{GDP}}{\text{Public capital}}\right)_t$$

In this equation, θ is the output elasticity and $\Delta Public\ capital$ is the annual additional investment.

Increased infrastructure investment has implications for the infrastructure stock relative to GDP in the United States. Current infrastructure stock is estimated at 64 percent of GDP. Closing the gap by investing one additional percentage point of annual GDP on an ongoing basis increases the infrastructure stock to 66 percent of GDP by 2020 and to 69 percent of GDP by 2030. This implies that the United States will be able to almost close the gap to the world average (which is infrastructure stock equal to 71 percent of GDP) by 2030.

We estimate that the annual direct effect from expanding the infrastructure stock by 2020 will equal $160 billion and that the effect by 2030 will equal $360 billion.

Estimating the GDP effect of higher productivity of infrastructure investment

When calculating the effect of more productive future infrastructure investment, we take a conservative approach, considering productivity improvements for transportation infrastructure only (roads, rail, ports, and airports). Our own estimates and the work of others confirm that transportation assets, especially roads and highways, are underperforming relative to other types of infrastructure and therefore have the largest potential for improvement. From earlier McKinsey Global Institute work, we have estimated that transportation accounts for 32 percent of the total infrastructure stock. Using this, we calculate the annual infrastructure spend as 32 percent of the 3.6 percent of GDP, which equals 1.2 percent of GDP.

To estimate the effect of efficiency improvements of 25 to 30 percent in infrastructure delivery, and total productivity gains of 35 to 40 percent in delivery, project selection, and operations, we build on the same MGI report, where examples of better planning, delivery, and operations were extrapolated to estimate the potential to achieve cost reductions. The savings potential was based on McKinsey & Company's work with governments and private-sector infrastructure players around the world, an extensive literature review, and insights from more than 400 case examples.

This implies that the United States can, in effect, get 60 percent more infrastructure for the same annual investment. Applying this to the annual total investment in transportation infrastructure means that by investing an additional

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204 See Pedro R. D. Bom and Jenny E. Ligthart, *How productive is public capital? A meta-analysis*, CentER and Department of Economics, Tilburg University, January 2008.

1.2 percent of GDP (equal to $200 billion annually), the effective, accumulated investment net of depreciation is $2.4 trillion. Using the same methodology and elasticity as for the direct supply-side effect, we arrive at our estimate of $120 billion in real GDP by 2020 and $250 billion by 2030.

6. TALENT: METHODOLOGY FOR ESTIMATING THE IMPACT OF IMPROVING WORKER TRAINING, POST-SECONDARY EDUCATION, AND K–12 EDUCATION

We calculate the GDP impact of improvements in higher education and worker training using an income-based approach, calculating the impact of each strategy based on the number of workers that attain a higher skill level and consequently a higher employment rate and higher wage. We calculate the GDP impact of K–12 student achievement through its impact on per capita GDP growth rate, as shown in academic literature.

To measure the impact of the seven strategies discussed to improve the US system of talent development, we create a baseline picture of the 2020 US labor force by projecting current trends of population growth, demographics, immigration, and educational attainment using data from the US Census, US Bureau of Labor Statistics (BLS), and the National Center for Education Statistics (NCES). We assume the unemployment rate will be 6 percent by 2020. Our baseline shows that the US labor force (16 years and older) grows to 164 million by 2020, with 154 million people employed.

Estimating the GDP impact of industry-specific short-term training

We assume that high school graduates receiving effective industry-specific training will exhibit the same labor force participation rate, employment rate, and wages of the associate degree population. We start with the baseline projection to calculate the total number of new high school graduates each year through 2020 and through 2030, less the share of high school graduates going on to pursue tertiary degrees; this works out to be 7.6 million people in 2020 and 13 million people in 2030. Based on current trends, 16 percent of these graduates will receive some sort of post-secondary, industry-specific training. Further improvement is considered against two benchmarks: Sweden (21 percent) and Finland (26 percent). We calculate that if the United States matches Sweden, it will train an additional 351,000 high school graduates cumulatively by 2020 and 589,000 by 2030. Matching Finland will train twice as many.

The GDP impact is then calculated as this additional population, multiplied by the increase of 2020 and 2030 baseline labor force participation rate, employment rate, and median wage from that of high school graduates to that of two-year, associate degree holders. We estimate the GDP impact to be $5.1 billion to $10.2 billion by 2020, and $9 billion to $18 billion by 2030.

In addition, there are currently some 1.3 million more unemployed high school graduates than the number prescribed by the natural rate of unemployment of 6 percent, and industry-specific training could improve their job prospects. Increasing the enrollment rate of industry-specific training among this group to Sweden's benchmark of 21 percent or Finland's 26 percent would train 65,000 to 130,000 additional skilled workers. If we assume these newly trained workers move from unemployment to assume the employment rate and median wage of associate degree holders, we estimate an incremental gain of $2 billion to $4 billion in GDP.

