United States Senate Committee on Commerce, Science and Transportation

Hearing on America COMPETES: Science and the U.S. Economy

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Testimony of
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Chairman Rockefeller, Ranking Member Thune and distinguished Members of the Committee, thank you for the opportunity to testify before you today about the importance of science to our nation and to the world. I am honored by the invitation and hope that my testimony may be helpful to you and your staff as you draft important legislation and make critical funding decisions that help to ensure the United States of America's scientific leadership. I believe that without scientific leadership, we will lose our leadership in technology and innovation. Without technological leadership, our economic and national security will be fundamentally weakened.

My name is Saul Perlmutter and I am a senior scientist at the Department of Energy Office of Science's Lawrence Berkeley National Laboratory and a Professor of Physics at the University of California, Berkeley. I am testifying today as a private citizen and not on behalf of Berkeley Lab or the University. My testimony today will explore these important issues:

1. Why curiosity-driven science is important and why we should care.
2. Why the whole of the United States' science enterprise – consisting of an interdependent ecosystem of agencies, universities, national laboratories and industry – is greater than the sum of its parts.
3. Why waning federal support for curiosity-driven science is stagnating our science enterprise and weakening the nation's innovation foundation – immediately threatening our international economic competitiveness and the prospects of a more peaceful and productive world.

Why curiosity-driven science is important

In 2011, I was awarded, along with two other scientists, the Nobel Prize in Physics for the discovery that the universe is expanding at an accelerating rate. This discovery came as a huge surprise to me, to my team and to the entire physics world. We had anticipated one of two outcomes: either the expansion would be slowing down, but still expanding forever; or that the universe was slowing so much that someday it would come to a halt, and then, collapse in on itself – both options due to the force of gravity.

Since our discovery in 1998, thousands of theories have been published that attempt to explain this extraordinary phenomenon. The most widely discussed idea is that an unknown energy fills all empty space and counteracts gravity's pull enough to fuel the universe's accelerating expansion. Scientists and the scientific media have dubbed this unknown entity "dark energy" – "dark" only to signify that we don't know what it is – and estimate that it makes up almost three quarters of the “stuff” of the universe. This is a remarkable prospect that begs further exploration – what is this stuff that makes up the majority of our universe.

Although the concept of “dark energy” is mindboggling, it would be even more earthshattering if the accelerating expansion is caused instead by a flaw in the laws of gravity, which were originally set down by Newton, and perfected by Einstein in his Theory of General Relativity. Gravity and its properties are considered well understood – down to many digits of certainty. Scientific and engineering understanding of gravity made the industrial revolution possible and ushered in the modern era. What if our current understanding is simply the first step in a much bigger and more complex theory?

Either way, scientists are energized to explore this cosmic mystery. These are questions that we must tackle. Curiosity drove our initial research and experiments – today, curiosity drives us to ask new questions and design new experiments to explore this cosmic riddle.

Why should the federal government fund this type of curiosity-driven research? It’s not just because it is exciting, although it is. It’s not just because this is exactly the type of science that attracts young people to science and engineering careers, although it is that too. It is primarily because, by broadening our base of knowledge and deepening our understanding of the world, we will provide our children with brighter, more peaceful futures, with more rewarding jobs, and longer lives. In a nutshell, scientific knowledge gives us the power to secure a better future.

I have no idea what the discovery of an accelerating universe will mean to the health of our economy and our ability to build a better and more peaceful world. Certainly, building experiments and tools, as we did, to measure our universe with greater and greater fidelity and efficiency has led to new and productive technologies, such as more sensitive CCD detectors that are now being used in health care. These spin-off technologies produce jobs and create economic activity. But, even more importantly, no one can credibly claim to know what wide-ranging benefits the discovery will ultimately have on society.

