# Eroding Our Foundation: Sequestration, R&D, Innovation and U.S. Economic Growth

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*Unless changed, sequestration will result in significant cuts to federal R&D investments from 2013-2021, leading to GDP losses of up to $860 billion.*

Because of the Budget Control Act, budget enforcement procedures known as *sequestration* will commence January 2013 unless Congress and the Obama Administration act otherwise. The sequester requires cuts in discretionary spending in order to achieve $1.2 trillion in savings from 2013-2021. When compared to 2011 spending levels, this will lead to a cut of 8.8 percent (or $12.5 billion) of federally funded research and development (R&D) in 2013 with similar cuts in the following years.[1] This cut to R&D expenditures will affect all government agencies, including the Department of Defense, the National Science Foundation the National Institutes of Health, the Department of Energy, and NASA.

Federal R&D plays a key role in driving U.S. innovation, productivity, and overall economic growth. We estimate that the projected decline in R&D will reduce GDP by at least $203 billion and up to $860 billion over the nine-year period, depending upon the baseline with which sequestration is compared. At $203 billion, the loss is equivalent to eliminating all sales of new motor vehicles for a half year, two years of airline travel, or six years of attendance at professional sporting events.[2] These R&D cuts will also result in job losses of approximately 200,000.

We generate these estimates by comparing sequestration to three alternative benchmarks. First, we compare sequestration to a benchmark that holds discretionary expenditures constant at their 2011 rates. Under this scenario, sequestration will lead to a shortfall in federal R&D of $95 billion from 2013-2021. Second, we introduce a benchmark where the R&D share of GDP remains constant. It should be noted that from 1994 through 2009, growth in federal R&D expenditures outpaced GDP growth by 20 percent, so even this benchmark would result in slower growth in R&D than in the past. Using this benchmark would result in a R&D shortfall of $330 billion. In other words, in order to increase federal R&D expenditures at a rate that simply keeps pace with the rest of the economy we would need to invest $330 billion more than the sequester allows over the 2013-2021 period. Lastly, we consider what level of R&D expenditures is needed for federal R&D expenditures to grow at the same rate as China's relative to its economy. Sequestration will leave the United States $511 billion behind in R&D investment when compared to expected Chinese R&D expenditure growth rates and expenditure levels.

R&D is a critical input for economic growth and therefore we estimate the implications of these cuts to the economy at large. We use the latest academic estimates which show how R&D impacts productivity to build an empirical model that analyses the impacts of R&D sequestration on GDP.[3] To be clear, the effects to GDP we measure do not stem from short-run reductions in government expenditures (Keynesian effects); rather the estimated effects are caused by the reduction in R&D and its impact on the underlying mechanisms of growth. Figure 1 estimates the cuts in federal R&D expenditures from sequestration and the related losses to GDP stemming from reduced innovation over the 2013-2021 period.

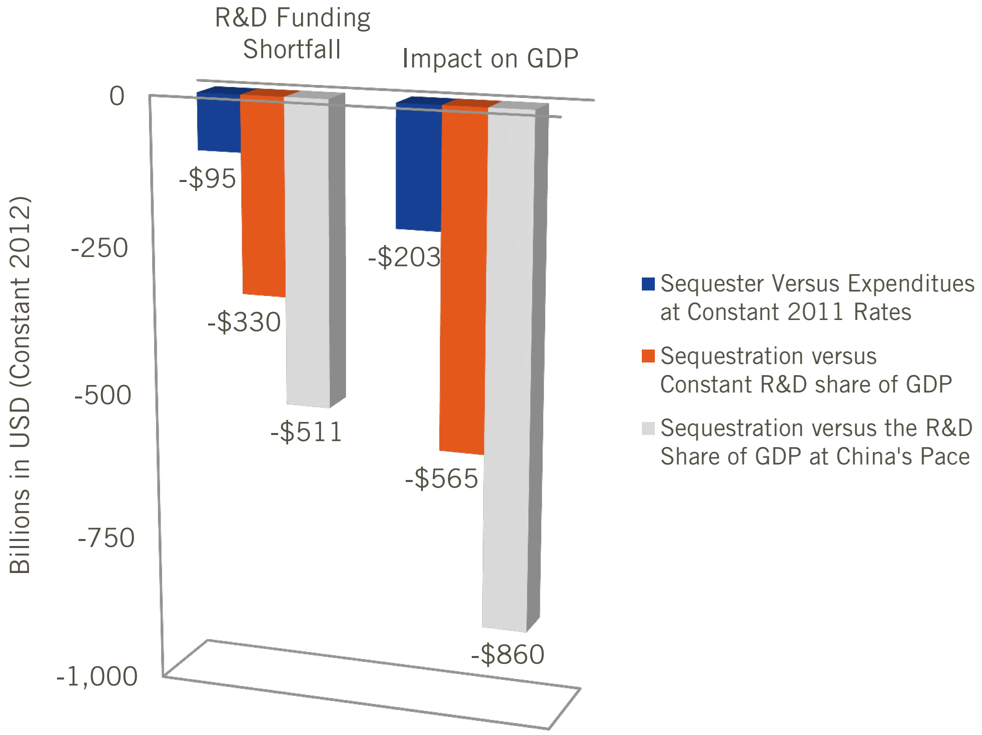

**Figure 1: R&D Funding Shortfalls and the Related Losses in Real GDP 2013-2021 Cumulative Effect, Sources: NSF, OMB, CBO, BEA, ITIF**

In addition to the losses in productivity and GDP, we find that R&D sequestration would reduce the knowledge base (publications and patents), U.S. international competiveness, and employment. We estimate that sequestration would result in U.S. scientific journal publications declining almost 8 percent and patents near 3 percent over the 9 year period, when compared to the Congressional Budget Office (CBO) baseline.

In order to estimate the effects of sequestration on employment, we use a similar technique to the GDP model, but supplement it with more traditional measures of how changes in federal spending affect employment. The employment effect from cutting R&D comes from both demand-side losses from decreased federal spending, and the supply-side effects from decreased innovation as related to the formation of new firms and expansion of existing ones. We estimate that sequestration of R&D would result in the U.S. economy having approximately 200,000 fewer jobs per year between 2013 and 2016. This would result in the U.S. unemployment rate being 0.2 percentage points higher than it otherwise would be.

Reducing the budget deficit is important, but it should not and does not have to come at the expense of growth-inducing investments in areas like federal support for R&D. In fact, undermining growth capability is disruptive to deficit control policy. While ensuring that the federal budget crisis comes under control is critical, everything should not be "on the table" when doing this. Cutting federal support R&D, a key "fuel" for the U.S. innovation economy engine, would not only lead to a relatively smaller U.S. economy and higher unemployment, it would reduce U.S. global competitiveness precisely at a time when the U.S. economy is struggling to stay in the race for global innovation advantage.

## THE SEQUESTER OF FEDERALLY FUNDED R&D: BUDGETARY EFFECTS

### General Impacts

When the Budget Control Act of 2011 was passed into law, both parties expected that the formation of the Joint Select Committee on Deficit Reduction would provide guidance leading toward a budget proposal that would successfully trim deficits by at least $1.5 trillion starting in mid-2012. However, because no legislation was passed by January 15th, 2012, automatic budget enforcement procedures built into the Budget Control Act were set into motion to reduce discretionary spending by $1.2 trillion over the period 2013-2021. These automatic budget enforcement procedures are commonly known as *sequestration.* Figure 2 illustrates the path of sequestration according to the Office of Management and Budget (OMB) for 2013 and the CBO for 2014-2021. Because most of the forecast is based on the CBO estimates, this benchmark will be referred to as the CBO baseline for the purposes of this report.

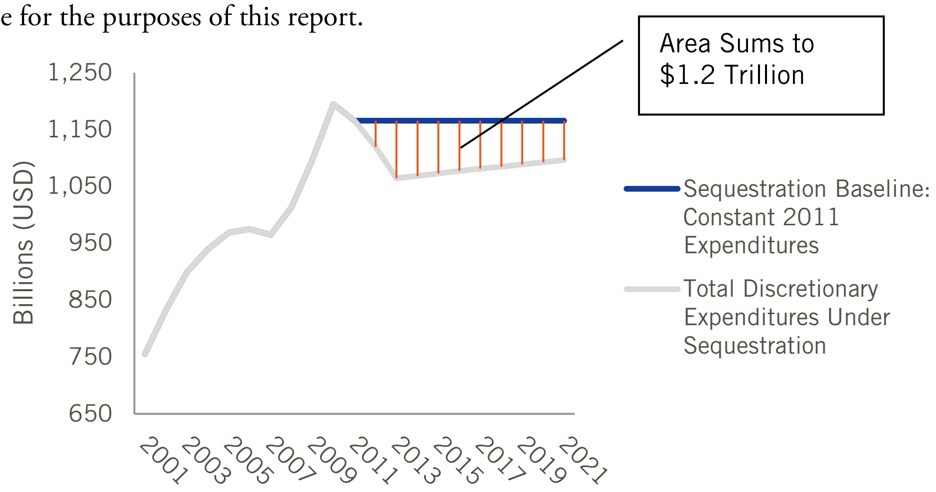

**Figure 2: Savings Achieved by Sequestration, Source: CBO, ITIF**

Unlike other possible measures, sequestration imposes across-the-board reductions in discretionary spending regardless of function or agency. As illustrated in Figure 3, discretionary defense spending will be cut by 9.4 percent starting in 2013 from the 2011 baseline, and then remain at those levels with minimal increases through 2021. Non-defense discretionary spending will be cut by 8.2 percent starting in 2013 and follow the same pattern. It is important to note that even the baseline of stable spending reflects a cut to real federal spending when factoring in inflation. For details on the effects on R&D expenditures, see Table 6 in the appendix. In addition, it should be noted that discretionary expenditures account for 40 percent of total government expenditures. The Budget Control Act has already cut $1 trillion, and sequestration will be on top of these already significant funding changes.

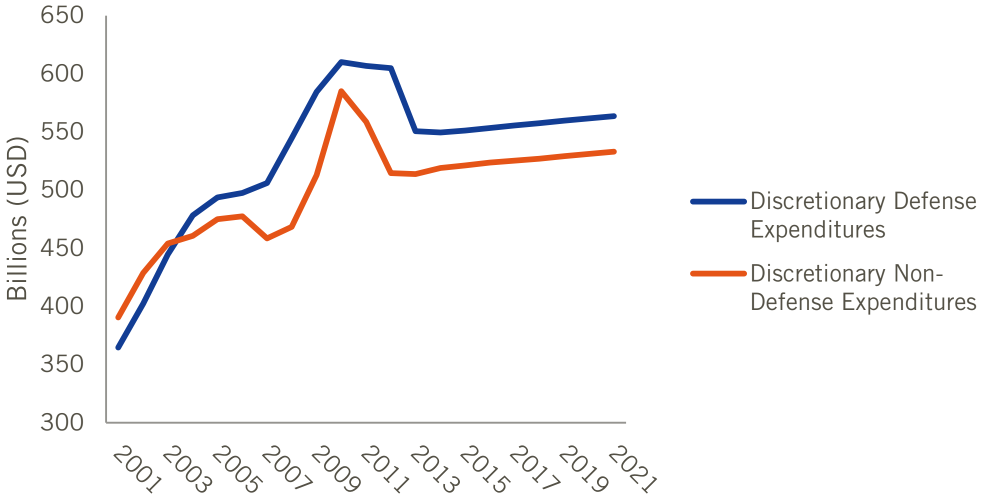

**Figure 3: Discretionary Expenditures Under Sequestration, Source: CBO, ITIF**

## The R&D Expenditure Shortfall

The R&D expenditure shortfall due to sequestration can only be estimated once a benchmark for comparison is chosen. The first benchmark is from the CBO. This benchmark is introduced because it is the baseline the CBO used to calculate the required $1.2 trillion in savings. This benchmark holds annual discretionary expenditures fixed at their nominal 2011 levels. Assuming that government agencies will maintain their relative R&D intensities (proportion of agency discretionary funds that are used for R&D) after sequestration occurs; R&D will remain fixed at its 2011 levels (see Figure 4). It is from comparing sequestration to this benchmark that the most conservative estimates of the size of the R&D expenditure shortfalls are calculated.[4] The cumulative R&D expenditure losses amount to $95 billion over the 2013-2021 period. This is the area between the Sequestration and the CBO baseline.