Rounding up these numbers, the total GDP impact of this approach is thus estimated at $7 billion to $15 billion by 2020 and $11 billion to $21 billion by 2030.

Estimating the GDP impact of better labor market outcomes for graduates of two- and four-year college programs

To determine the extent of poor labor market outcomes, we separately examine the distribution of earnings among tertiary graduates who work full time and those who work part time.[205] Based on census data, we find that 27 percent of college graduates working full time earn less than the median wage of full-time workers with an associate degree ($42,400 per year). Among associate degree holders working full time, 33 percent earn less than the median wage of a full-time high school graduate ($35,067 per year).

NCES data indicate that 5.8 million associate and 15.4 million bachelor's or advanced degree holders will enter the workforce between 2012 and 2020. Using the 2010 rate of employment for tertiary degree holders (0.924) and the ratio of full-time workers (71 percent for associate and 75 percent for bachelor's or advanced), we estimate that an addition 3.8 million associate and 10.7 million bachelor's or advanced degree holders will be working full time by 2020.

However, this number needs to be adjusted for those who opt into low-paying careers voluntarily. Using BLS data, we find that 7.3 percent of all bachelor's degree jobs pay a median salary that is less than the associate degree median earnings.[206] We assume that these bachelor's degree holders opt in to the lower-paying careers, and that their earnings do not represent a skills mismatch. We conclude that the remaining 73 percent of bachelor's degree holders who are earning less than the associate degree median wage could earn more if they gained a different skill set or more skills while in college.

Furthermore, to reduce the impact of geographic cost-of-living differences, we use university-reported data on median college graduate earnings with the college's geographic region from Payscale.[207] We compare, by region, the number of schools below the national and regional median wage and find that 15.8 percent of all schools below the national median were above their region's median (Exhibit A4). We assume that these schools have low wages for graduates because of low cost of living, and we remove that cohort from our target population of students who can benefit from better post-secondary schooling. We apply this adjustment to workers with associate and bachelor's degrees.

205 See US Census Bureau, Current Population Survey 2011, Annual Social and Economic Supplement. http://www.census.gov/hhes/www/cpstables/032011/perinc/new03_010.htm

206 See BLS, Table 1.7, Occupational employment and job openings data, projected 2010–20, and worker characteristics, 2010.

207 See Payscale College Reports, 2009–2011.

Exhibit A4

Roughly 16 percent of graduates earn less than the national median wage due to differences in regional costs of living

Regions where schools below national median are also below regional median

Regions where some schools below national median are above regional median

	Number of schools with graduates earning below the national median	+	Number of schools with graduates earning below their region's median	=	Number of schools unfairly categorized as performing below expectations
Northeast	102		145		n/a
Central South	105		77		28
Midwest	167		135		32
Mountain	15		22		n/a
Multistate	3		3		0
South Atlantic	107		86		21
West Coast	14		46		n/a
Total	**513**				**81**

81 of 513 schools (15.8 percent) with below-median performance can be explained by geographical cost-of-living differences

SOURCE: Payscale College Salary Report, 2010–12; McKinsey Global Institute analysis

After these adjustments, we find that 1.1 million associate and 1.8 million bachelor's or advanced degree holders who work full time can benefit from improved two- and four-year college programs. If we raise the wage of the 1.1 million associate workers who earn less than the high school median to at least the high school median wage, they would receive additional earnings of $10.9 billion in 2020; raising their wages to the associate's median would confer additional earnings of $18.5 billion in 2020. The 1.8 million bachelor's degree holders earning less than the associate's median could earn an additional $20.9 billion if we raise their wages to the associate's median; raising their wages to the bachelor's median would increase total earnings by $54.7 billion. Combining the effects on all three groups of full-time workers yields $31.8 billion to $73.3 billion of GDP impact in 2020.

To size the impact on the part-time working population, we repeat the same process and arrive at a 2020 GDP impact of $12.4 billion to $21.0 billion attributed to part-time workers. Combining full-time and part-time workers yields a total impact of $44.1 billion to $94.2 billion added to 2020 GDP. Applying the labor force growth of tertiary degree holders between 2021 and 2030 from NCES data, we project a GDP impact between $104.2 billion and $224.8 billion in 2030.

Estimating the GDP impact of more STEM graduates

We examine the impact of increasing the US graduation rate for science, technology, engineering, and math majors to the global average of 23.4 percent for bachelor's degrees and 19.8 percent for associate degrees. We first created a baseline STEM graduation rate for 2020 based on percent of STEM degrees granted in 2012 and the ten-year trend in degree representation among graduates from 2000 to 2011. As a result, we estimate that 14.5 percent of four-year graduates and 12.3 percent of two-year graduates between 2012 and 2020 will graduate as STEM majors. We discuss two levers for improving this rate.

