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CAN THE RESEARCH MODEL MOVE BEYOND ITS DOMINANT PATRON?
The Future of Support for Fundamental Research in US Universities

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ABSTRACT

The United States has been the leader in fundamental research for the last seven decades. Fundamental research is overwhelming undertaken in or in conjunction with research-intensive universities, and since the 1950s they have depended on US Federal funding to make this possible. This support has been consistently championed by Congress, is popular across the political spectrum and enjoys long public backing, in no small part because there remains a widespread trust in the societal benefits it provides. Yet the US now faces a dilemma over the future of this national achievement and the supporting arrangements making it sustainable. The 'social contract' for science and research now looks more tentative than at any time since the Space Race. This paper examines why many US university leaders, faculty, experts and policy-makers are increasingly concerned, what is driving this and how they are responding. Building on 37 interviews with university, academic and government leaders, this study uses a mixed methodology to explore perceived institutional challenges and the politics around them, alongside the responses and strategies of US research-intensive universities in the context of global, national and regional policies. This paper examines tensions in the relationship between universities and government, and between researcher and public, combining perspectives from a sample of leading research universities and from national policy leaders to offer insight into the intersection of Federal policy and local operationalization. It concludes that for the future of US basic science and research two factors are likely to be decisive, being whether the strength of the public backing for funding university-based fundamental research continues, and how universities respond if, and in the assessment of many, when this support erodes. If the current research system is to remain viable, universities will need to make greater efforts to rebuild trust and understanding with the US public and litigate anew their raison d'etre at the center of US research.

Keywords: Research Universities, Federal R&D Funding, Social Contract for Science.

The United States remains the single largest contributor to worldwide research, but this is changing. In 2000 the US accounted for 40 percent of global R&D output reducing to 29.3 percent by 2013. The EU showed a somewhat smaller decline from 27.3 per cent to 22.7 per cent. A central reason for this reduction is China's investment, which will likely surpass the US in total R&D funding by 2019 (Hourihan and Parkes 2016, 8). While China will eventually eclipse the US in total output as it invests in development and applied research, the US will remain the major provider of fundamental research for the foreseeable future.

In the US fundamental research relies on public and Congressional support that shows signs of eroding. For the first time since the Space Race US Federal government investment in fundamental research may decline. Since being elected in 2016 President Donald Trump has produced two budgets proposing to dramatically reduce Federal support for science and his administration continues to entertain criticism of high profile areas of science, such as climate research. This is the most hostility shown by a US Federal administration to science since the creation of the modern science state following the Second World War. The rhetoric of the administration and its sharp massage for the research community signals a more complex set of structural and political factors

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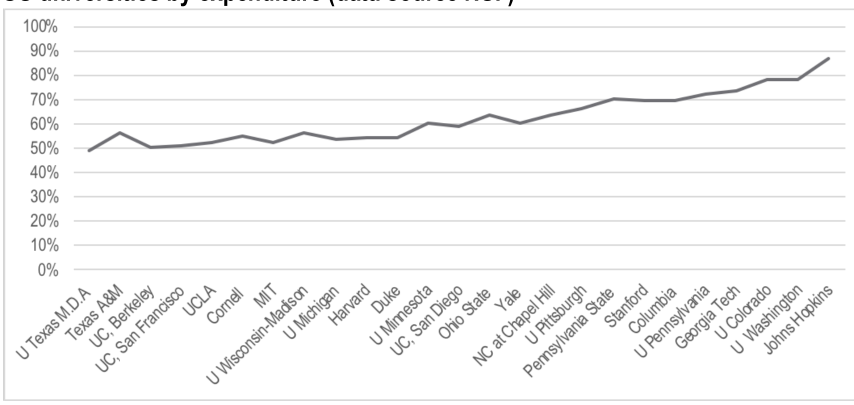
which pose a threat to the current system of university-based research. Many scientists, university leaders and advocates rightly voice concern that significantly reducing Federal funding in a haphazard or disruptive manner will undermine the US research effort.