It is important to note that if sequestration were to occur, R&D would likely be cut at even greater amounts. This is because for many federal agencies, R&D is much more discretionary than other core activities; it is easier to make steeper cuts to R&D in order to achieve an overall average cut to meet sequestration targets. Consider the Department of Defense (DOD), for example. The DOD is much less able and therefore much less likely to reduce spending on troops, logistics and replacement weapons, while long-term R&D spending is much more discretionary and susceptible to cuts. Nevertheless, for the purposes of this analysis we conservatively assume proportional cuts to R&D.

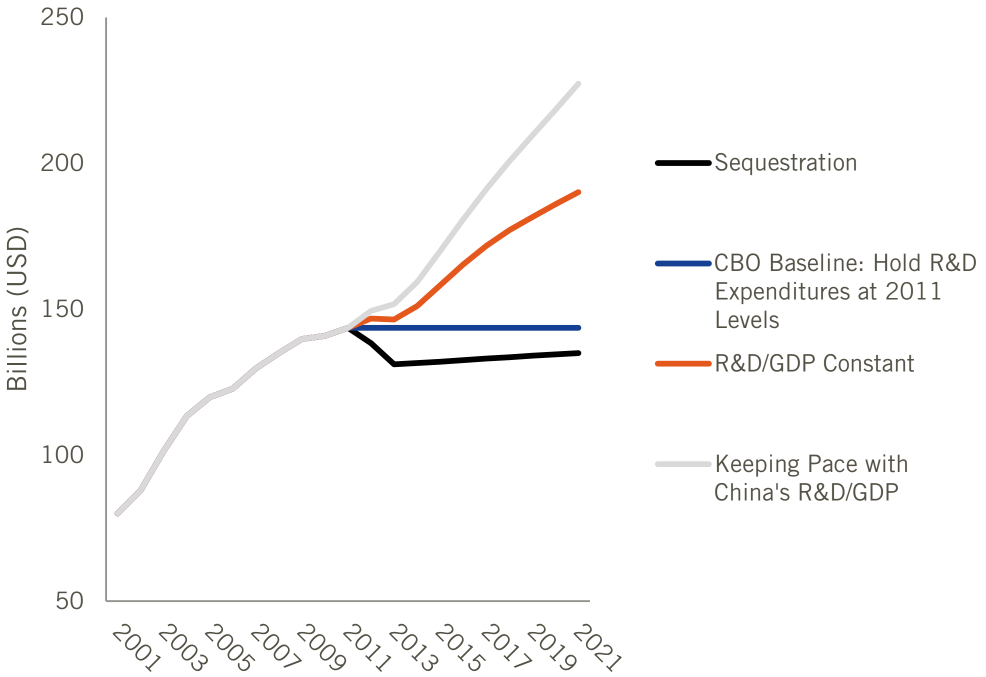

**Figure 4: Sequestration and the Three Federal R&D Expenditure Benchmarks, Sources: NSF, OMB, CBO, BEA, ITIF**

*Sequestration will cause an R&D expenditure shortfall of $330 Billion from 2013-2021 when compared to a benchmark where the R&D sector simply maintains its size relative to the rest of the economy.*

Though the first benchmark is reasonable from an accounting standpoint, when prior trends or global competition are considered, the CBO benchmark is highly misleading. This is because it does not account for inflation or GDP growth. Historically, nominal federal R&D has grown at least in pace with inflation. For this reason, we introduce two alternatives. The first is a benchmark where R&D expenditures maintain pace with real GDP. In other words, we consider an alternative where the ratio of R&D to real GDP remains constant. In virtually all analyses that look to measure whether a nation is becoming more or less innovative, the ratio of R&D expenditures to GDP is a key statistic, most often defined as a nation's R&D intensity.[5] A constant ratio of R&D to GDP would indicate that within the United States economy, the relative size of the R&D sector is neither growing nor declining. This therefore presents a neutral benchmark. When sequestration is compared with this benchmark, the R&D funding shortfall will reach nearly $330 billion over the nine-year period. Specifically, this is the area between the orange and black lines in Figure 4.[6] It presents a significantly different picture as to what the real costs of sequestration are to the producers of R&D here in the United States.

Finally, we introduce a third benchmark that increases R&D expenditures at the same rate as is expected from China from 2013-2021.[7] The reason for the introduction of this benchmark is clear. It is not enough for the United States to keep its R&D intensity the same; we need to increase it in order to maintain or increase our R&D standings internationally. Although technological leadership has been critical for its growth, currently the United States ranks ninth in total R&D intensity and 39th in non-defense government R&D expenditures as a percent of GDP.[8] While matching Chinese R&D growth is perhaps a difficult goal, it is one we should seriously consider. China is actively seeking to overtake the United States in technology and innovation, including defense technology.[9] When comparing R&D expenditures under sequestration with this final benchmark, the United States will experience a $511 billion dollar R&D expenditure shortfall over the period. Specifically, this is the area between the top and bottom lines in Figure 4. To put it in perspective, this is the same as completely eliminating all federally funded R&D investment for nearly four years at current expenditure levels. The following table details the relative annual shortfalls as shown in the figure above.

| Year | Sequestration vs. R&D at 2011 Level | Sequestration vs. Maintaining R&D's Share Relative to GDP | Sequestration vs. Expanding R&D at China's Expected Rate |
|---|---|---|---|
| **2013** | -12,484 | -15,326 | -20,646 |
| **2014** | -12,053 | -19,487 | -27,791 |
| **2015** | -11,561 | -26,197 | -37,903 |
| **2016** | -11,010 | -32,734 | -48,161 |
| **2017** | -10,534 | -38,580 | -57,975 |
| **2018** | -10,072 | -43,524 | -67,077 |
| **2019** | -9,569 | -47,558 | -75,419 |
| **2020** | -9,082 | -51,372 | -83,752 |
| **2021** | -8,610 | -55,079 | -92,205 |
| **Cumulative:** | **-94,976** | **-329,856** | **-510,930** |

**Table 1: Annual R&D Expenditure Shortfall (millions, USD, Constant 2012)**

In Figure 5, the expenditure shortfalls are illustrated over time. This shows the annual changes, as well as the cumulative effects (the area). It is revealing to see how large the R&D expenditure shortfall is under the two alternative benchmarks that take into consideration general economic relationships, rather than just accounting.

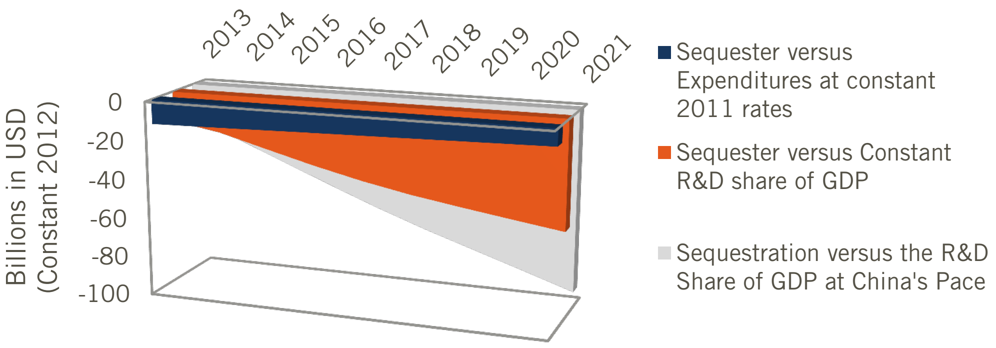

**Figure 5: Annual R&D Expenditure Shortfall Under Sequestration, Sources: NSF, OMB, CBO, BEA, ITIF**

### Sequestration of R&D Expenditures and the Effect on Government Agencies

There are large differences in the proportions of total expenditures allocated to R&D among the different government agencies. The proportion of R&D funding that is directed toward basic rather than applied research is also quite different. For example, the DOD dedicates 12 percent of its total discretionary expenditures to R&D, and of that, 20 percent goes to basic research. On the other end of the spectrum is the National Institutes of Health (NIH), which spends 97 percent of its total expenditures on R&D, and of that, 54 percent goes to basic research. So, out of the total discretionary expenditures of the DOD, only 2 percent goes to basic research, while 52 percent of the NIH's total discretionary budget is allocated to basic R&D. Agencies other than the DOD, NIH and National Science Foundation (NSF) do substantial amounts of R&D including the Department of Energy (DOE). The Department of Energy is currently the largest source of funding for research in the physical sciences. For a further look, Table 6 through Table 9 in the appendix includes full time-series of R&D expenditures across most of the government agencies. For brevity, we present the R&D paths of the NIH and NSF in the following discussion.

In Figure 6, we present the historical data on R&D expenditures of the NIH (left axis for scale) and the NSF (right axis for scale) with forecasts for 2013 through 2021. Though the levels of the expenditures are different between the two agencies, the trends prior to sequestration are clear. For over a decade, both the NIH and NSF invested increasing amounts in R&D. The sequester not only changes the trend, but it cuts expenditures from prior levels. Therefore, the amount of research done through agency funding will simply decrease. Due to risk and uncertainty, this loss in R&D will not be made up for by increases in private sector R&D, especially in the areas of basic R&D; private sector R&D is primarily "D"—development.