First, we sized the potential impact of reducing attrition among STEM majors to match non-STEM freshman majors. This leads to an increase in persistence among STEM majors from 53 percent to 76 percent and increases STEM representation among graduates from 14.5 percent to 17.9 percent.

We then calculate the necessary increase in enrollment to further increase STEM representation among graduates from 17.9 percent to the world average of 23.4 percent. Creating a baseline picture of STEM enrollment is challenging; estimates vary widely. We calculate that to get the graduation distribution of 2012, freshman STEM enrollment would have to be 15.1 percent. This falls in the range provided by the NCES Beginning College Survey. Based on our baseline projection of declining STEM representation among graduates, we estimate that freshman enrollment in STEM will decline to 13.9 percent by 2020, which is in the lower bounds of NCES data. To achieve a 23.4 percent graduation rate, freshman enrollment in STEM will need to improve from 13.9 percent to 20.5 percent.

The increase in the number of STEM degree holders among those who graduate between 2012 and 2020 has three effects. First, the number of STEM degree holders entering the workforce between 2012 and 2020 increases by 1.7 million, 1 million of whom we project will pursue a STEM job (assuming the diversion rate to non-STEM careers is unchanged from today). These STEM graduates will then receive a STEM wage premium of 25 percent, or roughly $14,500 on average. The combined effect of more STEM workers earning a wage premium leads to an increase in GDP of $25 billion over the baseline.

To extend the GDP impact to 2030, we apply the NCES projected growth rate of the bachelor's and associate workforce from 2012 to 2020 to the 2020 levels, and then calculate the additional graduates that are projected to enter the workforce from 2020 to 2030. Assuming that the STEM attrition and enrollment rate targets for 2020 have been reached and are sustained from 2021 to 2030, there would be three million additional STEM workers with tertiary degrees by 2030. Multiplying this by the wage premium of STEM jobs, we estimate the 2030 GDP impact to be $49 billion.

Estimating the GDP impact of higher-skilled immigration inflows

We discuss two scenarios: increasing the annual issuance of H-1B temporary worker visas, and substituting incoming family-sponsored permanent resident high-school graduates in the labor force for permanent residents with bachelor's or advanced degrees.

We assume the United States will increase the annual issuance of H-1B visas to the level seen in 2001, when 161,000 H-1B visas were issued. (The average for 2009–12 was 124,000.) This annual increase of 37,000 H-1B visas translates to an increase of 130,000 H-1B holders if one amortizes the additional issued visas evenly over six years. Assuming that these additional foreign workers earn the median tertiary-educated STEM wage of $65,000, we calculate the additional total earnings of $8.5 billion to both 2020 and 2030 GDP.

We then focus on increasing the average educational attainment of working-age family-sponsored permanent residents. Today there are 12.5 million permanent residents and 3 million temporary visa holders. In 2012, 49 percent of permanent residency permits were issued to immediate family members of citizens. An additional 39 percent were issued to second-degree relatives (extended family) of citizens and permanent residents (also called family-sponsored permanent residents). Only 4 percent are employment-based, who are generally highly skilled already.[208] We first project the number of working-age family-sponsored permanent residents who will be employed in 2020 and 2030, assuming the same educational breakdown of the foreign-born, non-citizen population as in 2012 and applying the same labor force participation rate and employment rate to the future population. We then substitute all of the projected net increase in high school graduate (or lower) workers who will be employed by 2020 and 2030, with bachelor's or advanced degrees. The difference in the labor force is calculated as 1.29 million, or roughly 17 percent of the 7.4 million incoming immigrants by 2020, and 3.1 million by 2030. The wage differential between these two groups yields an increase of $22 billion in earnings from the baseline by 2020 and $54 billion by 2030.

Calculating the GDP impact of raising K–12 student achievement

We base our approach on academic research that uses results from standardized international tests for 64 countries (23 in the OECD) going back 50 years to establish a link between student achievement and economic growth.[209] One standard deviation improvement in national academic achievement test scores translates to a 1.4 percentage point increase in per capita GDP growth rates for OECD countries (excluding Mexico and Turkey). We refine the approach based on subsequent research showing a strong but time-lagged relationship between student achievement and economic growth: one standard deviation improvement in achievement translates to a 0.9 percentage point increase in the per capita GDP growth rate within five years.[210]

To calculate the impact on growth, we assume the United States can begin a steady decade's worth of academic achievement growth, gradually building to a low of 30 points gained on the Program for International Student Assessment test and a high of 50 points gained on PISA in 2013 to 2023 (benchmarked to gains by Germany and Sweden). Based on findings by Atherton et al., we delay the impact of this achievement gain on per capita GDP growth by five years, but in 2018, we begin to increase the expected per capita GDP growth rate proportionate to the gains experienced five years previously. After 2028, we assume that the increase in academic achievement creates a permanently higher rate of per capita GDP growth of 0.3 to 0.6 points. By 2020, this leads to $60 billion to $100 billion more in GDP, and by 2030, a $770 billion to $1.3 trillion rise in GDP.