Universities are now the principal engine for advances in fundamental science and in the US expended over $68 billion on research in 2015, with direct US government financing to university research of over $37 billion, and accounting for an average of 55 per cent of their total reported expenditure to the National Science Foundation (NSF). The centrality of public funds is even more pronounced when State funding is included, as Figure 1 of the top 25 institutions by expenditure shows. For some of the largest research universities, such as Stanford University, Federal financing alone was approaching 70 per cent of their reported total expenditure and their next largest source was from their endowment and internal institutional general funds. The capacity of US universities, including Stanford, to provide internal backing benefits from indirect forms of government support, such as through tax breaks on some operations, means reported Federal and State direct financing likely understates the true level of government support for research.

Figure 1: Government (Federal and State) financed research, Proportion of the total research expenditure 2015, Top 25 US universities by expenditure (data source NSF)



The US Federal government began providing significant public financing for fundamental research in the latter part of the twentieth century, initially for defense but now mainly through agencies such as the National Institutes of Health (NIH). Section 2 of this paper details some of the effects and implications for universities of having a single dominant patron for research in the US government. One senior administrator and dean in a public university interviewed for this study summarized this impact, saying "science and research in US research-intensive universities would not be possible at the current scale and configuration without Federal support… it is not clear how we could achieve what we do without it" (Interview #4). University research expenditure is financed also from philanthropy (individuals' grants and foundations), contract and commercial income, State government funding for projects and overhead costs, and internal sources such as endowment income or subsidy from student fees. For most institutions, however, all these sources of financing are a supplement to direct Federal research funding, with no other source anywhere near as dominant. As a senior university administrator argued, "it is often hard to find non-government sources of support for research, especially where it is not in the STEM disciplines or where it is hard to explain its importance in a one-page press release" (Interview #23). Where universities are successful in securing non-Federal financing, such as through philanthropic gifts, these rarely cover the full costs or come entirely unfettered (see also OECD 2016).

Universities respond to government incentives, especially where they involve significant funds. The Federal government as patron has meant a strong interaction between government and institutional funding structures. Mechanisms and norms of internal university support have evolved as part of the reliance on Federal programs. There has been significant growth in some areas in response to infrequent but large program increases, for example the short-lived NIH boost in 2003, meaning continual but uneven pressure for more resources, and there is often an unavoidable subsidization of some areas of science from unrelated revenue streams, such as fee income. Federal funds for indirect costs (also known as F&A or overhead costs) remain crucial to ensuring universities can support research. As a number of interviewees for this study noted, there is a growing recognition too that internal university accounting structures need improvement.

National politics

Following the election of President Donald Trump in 2016, many commentators voiced concern for the hostility shown by the administration towards science. Despite this high-profile rhetoric, to focus on the possible actions of one administration downplays the longer term and more systemic political factors at play. For many supporters of fundamental research there has been a willingness not to dwell on the ugly inevitability that if it is to continue apace in the US under the present structures, it will likely require evermore public money. Section 4 of this paper shows that Federal research has been consistently supported as a part of the discretionary portion of the Federal budget. Yet brittle congressional support, growing contestation over different areas of science, such as climate science, and thin public engagement with research may mean this cannot be assumed into the future.

Many commentators (and interviewees for this study) fear competing requests for diminishing discretionary Federal funds means the NSF and NIH will inevitably have their available funds reduced over the longer term. The support for research funding in Congress and among federal political leaders is broad but shallow, reflecting the electoral cycle and political calculus. Deep support, where significant political capital is often needed, is confined to areas such as biomedical research. Other areas, such as climate science, have been subject to sustained partisan contestation. There is starkly uneven public support for contested areas split along partisan lines. For example, only 11 per cent of conservative Republicans say climate scientists understand the causes of climate change very well, whereas this is reversed for this liberal Democrats (PEW 2015a). The most worrying effect of contestation for many observers is that it undermines support for all science. While public engagement in science is remarkable compared to many places in the world, it is at times ranked at the bottom of the list for preferred government priorities (PEW 2015b).

The public pledge to support university-based science may be more tenuous than in any time in recent decades. Earlier justifications for government support, notably the existential threat of the Cold War which drove military research spending, are seemingly not forthcoming, though the rise of China as a research powerhouse may provide reason alone. Nor are some pressing problems seemingly yet persuasive despite their severity, with human induced climate change as one example (Wang 1999). If public enthusiasm for science wanes, so too does its political constituency. A tension sits at the heart of relations between the American democratic state and the scientific expertise it supports.