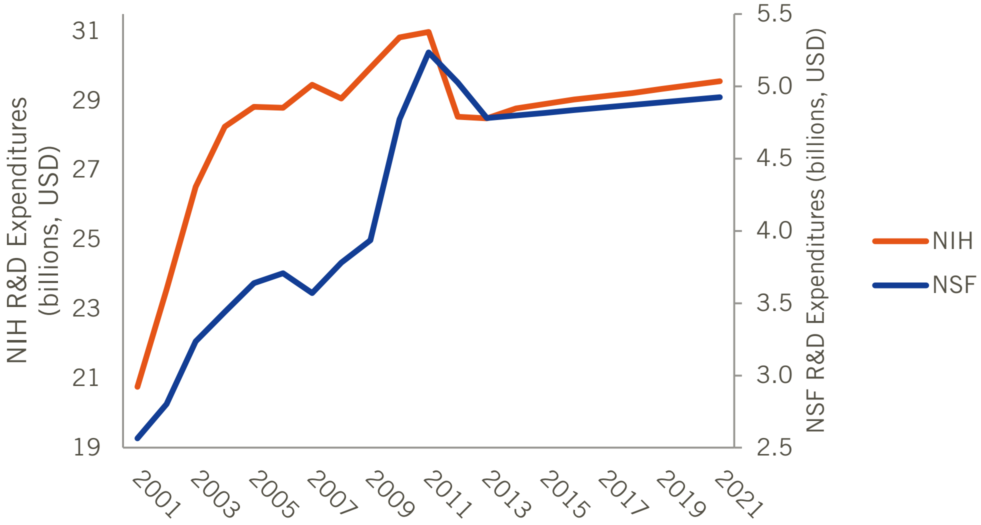

**Figure 6: Examples of Agency R&D Expenditures Under Sequestration, (billions, USD) Sources: NSF, OMB, CBO, BEA, ITIF**

## THE INNOVATION LANDSCAPE IN THE UNITED STATES

To understand the impact of federally funded R&D, it is important to have a basic knowledge of the innovation landscape (who funds and who performs R&D) in the United States. Within the United States, the federal government funds 31 percent of *all* R&D.[10] In addition, federal sources fund over 60 percent of all basic R&D.[11] Additionally compelling is the fact that federal agencies and the nation's universities perform 70 percent of all basic R&D in the United States.[12]

Sequestration not only diminishes the amount of R&D performed by federal agencies, it directly impacts both universities' and private firms' R&D performance. As mentioned, the federal government funds 31 percent of all R&D; however, government labs only perform 8 percent. So, of the 92 percent of R&D that universities and private firms perform the federal government funds 23 percent. This means that 21.16 percent of all university and private R&D is funded through federal expenditures. If 9 percent of this is cut, a decrease of 2 percent of R&D will be realized within the university and private R&D share, due to sequestration. If you add back in the federally performed R&D, a total loss of 3 percent in R&D performed will occur in 2013 due to sequestration.[13]

*Within the United States, the federal government funds 31 percent of all R&D and 60 percent of all basic R&D. As a result, the sequester will cause a 3 percent drop in total U.S. R&D in 2013.*

Federally funded research has been the source of many of today's top publicly traded companies, including Google, Cisco, and Genentech.[14] It is a fact that many (if not most) of the current "cutting edge" products and forms of communication the public consumes today came as a result of, or were directly based on, federally funded research. In addition, numerous economic studies have shown that the overall societal benefits of basic R&D are very large when compared to the realized costs and returns. What this means is that R&D has spillovers, or unintended positive consequences or externalities. In other words, one dollar spent on R&D, on average, produces significantly more than one dollar in output.

There are also economic "knowledge spillovers" associated with R&D. If an individual comes up with a new idea that solves a specific problem or answers a question, others are able to use this information in their own way. For example, when NASA commissioned research to explore ways to absorb the impact of both takeoff and reentry on astronauts, they certainly did not intend on creating a whole new industry with thousands of applications: memory foam. This unintended use led to the production of foam mattresses—those seen on TV that are custom fit to your body and that allow your sleep partner to jump up and down without disrupting your sleep. This is an example of both a knowledge spillover and an economic spillover, where the social benefit (an enhanced night's sleep) is significantly larger and tangential to the research's original intention. Now, it is also true that applied research has significant economic positive spillovers, though the magnitude is not as large because applied R&D has a generally narrower objective and therefore narrower applicability.[15]

To understand more fully the essential contribution of federally funded R&D, consider Figure 7. It is a popular visual representation that shows the relationship between federally funded R&D within universities and the related multi-billion dollar product markets over time in IT. What is clear from the figure is that industry relies heavily on the basic R&D performed through federal funding. In all major IT sectors except one, federally funded

R&D was the first to lay the building blocks from which the industry grew. Without the initial discoveries made by public R&D, over $80 billion in output per year would not exist today, and again, this is only regarding certain areas within the IT sector.

Some would argue that private businesses (the free market), if left to their own profit-seeking motives, would be more efficient and produce more relevant results than the R&D funded by the federal government. This is a misnomer, for various reasons. First, individual firms generally cannot face the scale and risk involved in most of the basic research done by federal agencies. There are few firms in existence that can tackle any of the broad questions being asked and answered through research at the government labs, or through federally funded research at universities. In addition, firms will simply not invest in research that has such an unknown outcome or application. Finally, because firms are intent on appropriating every dollar of potential profit associated with an invention, they actively seek to mitigate spillovers (hide their findings, or patent and charge others for their use). This limits the societal benefits, and also causes firms to minimize the amount of basic R&D in their research agenda. This is because the appropriability (ability to capture profits) of basic R&D is relatively low when compared to that of applied R&D.[16]

When the most probable outcome of basic research, because of its risk, is a negative-finding, to invest would be considered wasteful in a corporate setting. However, for the United States as a whole, the benefits of even negative results are undeniable. Also, as illustrated and discussed in Figure 7, basic knowledge and R&D often provide a platform for firms to build upon. Therefore, the more basic R&D that is publicly provided, the better aimed are private R&D expenditures.[17] In addition, businesses can access the results from the publicly funded R&D at a much cheaper rate (if not for free) than if competitor firms were to develop the R&D privately. In sum, the risk, together with the appropriability problem, are why the over 60 percent of the basic research currently performed in the United States would tend to disappear without government funding, with a significant adverse effect on follow-on industrial research.[18]

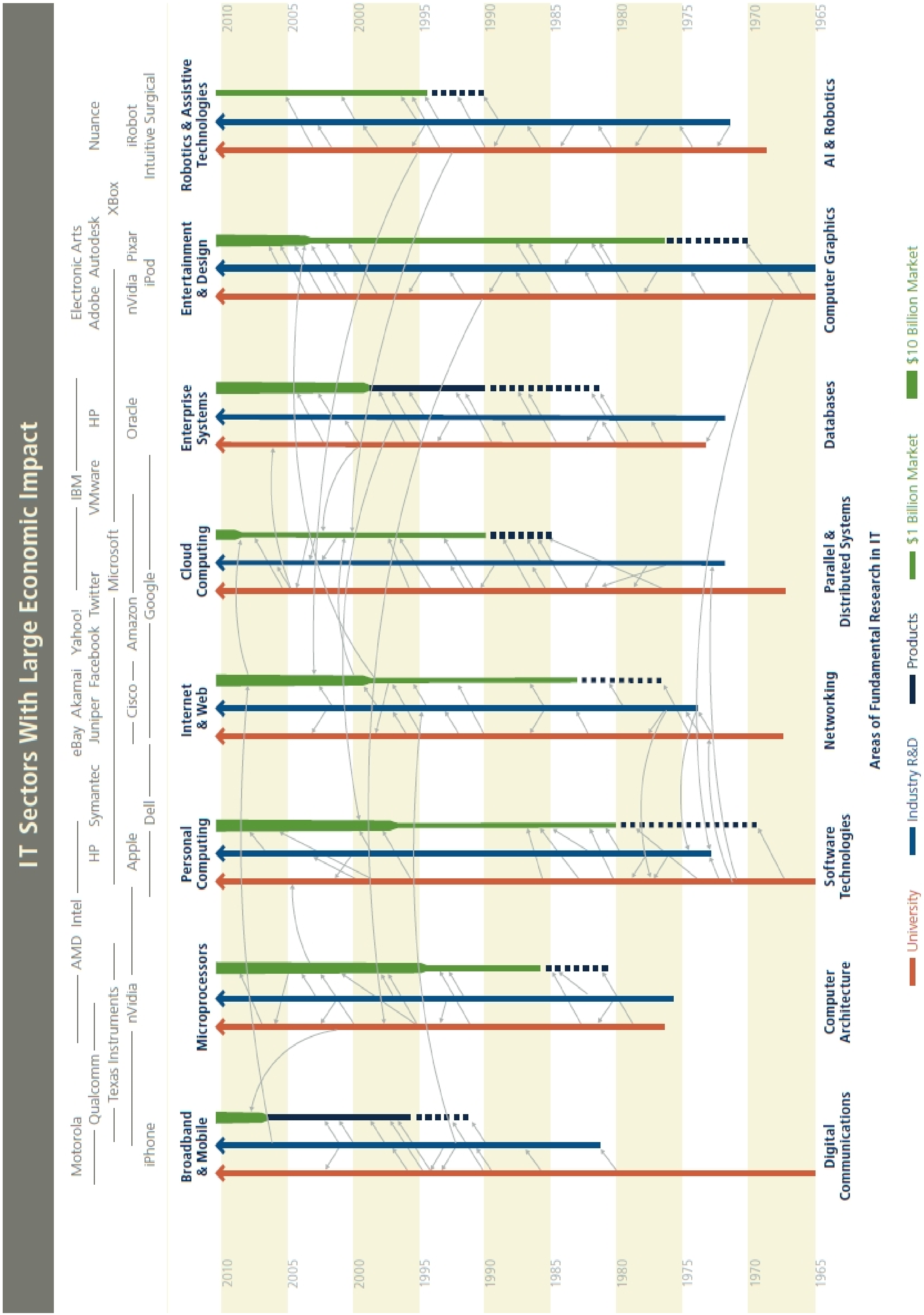

**Figure 7: R&D Tires Tracks Diagram, Source: NRC**[19]

## Sequestration of R&D and its Effect on the United States within the Global Innovation Landscape

As can be seen in Figure 8, the size of the R&D sector in the United States has remained relatively flat over the last 20 years at an average of 2.64 percent of GDP. Because sequestration reduces total R&D, this will force the ratio to decrease in 2013. In addition, because GDP will continue to increase while R&D expenditures remain flat, the ratio will decrease more and more over the 2013-2021 period. This has two effects. First, the United States will lose ground to those countries that already surpass it in the relative size of their R&D sectors within their economies. Second, it enables those countries below to make quicker gains within the global innovation landscape. The United States will not only see its internal R&D sector constrict, but its relative place in the global R&D sector will fall. In effect, sequestration forces the United States to become less competitive in industries on the innovative frontier, where significant potential GDP gains are generated.[20]