Estimating the improvement in K–12 achievement from turnarounds

To model the potential impact from turning around the bottom fifth of US high schools, we used the distribution of mean high school performance on the California CAHSEE math exam, which all high school students take, to understand what a typical distribution of school outcomes could look like. We then assumed that in a given year, half of these could be addressed as turnaround schools, with the odds of a successful school turnaround at 27 percent. This number is based on the percentage of high schools that received School Improvement Grants from

208 US Department of State, visa statistics 2012, Table II.

209 Eric A. Hanushek and Ludger Woessmann, "How much do educational outcomes matter in OECD countries?" *Economic Policy*, volume 26, number 67, July 2011.

210 Simon Appleton, Paul Atherton, and Michael Bleany, *International school test scores and economic growth*, Centre for Research in Economic Development and International Trade, University of Nottingham, No. 08/04, 2008.

the US Department of Education for turnaround efforts and that experienced double-digit improvement in student outcomes; this set turns out to be 96 of 354 high schools. Repeated efforts at turning around schools are assumed to have the same odds of success with each attempt.

After three years, a successful school turnaround is seen as bringing the school's pre-existing performance up to the mean of all schools, based on research suggesting that successful turnaround schools converge to the mean of school performance over time.[211] We then calculated a new mean for school performance based on the resulting distribution of schools. Because the mean of schools is the same as the mean of students, we took this new mean as the level of improvement possible, after converting CAHSEE scores to a comparable PISA score. Based on this approach, we estimate that turning around the bottom fifth of American high schools would add the equivalent of ten to 15 PISA points to US student achievement.

Estimating the improvement in US K–12 achievement from teachers, tools, and technologies

Our approach to calculating the impact of teachers and tools is based on a proprietary, research-based model of student achievement and teacher performance. The model develops a 20-year composition of the teacher workforce that segments teachers by characteristics such as years of service, subject of expertise, and measured effectiveness, among others. Input parameters to the model include class size, length of teaching day, impact of technological aids, definition of teacher roles and career ladder, compensation structure, and several others. Based on changes to the input variables, the model projects the composition of the teacher workforce in the future—including the number of teachers in various segments such as years of service, roles, and level of effectiveness. Based on this output, we can estimate the change in student achievement using research showing that top teachers can add 1.4 years of learning to the average student in a single school year, and an above-average teacher 1.2 years.[212] The model can be run for the entire US education system or for specific states, districts, or special-needs segments.

We assessed the possible impact of elevating the teaching profession through improved professional development, recruiting from the top third of graduates, differentiated and increased salaries, and merit-based retention on the distribution of teacher effectiveness, as measured by the impact on student learning in a typical year. With these changes, over time, the share of effective or highly effective teachers goes from today's 52 percent to 60 to 80 percent in 2020.

We then used the shifting distribution of teachers to predict the impact on the student population using the model to determine the likelihood a student would be assigned an effective teacher each year and the compound effects of those probabilities on the amount of learning the student had done after completing school (adjusted by student income-demographic category). We then convert the new average years of learning to its PISA equivalent using the annual gain on

211 Craig Hochbein, "Relegation and reversion: Longitudinal analysis of school turnaround and decline," *Journal of Education for Students Placed at Risk*, 2012.

212 See The New Teacher Project's *The Irreplaceables: Understanding the real retention crisis in America's urban schools*, 2012. Also see The Education Trust-West's *Learning denied: The case for equitable access to effective teaching in California's largest school district*, January 2012, and the MET project's *Gathering feedback for teaching*, January 2012.

national achievement tests to understand the increase in student cognitive skills in 2020. Based on this approach, we estimate that improving teacher quality in the United States could add the equivalent of 18 to 30 PISA points to US student achievement.

To estimate the potential benefit of broad-based adoption of new tools and technologies in the classroom, we begin with the same model of teacher impact on student outcomes as described above. We then increase the impact on student learning of an effective teacher and the number of students an effective teacher can reach using these tools. Under this scenario, the share of effective teachers increases to 74 percent, while the number of teachers required decreases by 700,000 from current numbers, allowing for more selective hiring. We then apply this over the ten-year period to estimate that using technology to extend and increase the impact of effective teachers could add the equivalent of 11 to 20 PISA points.

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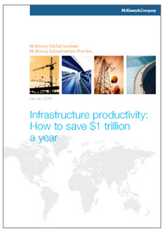

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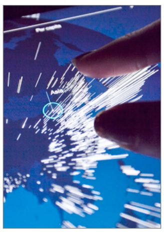

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