Responding to a growing dilemma

At both a governing-board and front-line level, there is a growing strategic predicament for research-intensive universities. Significantly diversifying sources of support is hard for many universities. Finding new sources of support where public funding is reducing means seeking either philanthropic contribution or commercial arrangement to cover the full costs. While these bring opportunities, they also carry significant constraints. The prospects are limited for scaling gifts and commercial sources of income, and they will likely be a supplement to the system than at its center. These sources of revenue come with other challenges which complicate their role in supporting research. Philanthropic funds are rarely unfettered by the wishes of donors and contracts are at times directed towards a commercial return for partners which is unrealistic for faculty to provide in a timely manner.

Renewing public and Congressional support for fundamental research, and the ongoing funding this implies, appears unavoidable in the immediate term. Such an aspiration is buoyed by coordinated efforts by many advocates (both national and local) to build public support and science literacy, examples include the March for Science in 2017 and the American Association for the Advancement of Science's (AAAS) Golden Goose Awards. There are efforts also to target specific problems, for example, to lobby Congress directly on critical issues, such as F&A/indirect costs.

Where government support retreats and new opportunities are pursued, research-intensive universities might need to carefully examine the implications for their missions. While this has routinely occurred in lean times without the prospect of a return to business as usual it raises more fundamental questions about the mission of US research universities and to what extent the public should be supporting research that is not commercially viable. This begs politicians to ask how much research their country should fund. Such questions bring unavoidable consequences for relations between government and universities.

For some observers and echoed by interviewees for this study, the current situation is not fully sustainable and there needs to be either more federal funds or less research. Where the prospects for future resourcing are fragile or unduly encumbered, it might be asked whether fundamental science and research can continue in its current form, and whether it is viable to continue its growth in scale.

The US social contract for science

One of the great strengths of the US research system is its foundation in a long standing social contract (Vest 2007; Guston and Keniston 1994). This has been characterized by strong public trust that providing significant funds to scientists and researchers will produce societal wide benefits. Research universities have become the chief drivers of fundamental research, even though governments continue to exert a significant influence on where and how it occurs through funding and regulation (OECD 2016).

The interviews undertaken for this project reveal the complexity of the relationship between public, government and researchers, and the challenges to the sustainability of research it generates. Central to this complexity is the ongoing reliance by university researchers on government funds. Federal support for fundamental science has fared well over many decades compared to other areas of discretionary spending, and given this, it is a reasonable conjecture the system will be stable for the immediate future.

The longer-term prospects, however, are far less certain. Unrelenting pressure on the discretionary budget means it remains to be seen if research spending can continue to hold up in the face of growing demands on government finances and a slowing revenue base. The available evidence suggests it is a fair assessment it will be unsustainable over the longer term, an appraisal shared by the experts interviewed for this project. What is harder to predict, and where interviewees shared little agreement, is what a world beyond current structures might look like. At present the strength of the US science state might remain, yet it is perhaps frailer than many people are ready to admit.

For the future of US pure science and research, two factors are likely to be decisive. The first is whether the potency of the public backing for funding university-based fundamental research continues, and the second is how universities respond if, and in the assessment of many, when this support erodes. While public and congressional support for funding pure science is widespread, there are signs this could diminish. On the one hand it appears less clear in the public mind what the societal benefits of university-based fundamental research are and hence why it should be a congressional priority. On the other hand, a growing contestation and partisanship for some areas undermine the credibility of the scientific enterprise itself. High profile partisan attacks and threats to federally defund these areas, such as for climate science, erode the legitimacy of all publicly supported research. Why government should support often opaque research above other priorities is not as obvious to the general public as it once was. In the immediate term there appears a need for a greater commitment from key advocates of fundamental research to ensure a wider understanding of the value of supporting science, especially when the financial capacity of government is strained.