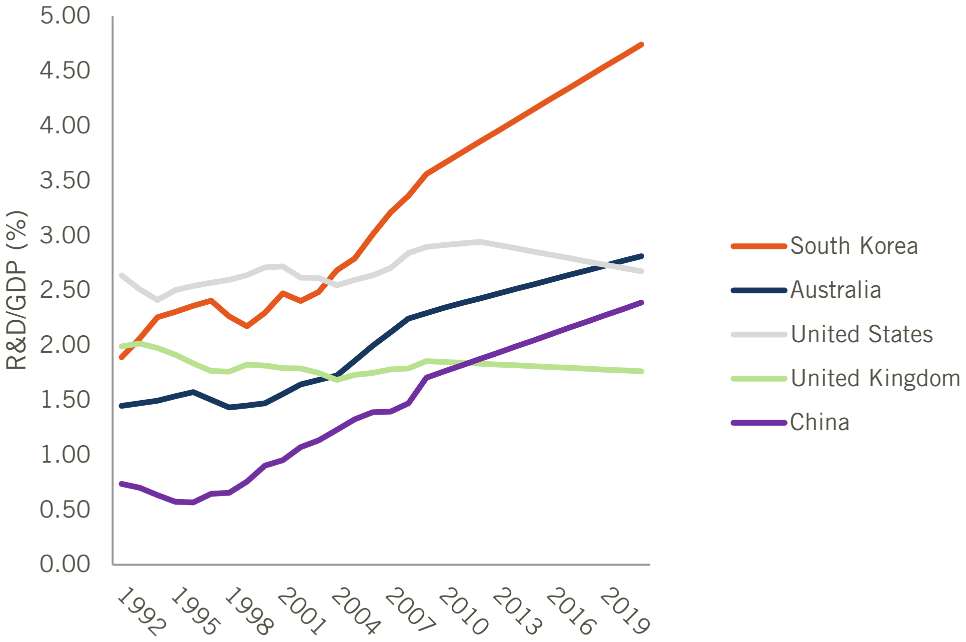

**Figure 8: R&D as a Percentage of GDP (Real 2005 USD & PPP), Source: OECD[21], ITIF**

Another way to look at the United States R&D investment in the global context is to consider the change in the level of R&D expenditures over time and how it compares with other countries. This can be seen from historical data in Figure 9. The clear leader in R&D expenditure growth has been China, with an annual growth rate in R&D expenditures of 18.59 percent from 1992 through 2009. The only OECD nation that has increased its level of investment in R&D at an average rate above 8 percent is Australia. The United States, United Kingdom, and Japan all increased R&D expenditures at a rate of less than 6 percent, or at a pace more than three times slower than China.

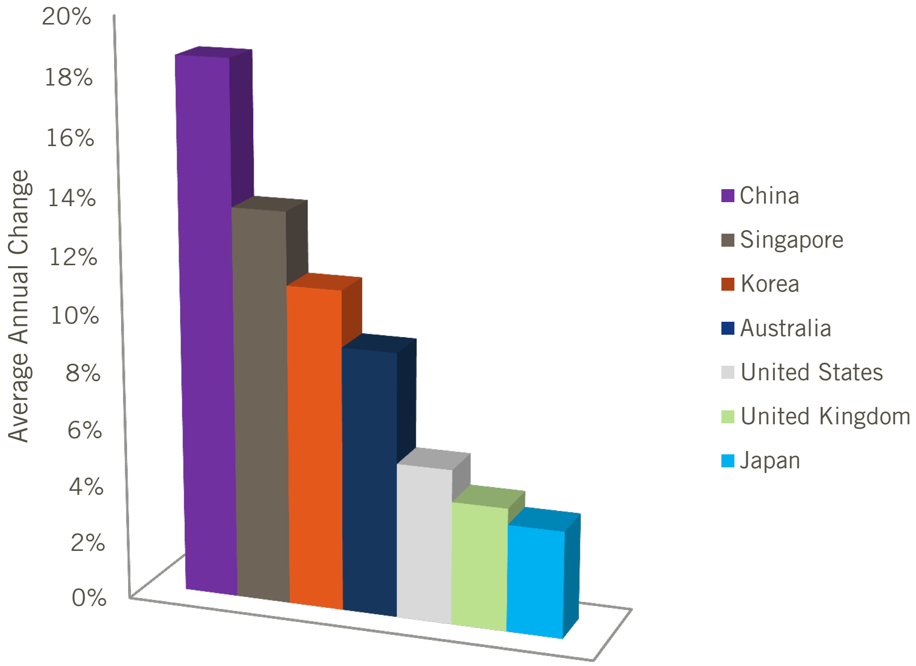

**Figure 9: Average Annual Increase in R&D Expenditures (1992-2009), Source: OECD**

The data on the changes in the levels of R&D expenditures in Figure 9 present a similar picture to those in Figure 8 of how the United States is faring internationally. It is clear that the United States is already falling behind relative to the growth in R&D investment that other countries are pursuing based on the average investment levels from 1992-2009. Nations that have clear innovation policies are making headway, and those that do not are certainly losing in the global innovation race.[22] Sequestration will amplify this trend, where the United States continues to decline relative to its international competitors.[23]

## HOW FEDERAL R&D GROWS THE ECONOMY

It has been outlined how sequestration will impact the innovation landscape both nationally and internationally. It is therefore critical to consider exactly how R&D investment affects the economy. This section will provide several case studies, as well as a brief outline of the previous academic studies on this particular question.

### Qualitative Evidence

Though there are hundreds of examples of spillovers and spinoffs, a few cases will suffice to illustrate how federal R&D can produce large unintended positive benefits.[24] Google, for example—one of the world's most powerful companies—would not exist if it were not for a grant provided by the NSF to Stanford researchers (graduate students Larry Page and Sergey Brin).[25] Today, Google directly employs over 20,000 people, and it has been estimated that over 50,000 additional jobs have been created to support the needs of the company.[26] Other examples are included below in Table 2.[27]

| Channel of Government Funded R&D | Performer of Basic R&D | R&D Description | Private Corporation (Spinoff) | Number of Internal Employees |
|---|---|---|---|---|
| National Science Foundation | Stanford | Transformative Search Engine Technologies | Google | 20,000 |
| Department of Defense | University of California, Berkeley | Developed computer workstations based on UNIX | Sun Microsystems | 33,000 |
| National Institutes of Health | University of Rochester | Pediatric Vaccines | Praxis Biologics (Pfizer) | (80,000) |
| National Institutes of Health and National Science Foundation | University of California, San Francisco and Stanford | Gene therapies for asthma, rheumatoid arthritis, blood clots, and cancer | Genentech | 11,000 |
| Department of Defense | Stanford | Networking Technologies | Cisco | 36,000 |

**Table 2: Case Studies of Federally Funded R&D and the Private Sector Benefits**

In each of the highlighted cases, without federally funded R&D, billions of dollars of output would not have been generated. There are also positive spillovers that cannot be measured well. For example, it is clear that drugs that stop the propagation of cancer (i.e. Genentech's Rituxan's effect on non-Hodgkin's Lymphoma[28]) have a positive economic effect, but attaching a dollar value to this type of health benefit is difficult.[29] Further evidence of societal impact is the fact that the term "to Google" has become standard jargon for talking about researching an idea on the Internet. The evidence is clear that federally funded R&D bolsters innovation and economic growth at a fundamental level by increasing productivity. It leads to the creation of new markets, new products, and new solutions to existing and undiscovered problems through both the research's intended outcomes as well as through positive spillovers.

## Academic Background and the Related Empirical Evidence

The academic research on R&D and the effects of innovation on the economy has both depth and breadth. Before examining some of the relevant studies, it is important to note that there are at least two major economic models that explain how economic growth is caused. Though it is an oversimplified synopsis, within macroeconomics, there are those who believe the economy tends toward an equilibrium growth rate (Keynesians), and those who believe that the trajectory of the economy is endogenously determined by technological progress (New-Growth economists). The first camp's model would indicate that the government's responsibility is to use monetary and fiscal policies to "smooth" out the business cycle. The second camp's model would indicate that the government's role should be in setting a stage where R&D and innovation are actively supported and induced, as they are the deeper causes of economic growth and increased welfare. There are certainly cases for both approaches, but to only acknowledge one or the other does not pay tribute to the significant research on economic growth that has proliferated over the last century.

It is not that either camp is necessarily right or wrong, but that the different models specifically answer different types of questions. The Keynesian model is useful over short time spans relating to business cycles and tractable fluctuations. However, when large structural changes to the underlying mechanisms (consumption, investment, government, and trade) occur, using Keynesian models to help with policy decisions is actually outside the realm of the questions that the commonly taught IS-LM or AS-AD models are able to answer. In fact, anything that changes the underlying mechanisms is considered exogenous to the model. Therefore, if one strictly adheres to the model, it would imply that government policy cannot affect the way that consumption or investment decisions are generated directly. Rather, changes in the interest rate are new inputs into an existing framework.

A departure from the Keynesian world is the New-Growth model, which is rooted in seminal work by Lucas and Romer from the late 1980s and early 1990s based on Schumpeterian approaches to growth. Lucas and Romer provide the conceptual basis for the role of knowledge production in economic growth, building on prior work by Solow.[30] Their work identified the fact that technological change and human capital were key drivers of long-term economic growth, and that these factors were determined within the economic system. This conceptual model departs from the Keynesian model in that it looks at the ways in which the underlying mechanisms and production processes change over time. It is primary to this report to present evidence that establishes R&D as a fundamental cause of economic growth and increased productivity. So, building on the New-Growth conceptual basis, the following literature identifies some of the key empirical work that reveals the positive relationship between R&D and growth as well as evidence of positive spillovers.

A brief review of the empirical literature on the economics of innovation often starts with Zvi Griliches' seminal empirical work on identifying the effect of R&D on productivity. Griliches finds a significant positive relationship between R&D and productivity. He also shows that the relationship is highly variable depending on the industry and country under consideration.[31] Building on Griliches' work, Coe and Helpman study spillovers in the international setting, looking at the differential impacts of local knowledge versus internationally sourced knowledge, and its potential to generate positive societal benefits.[32] Specifically, they relate changes in the R&D capital stock to changes in productivity. It should be noted that, holding employment fixed, changes in productivity are directly correlated to changes in GDP. For this reason, the terms "productivity gains" and "GDP growth" are often used interchangeably within the literature, as well as within this report.

Audrestch and Feldman's work revealed the need to consider a spatial dimension, and this bolstered a whole body of work on the geography of the economics of innovation.[33] Though Henderson et al. found that spillovers were often localized; this phenomenon seems to be disappearing.[34] Griffith et al. show that distance and agglomeration economies are becoming less important except in a few industries, such as pharmaceuticals, where laboratories and research locations (hospitals) must be co-located.[35] Bloom et al. find that spillovers are mitigated when firms are highly rival in output markets, advancing the need for publicly supported R&D.[36] Today, the studies of location have been extended by considering networks and the ways in which knowledge flows. Other work shows that networks as defined by industry, complementarities of product output or technology, culture, and even religion matter when considering how spillovers are generated and dispersed.[37]

Closely related to our report, Agrawal and Cockburn show that co-location of university research and industrial R&D is important for growth and related to the size of potential spillovers.[38] As previously shown in Figure 7, industrial research parks are built near universities in recognition of the fact that the two types of institutions tend to bounce ideas back and forth throughout the product development cycle. In addition, there are highly influential empirical studies of the knowledge spillovers of universities into the private sector, including work by Jaffe[39] and Zucker, Darby, and Armstrong.[40] More recent work by Aghion, Boustan, Hoxby, and Vandenbussche[41] and Kantor and Whalley[42] also examine spillovers from universities, and Furman and MacGarvie[43] examine the spillovers from basic science laboratories.