Pursuit of curiosity-driven science is not a luxury – it is the foundation of how real progress and societal advancement is made. Grand challenges that face our nation and world require more than incremental, marginal solutions. Short-term, near-horizon research and development, also referred to as applied research, will not by itself lead to transformational advances. Applied research is certainly critical for moving solutions forward, but transformational leaps in technologies and in answers to tough problems don’t happen without new discoveries that come from curiosity-driven science.

So although I don't know how my team's scientific accomplishments will affect society broadly, I do know that big discoveries make us stronger and more capable. I do know that the laser would not have been invented if your goal were to build a laser printer or perform laser surgery. The need for global positioning systems would not have spawned Einstein's Theory of General Relativity – a theory so apparently esoteric that it addresses questions such as "what happens to clocks traveling through space at speeds approaching the speed of light." I do know that quantum mechanics, the theory of how matter and energy behave at the atomic and subatomic levels, would not have been developed if you were building a medical imaging device or the iPhone. But, without the curiosity-driven science that led to the theory of quantum physics, we would not have MRIs, electron microscopes or the transistor, an invention underpinning the information technology world in which we now live.

I am certain that the discovery in 1998 of the accelerating expansion of the universe has and will make us a stronger nation and help to build a better and more peaceful world. But a discovery like this was not an easy task.

Our research began as a three-year project. Our energy level was high and our expectations were even higher. Ten long years later we finally presented the results that showed our universe was expanding at an accelerating rate. Our results and those of another research team sent the worldwide physics community reeling. We knew that it was a tough problem. We knew we had to invent brand new technologies that would help find the standard candles, a certain type of exploding star, a supernova, needed to make our measurements and plot our points. We knew this sort of experiment and analysis had never been done before. We didn't know it would take us as long as it did.

Fortunately we did not have the pressures placed on companies by vigilant investors eager for short-term returns. My team and I were researchers at a Department of Energy Office of Science national laboratory. There we were given the time, space and resources required to accomplish our mission and were supported by a commitment to world-class, leading-edge science.

Although it is a surprise to most people, DOE's Office of Science is the nation's largest funder of the physical sciences – including the field of physics. The national laboratory provided me a supportive and uniquely well-suited place to conduct my research. The Office of Science, supported by the federal government, with a strong and unwavering commitment to world-leading science, has the patience, resources and institutions needed to consistently deliver groundbreaking scientific and technological advances – the type of advances that win Nobel Prizes and create new knowledge that leapfrogs current understanding.

Why the whole of the United States scientific enterprise is greater than the sum of its parts

My research is primarily supported by the DOE Office of Science, but from the beginnings of my graduate and postdoctoral education and training through today, I am most certainly a product of the federal government's investment in a wide range of agencies, research programs, universities and facilities. As an early career scientist, I received funding from the National Science Foundation for research at the Center for Particle Astrophysics at Berkeley. This early funding helped to hone my skills as a researcher, prepared me for a successful science career, and initiated my research. Likewise, funding from NASA has supported work throughout my tenure as a scientist by providing valuable time on the Hubble Space Telescope and NASA grants for research. Collaborations with universities, industry, and other national laboratories have been a constant and critical part of my research career. In other words, it may not take a village, but it does take an ecosystem to advance scientific and innovation progress.

As illustrated by my career, the nation's science and innovation enterprise is underpinned by this complex ecosystem of people, ideas and tools. This scientific infrastructure, until recently, has been unmatched and has been the envy of the world. It grew out of a post-World War II commitment made by the federal government to support basic scientific research conducted at U.S. universities and national laboratories.

Our nation has never had a comprehensive science strategy. From time to time we marshal our scientific resources and talents to focus intently on certain large problems and opportunities, such as the Manhattan Project, the Race to Space and the Human Genome Project. But by and large, the development of our innovation enterprise has been an organic one, fueled by an entrepreneurial American spirit that embraces progress and always seeks to improve society by new knowledge and understanding.