Given the precarious prospects for the current scale of public support, the response by universities themselves becomes all the more critical if the US' fundamental research effort is not to be undermined. However, based on the preliminary findings of this study there are legitimate questions around whether the response to date will be sufficient to mitigate a serious decline. There remains much work to be done by institutions to build their capacity to diversify sources of support, and this will likely require a public conversation, as well as the support of government. As one interviewee put it "there probably needs to be a different model or universities need to stop supporting so much unfunded research" (Interview #32). If universities do not act to meet such concerns, they may soon have little say in how they are addressed.

Some stark conclusions are therefore unavoidable. There is a risk public trust will further erode and the social contract for science breaks down. In such circumstances, it is likely researchers would be less able to attract support from government or other benefactors. In many instances universities are still a long way from finding convincing answers should this come to pass. If the US system is to remain viable, universities and their advocates will need to make greater efforts to restate their science mission.

1. BACKGROUND AND APPROACH OF THE STUDY

This section sets out the rationale and background, by first defining the focus for this project as the operation of and support for 'fundamental' research as part of the broader set of activities categorized as research and development (R&D). Second, it sets out the reason renewed inquiry into support for fundamental research is valuable by highlighting the stakes of diminishing backing and the some of the consequences if US universities do not continue their current role as engines of fundamental research. It situates support for US fundamental research in the global context, and then details the method and approach used by the study.

Research versus development

Fundamental and applied research are usually captured alongside the process of development for the category of Research and Development or R&D. This project is primarily concerned with support for fundamental research in US universities rather than applied research or development. Because most investment in R&D is for the development side of the equation, it is helpful to briefly examining the distinction to situate debates over public funding for research. The vast majority of fundamental research now occurs with government support, while development occurs in both public institutions and private businesses. The defining quality of fundamental research is that it seeks to extend fundamental knowledge in a field, expanding understanding in a way not before known (Greenberg 1967). Development and applied research are aimed more towards a specific need or end use, and less interested in discovery for its own sake. Put crudely, a common formulation is the linear progression from fundamental to applied, and then translation into practical outcome, such as a new product or process. In the 1950's the National Science Foundation established the "technological sequence", with fundamental science as the principle source of innovation, and underpinning R&D

activity (NSF annual report 1952). Basic research creates new knowledge and eliminates dead ends, applied research converts this into something more actual, which development then turns in useful materials, processes and devices (NSF 1952). This linear paradigm has largely defined how research is framed by policy makers.

Neat linear divisions between types of research are artificial in practice (e.g. Stokes 2011), yet they often inadvertently mask a tension in science policy-making around the ‘usefulness’ of research efforts. Policy makers, public and universities consider questions of the aim of research as integral to whether or not it can and should be supported. This study is concerned with support for research that is focused on fundamental discovery. This distinction is significant because while there has been wide public and government support for this over the second half of the twentieth century (explored in later sections), growing calls for tangible outcomes that are visible in an everyday sense has meant fundamental research has had difficulty showing its ‘value’ to non-specialists.

What is at stake from diminishing support for research?

Uncontentious but at times downplayed, it is well established advances in life quality in contemporary societies owe much to fundamental research carried out in, or in conjunction with, universities. To examine the future of support in the US for fundamental research it is helpful to briefly restate the case for fundamental research, and what is at stake if it were to ever cease.

The value in advancing knowledge for its own sake has often been justification enough for advocates of fundamental research (Dupré and Lakoff 1962). Framed around human progress and enlightenment, such arguments have had less currency as defense for public investment and support, and explanation for why it should not be ultimately dispensed as concern of public policy. More persuasive for public and government alike has been that fundamental science and research show utility for human health and welfare. Its chief value is in fostering progress (often technological) so that for individuals can have a better quality of life than their parents (Nelson 1959).

It is uncontroversial that research has delivered better ways of doing things, in fields as diverse as epidemiology (Macoinko et al 2003) to engineering (Mowery 2004), despite being hard at times to precisely quantify the magnitude of effects on health and wealth (Coe and Helpman 1995; Griliches 1979). Direct contributions from pure research often go unremarked because of the lag involved before they translate into technology or other advances. Yet the link is clear in many fields, especially medicine and its long tradition of “bench-to-bedside” (Woolf 2008).