In summary, the empirical evidence shows that investment in R&D generates significant productivity gains and therefore increases GDP and real standards of living. Studies indicate that added productivity gains take place due to geographic proximity, due to industry (within and across industries, due to complementarities), and across networks. The research shows that knowledge flows (often measured as citations to patents or publications) are tightly correlated to the potential routes by which the spillovers occur. The evidence also reveals that these estimates are sensitive to probable measurement issues.

There are many questions related to how to measure innovative progress, as well as the impact a given innovation has on the greater economy. The R&D capital stock, total factor productivity (TFP), patents, publications and the related citations are generally the go-to data sources on which the prior analyses of technological progress and diffusion depend. The R&D capital stock is the dollar amount of total accumulated useful knowledge that is available for use in the United States at a given point in time. There are certainly issues in estimating the accumulation and depreciation of the R&D capital stock, primarily due to the difficulties in capturing accounting information that accurately measures investment in R&D and its value today.[44] TFP estimates are an indirect way to measure the effect that the R&D capital stock has on productivity growth. Hulten explains that TFP is open to a myriad of different interpretations because it is in fact residual a method of measuring technological progress.[45] However, by incorporating R&D capital into the National Income and Product Accounts (NIPAs), the estimates of TFP are made significantly more accurate.[46]

So, for the policymaker and for the purposes of this report, the key question is how R&D and GDP are causally related. For this, we turn to Hall et al., who present a metastudy of the impact of R&D on productivity growth.[47] It is from this work that we obtain the key elasticity used within our analysis. Hall et al. show that recent studies' estimates of the elasticity of R&D to GDP range from 0.03 to as high as 0.68. However, the most conservative estimate based on country level data shows an elasticity of 0.13. In addition, Coe et al. present the same number of 0.134 in their recent working paper.[48] What this number indicates is that if the R&D capital stock falls by one percent, it triggers a decrease in growth, causing GDP to decrease by 0.13 percent. Though this seems modest, when scaled to the national level, changes in the R&D capital stock have significant impacts on the growth rate of GDP. The Bureau of Economic Analysis (BEA) is actively measuring this data and looking to incorporate R&D within the investment category of the NIPAs. It is on their estimates of the R&D capital stock that we base our empirical model.

Because sequestration imposes cuts on an annual basis, there are both contemporary effects of changes in the R&D stock on GDP, as well as compound effects from previous expenditure cuts that impact GDP on an annual basis throughout the 2013-2021 period. However, the effects do not compound like a savings account. Rather, R&D capital depreciates, as mentioned earlier, and rather quickly. This should be clear, as that which is innovative today becomes obsolete quickly with the development of other, more advanced products.[49] So, for the purposes of this study, the cumulative effects fall off at the rate of 14.2 percent as estimated by Huang and Diewert.[50]

## EMPIRICAL ANALYSIS AND RESULTS

In the following section we will outline the empirical model and related results. The first subsection presents the estimates of the effects of sequestration of R&D on productivity growth and GDP. In the next and last subsections, we estimate the effects of the changes in the R&D sector due to sequestration on the knowledge base and, finally, employment.

### The Effect on GDP and Productivity

The empirical model is based on the following process. First, using the forecasts of R&D expenditures, we calculate the R&D expenditure shortfalls by comparing the annual levels of R&D expenditures under sequestration to each of the three benchmarks. These R&D shortfalls are converted into percentage changes in the R&D capital stock for each year by taking the ratio of the expenditure shortfall to the expected level of the R&D capital stock in each year minus any previous change, from 2013-2021. We are then able to utilize the elasticity estimated in Hall et al. and Coe et al. to calculate the impact on GDP. Finally, we sum the contemporaneous and residual effects from the expenditures shortfalls after properly accounting for depreciation.

For example, when comparing sequestration with the CBO baseline, the R&D expenditure shortfall in 2013 is calculated to be $12.4 billion. This is a decrease of 0.39 percent of the R&D capital stock, which is estimated at $3.2 trillion.51 We then multiply this percentage change by the elasticity of R&D to GDP, which is 0.13 according to Coe et al. This indicates that in 2013, GDP will decrease by 0.051 percent, or $8.1 billion, due to the productivity losses that would have otherwise been generated by R&D. However, the reduction continues to affect GDP throughout the 2013-2021 period. We use the depreciation rate, as indicated by Huang and Diewert, of 14.2 percent, so in 2014, the related decrease of GDP due to the 2013 expenditure shortfall is $6.9 billion. At the same time, in 2014, the United States experiences an additional R&D expenditure shortfall of $12.1 billion. This generates a decline in GDP of $7.3 billion. So, the net loss to GDP in 2014 is the sum of the two, or $14.2 billion. This process continues throughout the 2013 to 2021 period where in each year the total economic effect is a sum of an accumulated loss to GDP from prior R&D expenditure shortfalls, as well as the contemporaneous shortfall's effect on GDP.

The impacts of sequestration on productivity and GDP are outlined below in Figure 10, Figure 11 and Table 3. The related estimations of the losses to GDP are clearly dependent on the benchmark to which sequestration is compared, as the related R&D expenditure shortfalls are drastically different under each comparison. However, even when compared to the flat benchmark, the sequestration's effect is equivalent to throwing $203 billion in potential GDP away over the 2013-2021 period. The losses are more than double the expenditure shortfall. In other words, if the United States chose to follow the 2011 baseline rather than sequestration, the benefit would be more than double the cost over the nine years.[52]

Again, the OMB/CBO baseline is greatly misleading as to the scale of the real R&D shortfall the United States will experience due to sequestration of R&D. When an alternative benchmark that holds the size of the R&D sector constant relative to the rest of the economy over the 2013-2021 period is compared to sequestration, the results are significantly larger. The cumulative effect is a loss of GDP of $565billion. To put this in perspective, this is equivalent to approximately 14 percent of the entirety of expected GDP growth over the 2013-2021 period.

In the last scenario, when a benchmark of R&D expenditures that keeps pace with China is compared with sequestration, the cumulative loss in GDP is $861 billion. Though this is an upper bound it is important to consider, as this is what our loss will be in an international sense. In other words, the R&D expenditure shortfall will close the gap in total output between the United States and China by nearly $1 trillion over the 2013-2021 period.

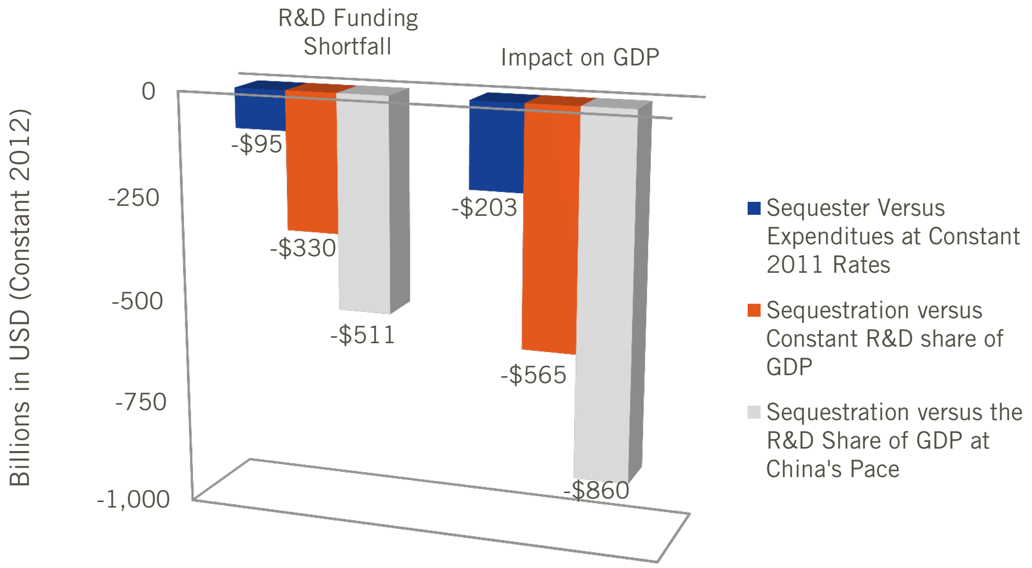

**Figure 10: R&D Funding Shortfalls and the Related Losses in Real GDP 2013-2021 Cumulative Effect, Source: NSF, OMB, CBO, BEA, ITIF**

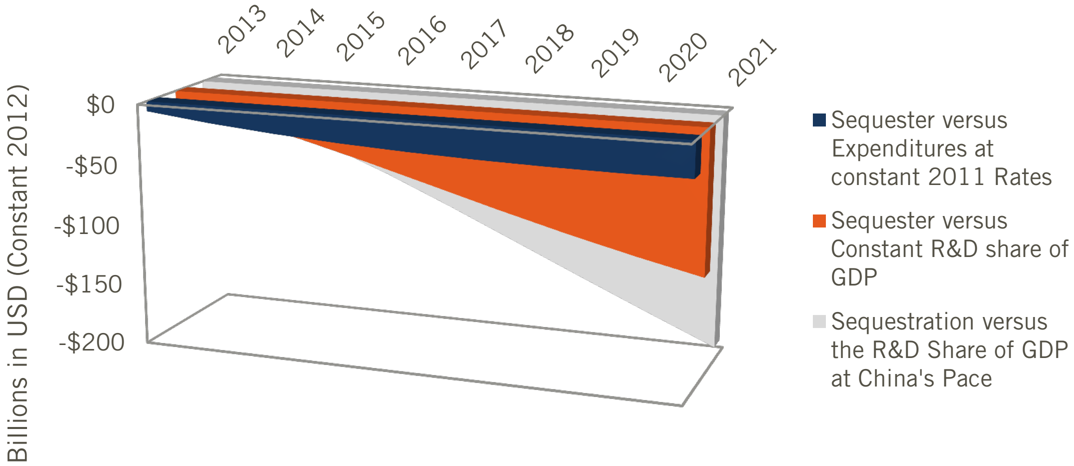

Figure 11: Annual Real GDP Losses due to Sequestration of Federally Funded R&D, Source: NSF, OMB, CBO, BEA, ITIF[53]

**The following table details the annual losses caused by sequestration of R&D expenditures.**

| Year | Sequestration vs. R&D at 2011 Rate | Sequestration vs. Constant R&D Share of GDP | Sequestration vs. R&D Share of GDP Increasing at China's Rate |
|---|---|---|---|
| 2013 | -$8,088 | -$9,929 | -$13,376 |
| 2014 | -$14,245 | -$20,341 | -$28,361 |
| 2015 | -$18,995 | -$32,842 | -$46,673 |
| 2016 | -$22,625 | -$47,102 | -$68,064 |
| 2017 | -$25,332 | -$62,306 | -$91,638 |
| 2018 | -$27,232 | -$77,541 | -$116,318 |
| 2019 | -$28,401 | -$92,008 | -$141,085 |
| 2020 | -$28,951 | -$105,414 | -$165,463 |
| 2021 | -$28,995 | -$117,670 | -$189,248 |
| **Cumulative:** | **-$202,865** | **-$565,153** | **-$860,226** |