People like Ernest Orlando Lawrence, the inventor of the cyclotron and the founder of Lawrence Berkeley National Laboratory, begged, borrowed, and otherwise obtained the resources needed to move science forward. In Lawrence's case he established a laboratory in 1931 on the campus of the University of California, Berkeley, that today is an international leader in basic science and energy technology development. Individuals like Lawrence, Fermi, Oppenheimer, and others, pushed the boundaries of knowledge and physics to aid in the Allied effort to defeat Nazism – in the process building the infrastructure and intellectual capacity that would lead to the national laboratory system. Other scientific, policy and political leaders worked tirelessly to establish the National Science Foundation and set its course as one of the greatest scientific grant-making organizations in the world. Miraculously, or serendipitously, these scientific initiatives, now agencies, and others, such as NASA, DARPA, NIST and NIH, have developed collectively into a powerhouse ecosystem of innovation. The results have been spectacular. A basic, but telling, metric is that of all the Nobel Prizes awarded in the sciences, medicine and economics, 48% of the winners have been from the United States.

As in a natural ecosystem, each component of our research and development enterprise has a role to play – contributing to its vitality and sustainability. For example, it is widely accepted that health research conducted by the NIH is very important. Each of us has a personal story about how advances in medicine and health care have touched our lives, our families and our friends. However, without discoveries in the physical sciences – such as in physics and chemistry – many of the breakthroughs and leapfrog advances in health care will not take place. Better understanding of materials and organisms at the most fundamental atomic and molecular levels leads to new discoveries that find their way into new medicines and treatments. Unfortunately, this linkage and the symbiotic nature of our scientific enterprise is not obvious and certainly not mainstream knowledge. So, please indulge me as I take a moment to describe the roles of various participants in the nation's innovation ecosystem. This description is not all-inclusive, but hopefully will provide a better sense of its nature and structure.

<u>Universities</u>

From the very beginning of our national history, universities have been centers of scientific inquiry and technology advancement. Referring to the 1862 founding of West Virginia University, a local paper wrote, "a place more eligible for the quiet and successful pursuit of science...is nowhere to be found." E.O. Lawrence, inventor of the cyclotron and founder of Berkeley Lab, graduated from the University of South Dakota in 1922 – his grounding in the sciences there laid the foundation for remarkable contributions to science and society. Universities educate and train future scientists and engineers, like Lawrence, and host research in an open and encouraging environment.

Universities are the great scientific hot houses that provide fertile ground for scientific collaboration and exploration. Science is typically an intimate endeavor at universities with principal investigators working side by side with their team of students and postdoctoral colleagues, conducting cutting edge research with new ideas and great enthusiasm. It is an environment of opportunity and passion that is very hard to replicate and generally unique to the university setting. The NSF, NIH, DOE's Office of Science and other grant making agencies fund the best and brightest at our universities to conduct the most compelling research – research that neither industry, nor any other institution would have the means or will to fund.

National Laboratories

DOE's national laboratories, spawned from the Manhattan project and subsequently home to large teams of scientists and scientific resources, build and maintain unique, large-scale and world-leading research tools that are utilized broadly by university and industrial researchers. These tools, such as the Advanced Light Source at Berkeley Lab, the Spallation Neutron Source at Oak Ridge, and the Center for Nanoscale Materials at Argonne – over 30 facilities in total throughout the DOE complex – provide tens of thousands of American researchers access to critical scientific capabilities that help them to maintain the nation's scientific leadership. These researchers come from both academia and industry; are funded by a host of federal agencies, philanthropic organizations and companies; and come from every state in the union.

National laboratories, from their inception, have assembled and nurtured multi-disciplinary teams of scientific experts to meet federal needs and address national R&D priorities and challenges of scale. With a more focused and flexible organizational system than universities, national laboratories can more easily adjust to concentrate intellectual and capital resources on federal mission needs and scientific advancement.

As mentioned previously, my research requires a broad team of astrophysicists, engineers, students, postdocs and others to accomplish its goals. These collaborations often include researchers from dozens of universities, other national laboratories and industry partners. Our accomplishments would not have been possible without this team approach and a national laboratory as the organizing and supporting institution.