Although difficult to draw such a seamless connection for all fields as it is for medical research, it is still broadly shown (Coe and Helpman 1995). For example, advances in areas like art history have had significant economic benefits (Ginsburgh and Mairesse 2012). Fundamental science is a key engine of technological progress, and hence along with education, it is one of the most important drivers for improved living standards and economic growth (Madsen and Murtin 2017).

The implications of significantly reducing the volume of quality fundamental research underway could be manifold, with the real implications not evident until long into the future with the pace of innovation and technological advancement slowing. It is impossible to know the real cost of ceasing fundamental research, however, given the clear benefits it has brought it is fair to assume the price might be a high.

The spectacular growth in research output since the end of the Second World War means it is now estimated research publications are doubling every 9 years (Nature 2014). Global R&D expenditure doubled between 2003 and 2013 and is approaching $1.7 trillion. Despite some concerns for a reduction in quality and growth in scientific fraud (Altman 1994), there is little doubt the swiftness of scientific progress in the latter part of the twentieth century meant by the early 2000s advances which only a few generations before seemed extraordinary became inconsequential in much of the public mind (Miller et al 1997).

The majority of fundamental research, especially that deemed longer-term and higher-risk, occurs in universities and other publicly supported research institutes. The OECD finds although universities account for less than 30 per cent of total expenditure on research and development (R&D) in member countries, they perform more than three-quarters of total pure basic research (OECD 2016, 128). These institutions have a long history of undertaking a substantial applied effort which is translated into immediate application, but they remain the chief locus of basic research. The OECD argues the growth in research output is driven by economic, environmental and health challenges as much as the particularities of where and how research is performed, researcher career paths, and long-standing institutional and organizational arrangements characterizing public research systems (OECD 2016).

Worldwide the main funder for fundamental research is government, with the public in OECD countries on average accounting for the majority of expenditure (OECD 2016, 128). This is most pronounced for the biggest contributors to overall basic research output, the United States and Japan. Similar patterns of majority government investment are repeated outside the OECD, for example Argentina funds 99 per cent, Mexico 98 per cent and Chile 95 per cent (see OECD 2016). In the majority of countries, the proportion of total R&D funded by government has not changed considerably in the last two decades, with the share around one-third on average. The aggregate proportion of government R&D among EU-15 countries has remained roughly constant since 2000. While the share of public funding has remained consistent, it has account for an ever-increasing proportion of fundamental research. Since 1985 OECD countries have nearly quadrupled their support for basic science.

At least in the immediate term, what happens to US public support for fundamental research has significant implications worldwide. Examining these macro output and funding trends does not fully capture the importance of US institutions to worldwide research. These institutions play an important role in training leading researchers and administrators for different nations and contribute to the overall leadership in many science fields which is not easily captured by aggregate dollars.

Worldwide, most R&D investment is by businesses for development, but this is not the case for fundamental research, which primarily occurs in universities with the support of public funds. Although the locus of research is shifting away from the US as dominant provider, the US will remain the most important contributor for some time to come, especially for fundamental research.

Universities over the centuries have reinvented themselves, responding to available resources, and the wishes of their communities and the state. While there is no prima facie reason to doubt universities cannot reinvent themselves again and continue research efforts under different arrangements, this does not preclude the setback of the research effort following any shock to the current system, in particular to the US. Few observers doubt this support is precarious at times, what is less agreed are the options if public and government retreat.

Methodology

The purpose of study is to develop a rich picture of the dynamics and prospects for support for research in US research-intensive universities. To examine this, the project develops a map of key structural and political factors, and the responses of stakeholders. This preliminary research report sets out initial findings from the study.

This study focuses primarily on how fundamental research is financed. In doing so it acknowledges funding is not the only issue faced by the research system in the US. Nonetheless, while related issues for the management and operation of US research universities are critical, such as the integrity of the peer review system, funding remains a valuable focus because it is the chief enabler. Universities are the principal engine for advances in fundamental science and any disruptive change to the efforts of their faculty risks compromising the fundamental research enterprise.