**Table 3: Annual Real GDP Losses from R&D Expenditure Shortfall (Annual Effect in millions, USD)**

## Effects on Knowledge Base (Patents and Publications) and Future Workforce

An alternative measure of the impact of sequestration considers how the relevant knowledge base will change. Because both private and public institutions rely on prior research to develop new ideas and products, the rate at which innovation occurs is tied to how much has been done in the past. Patents and publications can be thought of as fuel for the "engine" of productivity. As the knowledge base accumulates, it enables more innovation to occur, or at least to tackle more difficult or complex problems. According to a recent study, an exogenous shock of one million dollars to R&D producing universities generates on average 10 publications or one patent.[54] Though this study looks at changes to the general fund of universities and the effect on the knowledge base, it is similar in nature to the cuts incurred by agencies due to sequestration. From this relationship we estimate the annual and average effects presented in Table 4 on the following page. We estimate that sequestration would result in U.S. scientific journal publications declining almost 8 percent and patents near 3 percent over the 9 year period, when compared to the CBO baseline.

| Year | Journal Publications | Patents |
|---|---|---|
| 2013 | -9.2% | -3.3% |
| 2014 | -8.9% | -3.1% |
| 2015 | -8.6% | -3.0% |
| 2016 | -8.2% | -2.9% |
| 2017 | -7.8% | -2.8% |
| 2018 | -7.5% | -2.6% |
| 2019 | -7.1% | -2.5% |
| 2020 | -6.7% | -2.4% |
| 2021 | -6.4% | -2.2% |
| **Average:** | **-7.8%** | **-2.8%** |

**Table 4: Losses to the Knowledge Base (Sequestration Compared to CBO Baseline)**

The estimates of the change in publication rates are based on the recent study by Björk that reports that there are approximately 1,350,000 peer-reviewed scientific publications produced per year within the 24,000 journals that exist today.[55] Because of the Internet, nearly all published research is available from all countries. So, the relevant knowledge base to consider is the global one. The estimates of the change in patenting rates are derived from the United States Patent and Trademark Office (USPTO) report that shows that there were 382,679 patents filed in 2011, including both foreign and domestic assignees.[56] It is important to recognize that the effect on publications is considerably larger than the effect on patent rates. This is primarily because federal R&D expenditures are responsible for 60 percent of all basic R&D produced in the United States. This is further justification for the use of the estimates of Whalley and Hicks, as their research is tied to universities that primarily focus on basic R&D.[57]54

As industrial producers increasingly cite publications, the significant reduction in basic R&D and the related publications will have long-term impacts on industry output potential. This effect is not incorporated into the model, but would make the impacts or R&D sequestration on GDP even larger in the long run.

Tied directly to the production of knowledge is the production of a highly skilled workforce for the future. The support and expansion of the number of graduate students is critical. One key way to expand the number of American residents receiving PhDs is to expand financial support frothier education. Indeed, the science policy community has frequently advocated for increasing the number of available federal graduate fellowships.[58]

As the government agencies are the key funders of graduate fellowships, sequestration will potentially choke off this vital resource that enables American scientists and engineers to pursue their careers, both academic and within industry.[59]

## The Effects on United States Employment (Short-Run)

In order to estimate the effects of sequestration on employment, we use a similar technique as in the analysis on productivity and GDP. The discussion of federal spending on employment is often confused. It should be noted that cutting federal spending in periods of full employment should have minimal impacts on employment. While the jobs directly supported by the federal spending would be lost, the savings generated would lead to the creation of other jobs, either through lower interest rates from cutting the national debt, or through higher consumer spending due to lower taxes. However, the story is very different in periods of less than full employment, which the United States is currently experiencing and is likely to experience for several years into the future. In this case, cutting R&D funding would lead to reduced jobs with fewer compensating new jobs to take their place.

However, this effect can be broken down into two sub-effects. First, there are the short-term job losses due to current worker displacement from the expenditure cuts. This is the standard Keynesian effect and the Keynesian job-multiplier in effect where the direct, intermediate and induced jobs are temporarily lost. However, there is an addition effect that is specific to R&D. Because decreases in R&D have a further deleterious effect on the economy from the losses in potential growth, the jobs that could have been created are also lost. This is the Schumpeterian effect on employment.

It is possible to estimate both the short-term Keynesian effects, as well as the Schumpeterian effects of R&D investment on jobs. For estimates of the Schumpeterian effect, we turn to the recent work of Bogliacino and Vivarelli who estimated that a 1 percent decrease in R&D stock leads to at least a 0.17 percent decrease in employment.[60] In addition, based upon prior findings on the Keynesian effects, we estimate employment losses based on the fact that expenditure cuts of $1million lead to short run losses of approximately 10 high-skilled jobs in R&D.[61] We can them gain a rough estimate of the annual net job losses by combining the R&D expenditure data and the BLS data on employment to derive the Schumpeterian Effect, while using the simple metric to calculate the Keynesian effects.

Finally, because the rate of economic recovery is difficult to predict, knowing when full employment will occur is not possible. In addition, it is unclear how the rate of unemployment and the relationship between government expenditure cuts are related. However, we believe it is clear that recovery will clearly take some time to occur, and thus we illustrate the annual effects on employment from 2013 to 2016.

It is worth noting that there is bipartisan support for the view that discretionary spending cuts will cost the United States jobs, as we have seen in the debate over the impacts of defense cuts on jobs due to sequestration. The research supports these views, but only as long as there is underemployment. As the current unemployment rate is 8.1 percent, there is clearly significant improvement needed to achieve the estimated 5 percent, which is the approximate natural rate of unemployment.

| Year | Keynesian Effect | Schumpeterian Effect | Net Effect |
|---|---|---|---|
| 2013 | -124,837 | -94,472 | -219,308 |
| 2014 | -120,535 | -85,599 | -206,134 |
| 2015 | -115,613 | -77,002 | -192,615 |
| 2016 | -110,101 | -68,739 | -178,840 |
| Average Annual Losses: | -117,771 | -81,453 | -199,224 |

**Table 5: Effects on Employment (Sequestration Compared to CBO Baseline)**

## CONCLUSION

Over the last quarter century, federal R&D investment has stalled, especially compared with past trends and the performances of other nations. To match federal R&D investment as a share of GDP in 1987, Congress would need to increase R&D investment by $110 billion. To match South Korea, the nation with the highest share of government R&D to GDP, Congress would need to invest on average $79 billion more per year than sequestration permits. So, even maintaining R&D at current levels, as is the assumption in the CBO baseline, would represent a failure to respond to the competitive challenge of the new global innovation economy. Cutting R&D as called for by the sequestration would obviously be worse.

We estimate, depending on the benchmark used, that R&D cuts from sequestration would result in losses to GDP of between $203 and $860 billion. This indicates that GDP in the United States will increase nearly one trillion dollars less than China's over the 2013-2021 period, due solely to the cuts in R&D expenditures that sequestration requires. We agree that deficit reduction is clearly a necessary task. However, as growth is a key component to achieving that task, the evidence presented clearly shows that cutting R&D expenditures will in fact negate efforts to reduce the deficit.

Though there must be cuts to discretionary and non-discretionary spending over the upcoming years, we strongly recommend that policymakers act swiftly to put into place an alternative to sequestration that does not impact the R&D efforts both performed and supported through the various government agencies. In order to remain competitive in the face of global competition in innovation, we should be increasing our investment in R&D. If we do not, then we will fall further behind our competitors. This will greatly impede our ability to generate export-oriented growth, as our ability to generate new and useful products will fall both nationally, and especially internationally.

# APPENDIX A: FORECAST DATA AND THE EMPIRICAL MODEL

## Forecasts of R&D Expenditures and the Shortfalls Under Sequestration

The estimates of the economic effects of sequestration are based on aggregated agency level R&D expenditure forecasts. In order to forecast the rates of total discretionary spending, we first use data on the historical ratios of total discretionary expenditures to GDP from 1992 through 2011. We then similarly identify the ratios of individual agency discretionary expenditures to total discretionary expenditures. Finally, we compile the within-agency discretionary R&D expenditures as a proportion of each agency's total discretionary expenditures.

As a benchmark for the various forecasts, we utilize the Congressional Budget Office's (CBO's) forecast of real GDP through 2021.[62] By exploiting the correlations among and between the outlined time-series and ratios, we are then able to forecast forward the within-agency R&D expenditures, as well as the total amount of discretionary expenditures that go toward R&D. A key characteristic of the model is that within-agency R&D intensities (the proportion of R&D expenditures to total discretionary expenditures) are assumed to remain constant throughout the forecast period. The within-agency R&D intensities are derived from the existing data. After completing the forecast algorithm, we are able to forecast the discretionary R&D expenditures according the different possible expenditure paths we have outlined. It is from the relative shortfalls that the effects on the R&D stock are calculated, and then the effects on GDP.

The various forecasts under the sequestration and three benchmarks at the agency level are presented in the following tables. All the following flows are in nominal levels.

Table 6: R&D Expenditures Under Sequestration (billions, USD)

| Year | DOD | NIH | NASA | NSF | DOE | USDA | DOT | Defense R&D | Non-Defense R&D |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | 45,713 | 20,758 | 6,126 | 2,566 | 1,314 | 1,657 | 1,640 | 44,147 | 35,942 |
| **2002** | 53,016 | 23,560 | 6,270 | 2,803 | 1,327 | 1,606 | 1,838 | 48,238 | 39,673 |
| **2003** | 63,048 | 26,517 | 7,355 | 3,235 | 1,403 | 1,708 | 1,869 | 57,328 | 44,112 |
| **2004** | 69,593 | 28,251 | 7,612 | 3,439 | 1,343 | 1,750 | 1,863 | 65,345 | 48,034 |
| **2005** | 74,047 | 28,824 | 7,300 | 3,638 | 1,296 | 1,820 | 1,847 | 70,646 | 49,200 |
| **2006** | 78,037 | 28,797 | 8,204 | 3,707 | 1,195 | 1,869 | 1,711 | 73,043 | 49,752 |
| **2007** | 82,272 | 29,461 | 9,024 | 3,569 | 1,893 | 1,857 | 1,361 | 77,078 | 52,611 |
| **2008** | 84,713 | 29,063 | 8,323 | 3,781 | 1,896 | 1,864 | 1,394 | 79,601 | 55,346 |
| **2009** | 85,166 | 40,389 | 6,891 | 3,936 | 3,318 | 1,935 | 1,440 | 82,918 | 56,911 |
| **2010** | 84,866 | 30,827 | 6,205 | 4,772 | 2,014 | 2,043 | 1,336 | 81,090 | 59,836 |
| **2011** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2012**[63] | 80,039 | 28,537 | 7,013 | 5,026 | 1,992 | 1,898 | 1,333 | 79,425 | 58,902 |
| **2013** | 76,119 | 28,492 | 6,670 | 4,780 | 1,895 | 1,739 | 1,268 | 72,332 | 58,809 |
| **2014** | 76,401 | 28,779 | 6,695 | 4,798 | 1,902 | 1,756 | 1,272 | 72,170 | 59,401 |
| **2015** | 76,690 | 28,909 | 6,720 | 4,816 | 1,909 | 1,764 | 1,277 | 72,392 | 59,671 |
| **2016** | 77,011 | 29,036 | 6,748 | 4,836 | 1,917 | 1,772 | 1,283 | 72,682 | 59,933 |
| **2017** | 77,286 | 29,130 | 6,772 | 4,854 | 1,924 | 1,778 | 1,287 | 72,964 | 60,127 |
| **2018** | 77,553 | 29,222 | 6,795 | 4,870 | 1,930 | 1,783 | 1,292 | 73,237 | 60,316 |
| **2019** | 77,846 | 29,337 | 6,821 | 4,889 | 1,938 | 1,790 | 1,296 | 73,502 | 60,554 |
| **2020** | 78,130 | 29,449 | 6,846 | 4,907 | 1,945 | 1,797 | 1,301 | 73,759 | 60,784 |
| **2021** | 78,404 | 29,556 | 6,870 | 4,924 | 1,951 | 1,804 | 1,306 | 74,008 | 61,007 |