Industry

Unfortunately, the days of the big industrial basic science laboratory are over. As the Department of Commerce's January 2012 report on "The Competitiveness and Innovative Capacity of the United States" expounded upon, investments in basic, curiosity-driven science don't pay out directly for commercial investors, whereas the returns for society are eventually large. Even so, industry still plays a different but important role in the innovation ecosystem.

Industry delivers technological advances to the marketplace and to society by making strategic, early investments in new technology. Businesses rely on scientific and engineering talent produced by universities and trained at national laboratories to meet their workforce needs and remain globally competitive. Through in-house applied research and by harnessing scientific advances and technology developed at universities and national laboratories, industry drives commerce and innovation.

And, finally, researchers from industry utilize the unique scientific tools of the national laboratories to move technologies to the marketplace.

Why economic and national security are threatened by waning support for science

As a Nobel Laureate, I am constantly invited to events to launch new scientific initiatives and inaugurate or review new research programs. Unfortunately, the majority of these invitations are coming from other countries – China, South Korea, Germany, France, Saudi Arabia, Switzerland, etc. – not from the U.S. Although my experience is certainly anecdotal, the implications are backed up by real data. The data clearly shows how other nations are increasing their investments in basic science, unlike in the U.S. where support for and forward movement on basic science appears to be stagnating. Data supporting this may be found at http://www.nsf.gov/statistics/seind12/c0/c0i.htm and attached to this testimony.

My field of physics and astrophysics offers a cautionary tale about the effects of scientific stagnation on innovation leadership. With the demise of U.S. plans to build the Superconducting Super Collider in the 1993, and the corresponding rise of European leadership to build the Large Hadron Collider at CERN, the center of gravity for particle physics at the energy frontier moved from America to Europe. Now, instead of doing their research on American soil, U.S. science students, postdocs and early career scientists who study the Higgs boson and other high-energy particles are cutting their teeth in Europe.

Fortunately, in some physics fields, such as my field of study, astrophysics and cosmology – the study of the cosmos – the United States still maintains scientific leadership. But, that leadership, too, is threatened. Since shortly after the discovery of dark energy, my colleagues and I, and other research teams around the country, have proposed follow-up experiments, both large and small, in space and ground-based, to study dark energy with greater precision. Even with high rankings from agencies and the scientific community for each of these proposed experiments, interagency gridlock and now "no new starts" have left them in a state of almost suspended animation. Meanwhile the European Space Agency is moving ahead with plans to launch their own dark energy space mission, called Euclid, as early as 2020 – seizing leadership in dark energy research. Research thrives on competition; we need to compete, not forfeit.

Some will argue that during periods of constrained budgets all federal investments must be curtailed, cut back and reduced. Admittedly, there are always opportunities to find efficiencies and reduce costs. But, scrimping on science and holding up scientific progress, for whatever reason, is penny wise and pound foolish. Even in tough economic times and tight budgets it is possible to spend money wisely and make the investments necessary to reap a brighter future. The economic argument, though perhaps not immediately obvious to some, is singularly compelling. Yet, there is a broader and perhaps more important argument to be examined. Scientific advancement has made the world a better place – living standards are rising across the planet, fewer people are hungry and life spans are increasing. Science paves the way for a more peaceful and productive existence.

Yet, when trouble arises somewhere around the world or at home, whether natural or manmade, we must be prepared. Our response to natural and manmade disasters of the future will require sophisticated technologies yet invented. Threats may include comets or asteroids crashing to earth, volcanoes darkening the planet's skies and, of course, the scourge of war. Today our nation has a strong base of innovation and technological leadership because we have funded and nurtured the best curiosity-driven science portfolio the world has ever known. If we don't continue to nurture curiosity-driven science, will we have the capacity to meet the threats of the future – say in twenty or thirty years? If we lose our scientific leadership, we weaken our true national security. It is that simple.