Guiding the study are two questions. First, what are the major factors influencing how US research-intensive universities securing the necessary funds and support to enable fundamental research? Second, what strategies are both public and private universities developing in response to these factors? To operationalize these, the project employs a mixed methodology, combining subject expert and practitioner interviews with publicly available data on the US research system. In this way, the study seeks insight into how US research universities are contending with emergent challenges to sustaining their overall research effort.

The study identified three groups of potential interviewees. These were classified as:

1. senior administrators and institutional leaders from leading research-intensive universities with direct experience of research management in their institutions,
2. policy makers and analysts with expertise in research and funding policy at a federal level, and
3. political practitioners (representatives and advisers) with direct experience of federal support for higher education.

Initially 50 potential interviewees were approached, with additional prospective interviewees contacted following a chain sampling method (Marshall 1996; Goodman 1961). This resulted in 37 completed interviews in late 2017 representing over 20 organizations. Of the interviewees 19 were senior administrators (either current or former Presidents or their deputies, or Deans) from five private and four public leading research universities. To ensure feasibility while seeking the widest achievable breadth of insight, a mix of public and private universities were chosen from five states. All these universities had a research budget of at least $500 million per year and were ranked in the Shanghai ranking (ARWU 2017). Seven of the nine universities were in the top 100 of the Shanghai ranking in 2017 and several were in the top 10.

For the second group, potential interviewees were identified at the major policy, representative and advocacy groups for the large research-intensive universities (including the American Council on Education, the American Association of Universities (AAU), the American Association for the Advancement of Science (AAAS) and the Association of Public and Land-grant Universities (APLU)), as well as other stakeholders familiar with the politics of research funding, such as legislators. This resulted in 18 interviewees, each with people having expertise in research policy and funding for higher education or Federal research policy and capturing the major representative bodies. The majority of these people held senior positions in their organizations, equivalent to at least vice presidents. Two interviewees had previously held senior roles with the NSF.

Due to the small number of interviews and therefore the ease of identification of participants, a de-identified list of interviews appears in Appendix 1, providing indication of role type and category of affiliated organization, with specific titles removed.

The interviews were designed to offer insight into how these leaders and experts understand the challenges in sustaining support for research, primarily funding, as well as the strategies universities are pursuing, including specific examples of enacting these strategies and reflection on their success or otherwise. This was informed by a Grounded Theory approach (Charmaz and Belgrave 2007). A common set of questions was developed for the different groupings. Each was asked to identify the main features, prospects and challenges for research support, including the politics. University-based leaders and experts were additionally asked about the specific strategies for diversifying support, such as philanthropy and commercialization.

This paper sets out preliminary analysis of the data and identifies debates, risks and strategies advocates and universities are pursuing to mitigate against these. Through synthesizing the insights of research leaders and managers, as well as interviews with policy makers and supplemented with analysis of the political context in which each university operates at a local, national and global level, a map of key dimensions can be developed.

These dimensions were classified into those which were structural, relating to the external mechanisms for support for research, primarily funding, and those internal to the operation of universities. Alongside this was analysis of the politics of these structural factors, including dimensions of Federal political support which have implications for the future of research support at US universities. Combined, this provides insight into how universities can better manage support for their research workforce and undertakings, and how governments of all levels might make better use of their limited resources.

The following sections presents the preliminary analysis and findings derived from the 37 interviews and subsequent analysis. As there are many steps in the chain to support research, relying on both public federal funding and the capacity for universities to make up the difference, this paper presents its analysis around common themes and actors. The first section shows why Federal funding is crucial to enabling fundamental research, the second explores how universities internally support research, the third section examines the politics around research funding and the fourth briefly summarizes strategic responses by universities and their advocates.

2. THE ONGOING RELIANCE ON A "DOMINANT PATRON" FOR US RESEARCH

This section sets out the first dimension identified through the interviews affecting future support for university-based research. This is the structure of funding for research, and in particular the ongoing role of the Federal government as "dominant patron". As one senior administrator and dean in a public university summarized it, "science and research in US research-intensive universities would not be possible at the current scale and configuration without Federal support… it is not clear how we could achieve what we do without it" (Interview #4).