Table 7: R&D Expenditures at 2011 Levels (billions, USD)

| Year | DOD | NIH | NASA | NSF | DOE | USDA | DOT | Defense R&D | Non-Defense R&D |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | 45,713 | 20,758 | 6,126 | 2,566 | 1,314 | 1,657 | 1,640 | 44,147 | 35,942 |
| **2002** | 53,016 | 23,560 | 6,270 | 2,803 | 1,327 | 1,606 | 1,838 | 48,238 | 39,673 |
| **2003** | 63,048 | 26,517 | 7,355 | 3,235 | 1,403 | 1,708 | 1,869 | 57,328 | 44,112 |
| **2004** | 69,593 | 28,251 | 7,612 | 3,439 | 1,343 | 1,750 | 1,863 | 65,345 | 48,034 |
| **2005** | 74,047 | 28,824 | 7,300 | 3,638 | 1,296 | 1,820 | 1,847 | 70,646 | 49,200 |
| **2006** | 78,037 | 28,797 | 8,204 | 3,707 | 1,195 | 1,869 | 1,711 | 73,043 | 49,752 |
| **2007** | 82,272 | 29,461 | 9,024 | 3,569 | 1,893 | 1,857 | 1,361 | 77,078 | 52,611 |
| **2008** | 84,713 | 29,063 | 8,323 | 3,781 | 1,896 | 1,864 | 1,394 | 79,601 | 55,346 |
| **2009** | 85,166 | 40,389 | 6,891 | 3,936 | 3,318 | 1,935 | 1,440 | 82,918 | 56,911 |
| **2010** | 84,866 | 30,827 | 6,205 | 4,772 | 2,014 | 2,043 | 1,336 | 81,090 | 59,836 |
| **2011** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2012**[64] | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2013** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2014** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2015** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2016** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2017** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2018** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2019** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2020** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2021** | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |

Table 8: R&D Expenditures at Expected GDP Growth Rate (billions, USD)

| Year | DOD | NIH | NASA | NSF | DOE | USDA | DOT | Defense R&D | Non-Defense R&D |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | 45,713 | 20,758 | 6,126 | 2,566 | 1,314 | 1,657 | 1,640 | 44,147 | 35,942 |
| **2002** | 53,016 | 23,560 | 6,270 | 2,803 | 1,327 | 1,606 | 1,838 | 48,238 | 39,673 |
| **2003** | 63,048 | 26,517 | 7,355 | 3,235 | 1,403 | 1,708 | 1,869 | 57,328 | 44,112 |
| **2004** | 69,593 | 28,251 | 7,612 | 3,439 | 1,343 | 1,750 | 1,863 | 65,345 | 48,034 |
| **2005** | 74,047 | 28,824 | 7,300 | 3,638 | 1,296 | 1,820 | 1,847 | 70,646 | 49,200 |
| **2006** | 78,037 | 28,797 | 8,204 | 3,707 | 1,195 | 1,869 | 1,711 | 73,043 | 49,752 |
| **2007** | 82,272 | 29,461 | 9,024 | 3,569 | 1,893 | 1,857 | 1,361 | 77,078 | 52,611 |
| **2008** | 84,713 | 29,063 | 8,323 | 3,781 | 1,896 | 1,864 | 1,394 | 79,601 | 55,346 |
| **2009** | 85,166 | 40,389 | 6,891 | 3,936 | 3,318 | 1,935 | 1,440 | 82,918 | 56,911 |
| **2010** | 84,866 | 30,827 | 6,205 | 4,772 | 2,014 | 2,043 | 1,336 | 81,090 | 59,836 |
| **2011**[65] | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2012** | 85,195 | 31,676 | 7,465 | 5,350 | 2,121 | 1,933 | 1,419 | 81,460 | 65,383 |
| **2013** | 84,977 | 31,595 | 7,446 | 5,337 | 2,115 | 1,928 | 1,415 | 81,252 | 65,216 |
| **2014** | 87,641 | 32,586 | 7,679 | 5,504 | 2,181 | 1,989 | 1,460 | 83,798 | 67,260 |
| **2015** | 91,819 | 34,139 | 8,046 | 5,766 | 2,285 | 2,083 | 1,529 | 87,794 | 70,467 |
| **2016** | 95,932 | 35,668 | 8,406 | 6,025 | 2,388 | 2,177 | 1,598 | 91,726 | 73,623 |
| **2017** | 99,600 | 37,032 | 8,727 | 6,255 | 2,479 | 2,260 | 1,659 | 95,233 | 76,438 |
| **2018** | 102,736 | 38,198 | 9,002 | 6,452 | 2,557 | 2,331 | 1,711 | 98,232 | 78,844 |
| **2019** | 105,368 | 39,177 | 9,233 | 6,617 | 2,623 | 2,391 | 1,755 | 100,749 | 80,865 |
| **2020** | 107,864 | 40,105 | 9,452 | 6,774 | 2,685 | 2,447 | 1,796 | 103,135 | 82,780 |
| **2021** | 110,289 | 41,007 | 9,664 | 6,926 | 2,745 | 2,502 | 1,837 | 105,453 | 84,641 |

Table 9: R&D Expenditures Following China's Expected Expenditure Path (billions, USD)

| Year | DOD | NIH | NASA | NSF | DOE | USDA | DOT | Defense R&D | Non-Defense R&D |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | 45,713 | 20,758 | 6,126 | 2,566 | 1,314 | 1,657 | 1,640 | 44,147 | 35,942 |
| **2002** | 53,016 | 23,560 | 6,270 | 2,803 | 1,327 | 1,606 | 1,838 | 48,238 | 39,673 |
| **2003** | 63,048 | 26,517 | 7,355 | 3,235 | 1,403 | 1,708 | 1,869 | 57,328 | 44,112 |
| **2004** | 69,593 | 28,251 | 7,612 | 3,439 | 1,343 | 1,750 | 1,863 | 65,345 | 48,034 |
| **2005** | 74,047 | 28,824 | 7,300 | 3,638 | 1,296 | 1,820 | 1,847 | 70,646 | 49,200 |
| **2006** | 78,037 | 28,797 | 8,204 | 3,707 | 1,195 | 1,869 | 1,711 | 73,043 | 49,752 |
| **2007** | 82,272 | 29,461 | 9,024 | 3,569 | 1,893 | 1,857 | 1,361 | 77,078 | 52,611 |
| **2008** | 84,713 | 29,063 | 8,323 | 3,781 | 1,896 | 1,864 | 1,394 | 79,601 | 55,346 |
| **2009** | 85,166 | 40,389 | 6,891 | 3,936 | 3,318 | 1,935 | 1,440 | 82,918 | 56,911 |
| **2010** | 84,866 | 30,827 | 6,205 | 4,772 | 2,014 | 2,043 | 1,336 | 81,090 | 59,836 |
| **2011**[66] | 83,328 | 30,982 | 7,302 | 5,233 | 2,074 | 1,891 | 1,388 | 79,675 | 63,950 |
| **2012** | 86,729 | 32,247 | 7,600 | 5,447 | 2,159 | 1,968 | 1,444 | 82,926 | 66,560 |
| **2013** | 88,064 | 32,743 | 7,717 | 5,530 | 2,192 | 1,998 | 1,467 | 84,203 | 67,585 |
| **2014** | 92,459 | 34,377 | 8,102 | 5,806 | 2,301 | 2,098 | 1,540 | 88,406 | 70,957 |
| **2015** | 98,611 | 36,665 | 8,641 | 6,193 | 2,454 | 2,237 | 1,642 | 94,288 | 75,679 |
| **2016** | 104,882 | 38,996 | 9,190 | 6,587 | 2,611 | 2,380 | 1,747 | 100,284 | 80,492 |
| **2017** | 110,853 | 41,216 | 9,713 | 6,962 | 2,759 | 2,515 | 1,846 | 105,993 | 85,074 |
| **2018** | 116,401 | 43,279 | 10,200 | 7,310 | 2,897 | 2,641 | 1,939 | 111,298 | 89,332 |
| **2019** | 121,533 | 45,187 | 10,649 | 7,632 | 3,025 | 2,758 | 2,024 | 116,205 | 93,270 |
| **2020** | 126,650 | 47,090 | 11,098 | 7,954 | 3,152 | 2,874 | 2,109 | 121,098 | 97,198 |
| **2021** | 131,828 | 49,015 | 11,551 | 8,279 | 3,281 | 2,991 | 2,196 | 126,049 | 101,171 |

## Outline of the Empirical Model:

$$\mathit{Total\ Economic\ Effect} = \sum_{t=2013}^{t=2021} \left( \Delta GDP_t (1+\delta)^{2021-t} \right) |$$

$$\Delta GDP_t = \sum_{m=2021-t}^{2021} \left( (1+\%\Delta GDP_t)(GDP_{t-1} - \underbrace{(\sum_{l=2}^{b} GDP_{t-1} - GDP_{t-l})}_{\text{This adjusts the base by the prior years loss}} \right)^{2021-t} |$$

$$\%\Delta GDP_t = \left( \frac{\partial GDP}{\partial \text{R\&D Stock}} \right)_{Hall/Coe} \left( \Delta \text{R\&D Stock}_t \right) |$$

$$\Delta \text{R\&D Stock}_t = \left( \left( \text{R\&D Stock}_{BEA,t} \right) - \underbrace{\left( \sum_{l=2}^{b} \text{R\&D Stock}_{BEA,t-1} - \text{R\&D Stock}_{BEA,t-l} \right)}_{\text{This adjusts the base by the prior years loss}} \right) - \ldots$$

$$\ldots - \Delta \text{R\&D Expenditure}_t \,|$$

$$\Delta \text{R\&D Expenditure}_t = \sum_{A=1}^{8} \left( \text{R\&D Expenditure}_{Sequester,A,t} - \text{R\&D Expenditure}_{Baseline\ i,A,t} \right)$$

$$\left( \frac{\partial GDP}{\partial \text{R\&D Stock}} \right)_{Hall/Coe} = 0.13 \text{ as shown in Hall et al. 2009, and Coe et al. 2008}$$

$\delta = -.142$ as derived in Huang & Diewert, 2009

$\text{R\&D Stock}_{BEA}$ = R&D Stock as monitored by the BEA's R&D Satellite Account

$b$ = the number of years between year t and 2012. This is used to adjust the base for any prior losses, and properly compound the net effects over time.