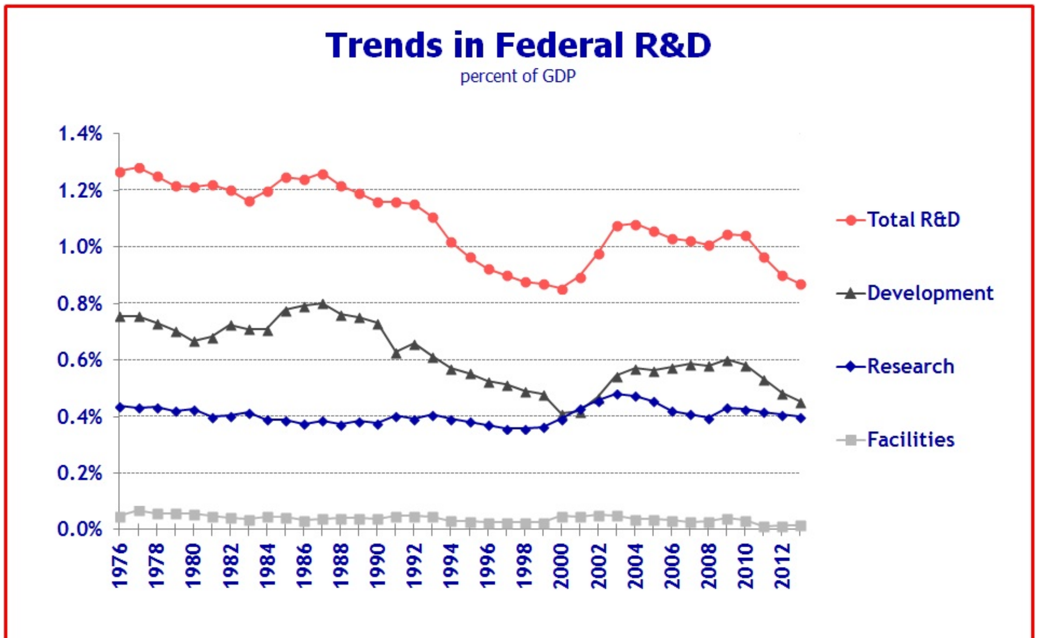
Even if faced with tough budgets, science cannot stand still. By its very nature it is new and ever changing, and requires consistent and continuous forward movement. "No new starts" means not doing science. It means losing the U.S.'s role as a light and leader for the world. It means not attracting and educating the next generation of scientists. It means not being ready for future challenges. Science is the act of discovery. It is not science if it sits still.

Conclusion

With the current fixation on short time lines and near horizons, I doubt that my team's Nobel Prize winning research would be funded today. How many young scientists with Nobel Prize quality ideas and ambitions are not being funded today in the United States? How many are now doing or will do their research in other countries, winning for them the gold of the Prize, but also the economic potential of their discoveries? America set the bar high in its support of science and technology development. Other countries, admirably, are ramping up their innovation engines and in many ways are attempting to emulate our successes. Although we should applaud these efforts, we cannot afford to be complacent and let other countries pass us by. We must stay in the race and compete. Regardless of when and where the mystery of "dark energy" is uncovered it will be a tremendous accomplishment for the world. Yet, from my perspective, as a United States scientist and teacher, I hope that we make these advances here, at home and thereby contribute to humanity's progress.

In closing, the U.S. innovation ecosystem is one of our most precious assets – indeed, one of the world's most precious assets. The federal government has a fundamental responsibility to keep this ecosystem healthy because it gives the nation a powerful competitive edge, providing solutions to major national challenges and fueling economic growth, and because it continues to make the world a better place. Universities and laboratories have a responsibility to conduct first-rate research on key scientific and technological problems with intellectual rigor and efficient use of resources. Working together, we strive to transfer the results of this research to markets and people around the world for the benefit of society as a whole.

Thank you for the opportunity to testify at this important hearing. I am happy to answer any questions that you may have.



Source: Up to 1994 - National Science Foundation, Survey of Federal Funds for Research and Development; 1995 to Present - AAAS *Research and Development* series. GDP figures are from *Budget of the U.S. Government FY 2013*. FY 2012 and FY 2013 figures are latest estimates.
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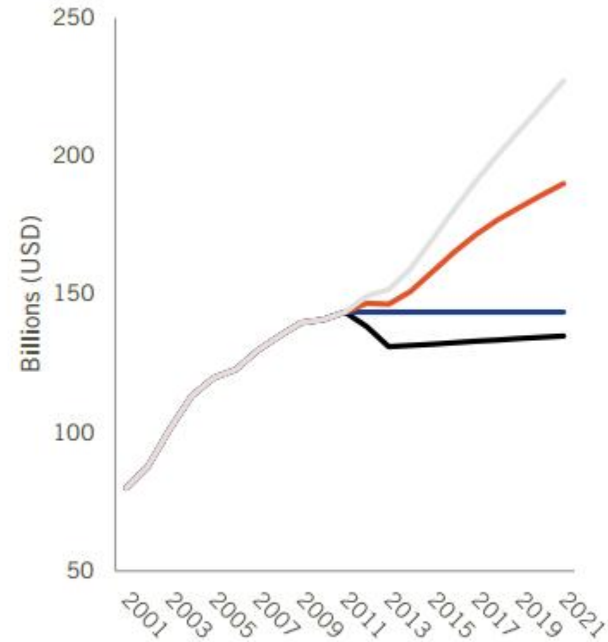
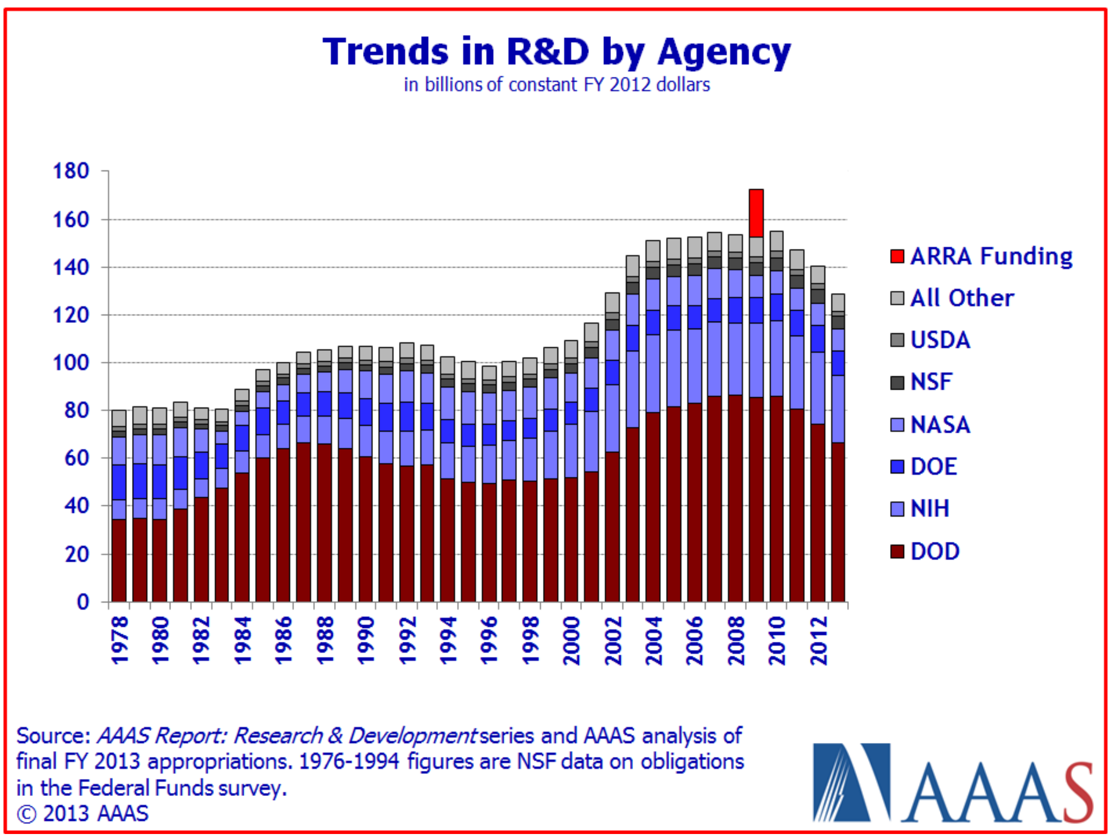
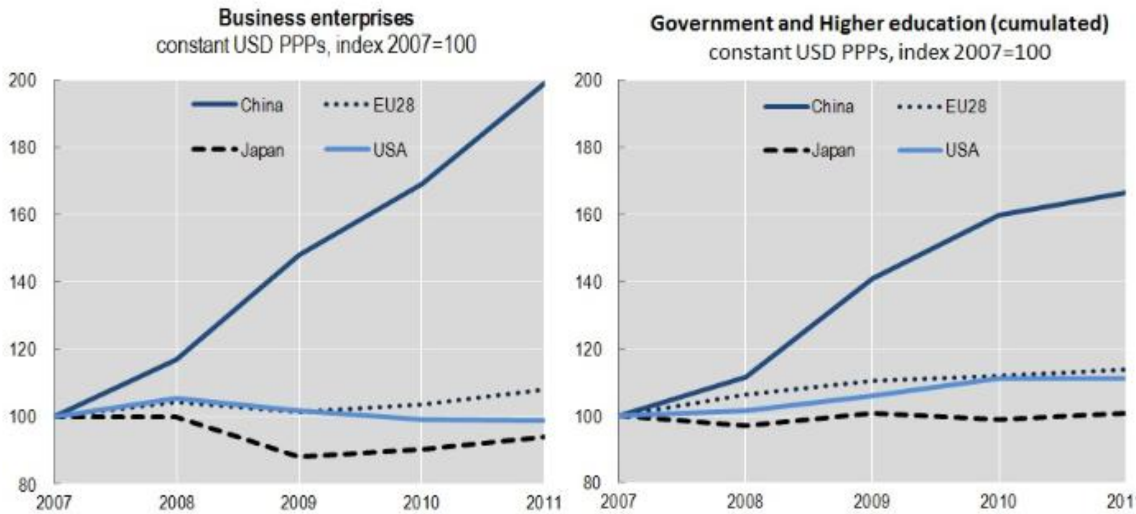