If $t = 2013 \rightarrow GDP_{t-1} = GDP_{CBO,t-1} \,|\, GDP_{CBO}$ = Congressional Budget Office GDP Forecast

$$\mathit{Baseline} = \begin{cases} \text{Constant 2011 Expenditures} \\ \text{Constant GERD/GDP ratio} \\ \text{Increase GERD/GDP at China's Average Rate} \end{cases}$$

$A$ = Government Agencies = $(DOD, DOE, DOA, NSF, NIH, NASA, DOT, Other)$

- R&D Stock from the BEA Satellite account is forecast forward based on the average change in the R&D Stock/GDP Ratio from 1992 through 2008. The revised August 2012 CBO forecast of real GDP through 2021 is the benchmark from which these projections are calculated.
- R&D benefits fall off at the rate of the R&D depreciation rate found by Diewert 2009: 14.2%.[67]
- The elasticity of the R&D stock to GDP is from Hall 2009 and is approximately 0.13. This means a 1% change in the R&D stock will cause a 0.13% change in GDP.[68]47

We have also utilized alternative R&D capital depreciation rates, and as this is a structural model, it does impact the size of the economic returns. In addition, the outcomes are sensitive to the size of the R&D-GDP elasticity incorporated into the model. Alternative results based on various assumptions are available from the authors upon request.

An alternative model simply based on the net present value of the "Return on Investment" has also been estimated. However, due to the wide range of estimated ROIs in the literature, introducing an objective ROI for the purposes of this national level study is not possible.

### Alternative model:

$$\mathit{Economic\ Effect} = \sum_{t=2013}^{2021} \left( \left( \Delta \text{R\&D Expenditure}_t \right) (1 + \mathit{ROI})^{2021-t} \right)$$

It should be noted that if the ROI is calibrated to 10 percent, then the results are very close to those presented in the analysis using the model outlined above. We choose to use the model that is based in the literature, and it is also more conservative in its results.

Table 10: Alternative Economic Model Using Compound 10 Percent ROI in NPV

| **Alternative Benchmarks for Analysis** | R&D Expenditure Shortfall Under Sequestration | Economic Effect |
|---|---|---|
| **Constant at 2011 Expenditures:** | -$104,579 | -$246,592 |
| **Increased at Rate of GDP Growth:** | -$339,459 | -$800,427 |
| **Matched to China's R&D Path:** | -$520,532 | -$1,227,388 |

# ENDNOTES

1. Though the initial cuts differ between defense and non-defense—9.4 and 8.2 percent respectively—the average across all R&D is 8.8 percent. This is calculated from the baseline from which the OMB and CBO calculated the actual changes to discretionary expenditures under sequestration. It should be clear that this baseline is purely based on accounting procedures. This can be misleading when considering the United States' innovative output in a global setting.
2. BEA: Consumer Spending (table 2.4.5., personal consumption expenditures by type of product; (Accessed 16, September 2012), http://www.bea.gov/national/consumer_spending.htm.
3. David T. Coe, Elhanan Helpman, and Alexander W. Hoffmaister, "International R&D Spillovers and Institutions," *European Economic Review* 53, no. 7 (October, 2009), p. 723-741.
4. The R&D expenditure shortfall is the distance between a given benchmark and sequestration at a given point in time. The cumulative difference is the difference between the relative areas. The flows are in nominal levels, whereas any calculated economic impacts are in real 2012 USD.
5. "Arrested Development: America and Europe are Relying on Private Firms in the Global R&D Race," *Economist*, August 25, 2012, http://www.economist.com/node/21560863; National Science Board, "Research and Development: National Trends and International Comparisons" in *National Science and Engineering Indicators 2012* (Arlington, VA, National Science Foundation, 2012), http://www.nsf.gov/statistics/seind12/c4/c4h.htm; Daniel Lederman and William F. Maloney, "R&D and Development" (working paper no. 3024, World Bank Policy Research, April 2003), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=402480; OECD (2012),"Main Science and Technology Indicators," (database, OECD Science, Technology and R&D Statistics), doi: 10.1787/data-00182-en (Accessed on 07 September 2012); "Science, Technology and Innovation in Europe," *eurostat Pocketbooks*, (Accessed 07, September 2012), http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-11-118/EN/KS-31-11-118-EN.PDF.
6. This is the same as keeping the R&D/GDP ratio constant over the upcoming nine-year period. This should be our benchmark for R&D expenditures. If we institute policy that does anything less, it will guarantee that the United States will fall significantly behind relative to our international competitors.
7. This benchmark is based on the assumption that the United States increases its R&D to GDP ratio at the same rate as China. It is assumed that the trend of R&D/GDP for China from 1992-2011 will continue throughout the period.
8. National Science Board, "Research and Development: National Trends and International Comparisons" in *National Science and Engineering Indicators 2012* (Arlington, VA, National Science Foundation, 2012), http://www.nsf.gov/statistics/seind12/c4/c4h.htm; Robert D. Atkinson, Stephen Ezell, and Luke A. Stewart, *The Global Innovation Policy Index* (Washington, D.C.: ITIF/Kauffman Foundation, March 2012), http://www2.itif.org/2012-global-innovation-policy-index.pdf.
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10. National Science Board, "Research and Development: National Trends and International Comparisons," p. 12–13, fig. 4-3.
11. "The federal government is the primary source of funding for basic research conducted in the United States, providing some 60 percent of funding. The second largest source of basic research funding is the academic institutions themselves." From: Sparking Economic Growth (Washington, D.C.: Science Coalition, April 2010), p. 3, http://www.sciencecoalition.org/successstories/resources/pdf/Sparking%20Economic%20Growth%20Full%20Report%20FINAL%204-5-10.pdf.
12. National Science Board, "Research and Development: National Trends and International Comparisons," p. 14 table 4-3.
13. This is rooted in the fact that federal funding is often the source from which the basic building blocks of the fully developed private sector products are built. Federal funding flows through the government agencies, and is often used at national laboratories where all the major players work together to answer big-picture questions. Another channel is when agency funding flows to universities through grants, where basic research is performed. Often universities and private sector firms also partner, as is shown clearly in Figure 7. However, it is the federal funding that enables most of the university based research to occur.; Fred Block and Matthew R. Keller, *Where Do Innovations Come From? Transformations in the*

*U.S. National Innovation System,1970-2006* (technical report, ITIF, Washington, D.C., 2008), http://www.itif.org/files/Where_do_innovations_come_from.pdf.

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15. Nicholas Bloom, Mark Schankerman, and John Van Reenen, "Identifying Technology Spillovers and Product Market Rivalry"(working paper no. 13060,NBER, April 2007), http://www.nber.org/papers/w13060; Ufuk Akcigit, Douglas Hanley, and Nicolas Serrano-Velarde, "Back to Basics: Private and Public Investment in Basic R&D and Macroeconomic Growth," (working paper, Department of Economics, Western University, London, Ontario, Canada, October 28, 2010), http://www.economics.uwo.ca/conference/CMSG_2010/papers/akcigit_hanley_velarde.pdf.
16. "It may be optimal from a welfare perspective to use R&D subsidies when the source of R&D distortions originates from the surplus appropriability problem and technological spillovers in the form of knowledge spillovers, creative destruction, and duplication externalities are absent. Hence, R&D subsidies may constitute the welfare maximizing policy even when subsidies directly targeted on monopoly pricing could be applied. The result holds when dynamic gains are important relative to static gains and when government spending is restricted, i.e., below the required effort for correcting completely for market failures. The argument is developed in a semi-endogenous growth model where the only distortion is monopoly pricing of intermediate goods." From: Anders Sorenson, "R&D Subsidies and the Surplus Appropriability Problem," B.E. Journal of Macroeconomics (2006).
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18. Sparking Economic Growth, p. 3.
19. Committee on Depicting Innovation in Information Technology, et al., Continuing Innovation in Information Technology(Washington, D.C.: National Academies Press, 2012), http://www.nap.edu/openbook.php?record_id=13427.
20. National GERD/GDP ratios are projected forward based on average changes from 1992 through 2009 from the referenced OECD data. The U.S. ratios are projected forward after accounting for the R&D sequestration.
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22. Robert D. Atkinson and Stephen J. Ezell, I*nnovation Economics: The Race for Global Advantage* (New Haven: Yale University Press¸2012).
23. Though the trends are important to recognize, the overall level of R&D expenditures in the United States are around $400 billion, whereas the next nearest is China at $178 billion. However, this gap will quickly disappear if sequestration occurs.
24. Sparking Economic Growth.
25. According to the global research agency Millward Brown, Google has been number one (as of 2010), and remained in the top three in their BrandZ charts ranking companies according to their calculated global brand recognition. See: "BrandZTM Top 100 Most Valuable Global Brands 2012," *Millward Brown Optimor*, 2012, http://www.millwardbrown.com/brandz/2012/Documents/2012_BrandZ_Top100_Chart.pdf.
26. These 50,000 jobs include both indirect and induced jobs: intermediate good suppliers and service sector growth to support employees relatively.
27. For a complete listing and description of the top 100 Federally Funded R&D spinoffs, see: Sparking Economic Growth.
28. Generic: rituximab. For details see: http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0000388/.
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    $\ln(\text{Productivity}) = \beta(\ln(\text{R\&D Expenditures})) + \varepsilon$

    The result we use is located in the last column, top row of Table 4. This is run on the largest sample with appropriate controls for country level heterogeneity (country level fixed effects).

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53. It is important to note that these declines are net of the R&D expenditures themselves. The GDP losses only capture the lost value-added, as the dollars spent on R&D could be spent elsewhere in the economy. Finally, as it is not possible to predict how those dollars would be spent or invested alternatively, these estimates do not account of the alternative rates of return. It could be possible to benchmark alternative rates of return from average bond rates or average market yields. However, as outlined within the report, with high volatility and unstable links between asset prices and their fundamental values, using financial market returns as a benchmark is subject to large errors in valuation. Because the results are cautious in their use of elasticities and R&D capital depreciation, it is unclear how much a further structural addition (based on assumption) to the model will add to the forecast's legitimacy.

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64. The data post-2011 is held constant, as this is the benchmark from which sequestration's calculated savings of $1.2 trillion over the 2013-2021 period is calculated.

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65. The post-2011 R&D expenditures trend with the CBO's updated forecast of real GDP to establish a benchmark where the R&D/GDP ratio remains constant over the period. Based on the growth in R&D expenditures from 1992 to 2011, this is emphasized as both an achievable and reasonable benchmark.
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## ACKNOWLEDGEMENTS

The authors wish to thank the following individuals for providing input to this report: William Andresen, Abby Benson, William Bonvillian, Sue Garman Kranias, Philip Lippel, Kari MacCarron, Jennifer Poulakidas, Elizabeth Stewart, Barry Toiv, and Carrie Wolinetz. Any errors or omissions are the authors' alone.

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## ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a Washington, D.C.-based think tank at the cutting edge of designing innovation strategies and technology policies to create economic opportunities and improve quality of life in the United States and around the world. Founded in 2006, ITIF is a 501(c) 3 nonprofit, non-partisan organization that documents the beneficial role technology plays in our lives and provides pragmatic ideas for improving technology-driven productivity, boosting competitiveness, and meeting today's global challenges through innovation.

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