Figure 4: Sequestration and the Three Federal R&D Expenditure Benchmarks, Sources: NSF, OMB, CBO, BEA, ITIF



OECD R&D Intensity Indicators



The latest OECD estimates on Gross Expenditures on R&D (GERD) confirm that the modest recovery initiated in 2010 continued into 2011.

For the whole OECD area, total R&D expenditures grew in real terms by 1.3% in 2010, mainly driven by the higher education and government sectors, while business R&D only increased by 0.6%.

OECD estimates indicate an overall real growth rate for GERD of 2.1% in 2011 driven by a gradual recovery in business R&D (2.8%) and sustained growth in research in the higher education sector (2.5%), despite a reduction in government R&D (-1.2%).

In the EU area, total GERD grew by 3.2% in 2011, driven by the business sector (4.2%), mainly Germany's (6.4%). In contrast, US R&D fell by 0.5% in real terms, with growth in higher education offset by lower government and business R&D. After a 2.5% drop in 2010, US business R&D (BERD) declined by a further 0.4% in 2011.

GERD in China continued to growth at a rapid pace (14.1%), mainly driven by business R&D which in 2011 reached more than half the level of US BERD, and 81% of EU BERD.

Main Science and Technology Indicators (MSTI) 2013/1

Last update: 16 July 2013

Direct link **to the MSTI dataset in OECD.stat**
Short address for this page: www.oecd.org/sti/msti