The centrality of Federal funding is a widely supported component of the system, coming from a long-standing and deliberate effort by government to fund science. While it has been central to the success of US fundamental science, it has meant US research universities, responding to the incentives government has provided, have followed a path dependent logic to structure their efforts. The US Federal government began providing significant public financing for fundamental research in the latter part of the twentieth century, initially through defense avenues but increasingly through agencies such as the NIH. The heavy and in many cases overwhelming reliance on Federal funding for university-based research means it accounts for at least an average of 55 per cent of reported research expenditure at all large US research universities (NSF 2017). The following examination shows that for major public and private universities, despite a diversity in the sources of research support, Federal funds are the unavoidable linchpin.

Sources of finance for university-based research

There are different accepted approaches to effectively measuring research effort, from input indicators such as person hours to output measures such as the number of scientific papers published. While there is no universally agreed measure, a useful indicator is how much research universities report they fund it each year, as it is widely reported and uses a common unit, money. This too is a useful gauge of overall Federal support for research, as direct funding is a central means of support for research, acknowledging it is not the only one. Table 1 captures 2015 reported expenditure by US universities on research as recorded by the NSF.

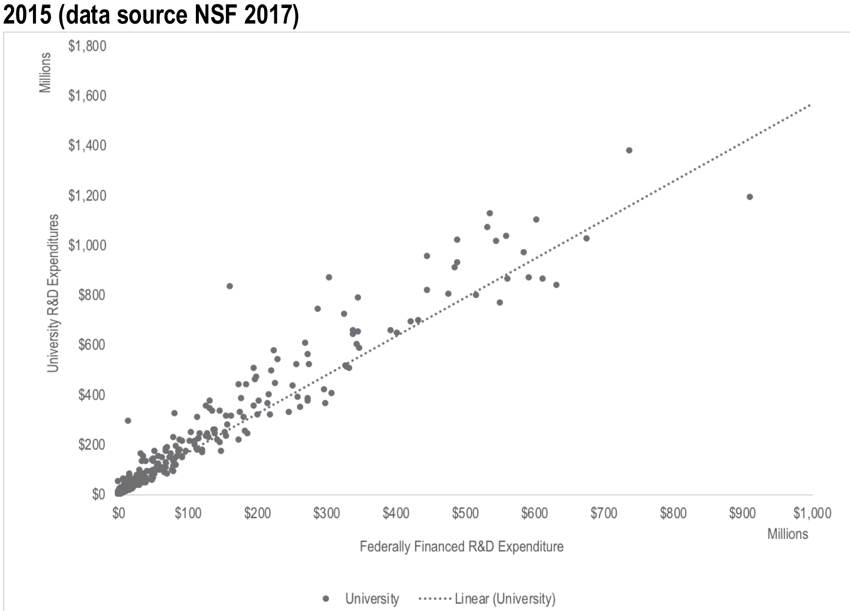
Table 1: Reported US university research expenditure by source of financing, 2015 (Source NSF 2017)

	Total R&D Expenditure	Federally financed	State/Local financed	Business financed	Non-profit and foundation financed	Internally financed	All other sources
University research expenditure by source ($b)	$68.66	$37.87	$3.81	$4	$4.23	$16.71	$2.02
Number of universities with expenditure from this source	609	605	515	474	529	563	360

In 2015 there were 609 universities reporting research expenditure ranging from $212,000 to over two billion dollars per year, for a total of over $68 billion. More than half of this was financed by the Federal government ($37.87 billion). The next largest source for research financing ($16.1 billion) was from the institutions themselves, such as endowment spending and subsidy from fees. Universities reported that their endowments totaled over $574 billion in 2017, but close to half of this was with just 20 universities, with the average research-intensive university having an endowment in the 100s of millions (NACUBO 2017). Indirect forms of government support, such as through tax breaks on some operations, almost certainty contributed to the capacity of universities to provide this internal backing, so the reported direct Federal financing likely understate the true level of support from the United States government.

Examining patterns of support shows Federal financing is closely correlated with total expenditure irrespective of where universities source the reminder of their total research expenditure. Figure 2 illustrates the correlation between total expenditure and Federal funding for 605 universities in 2015.

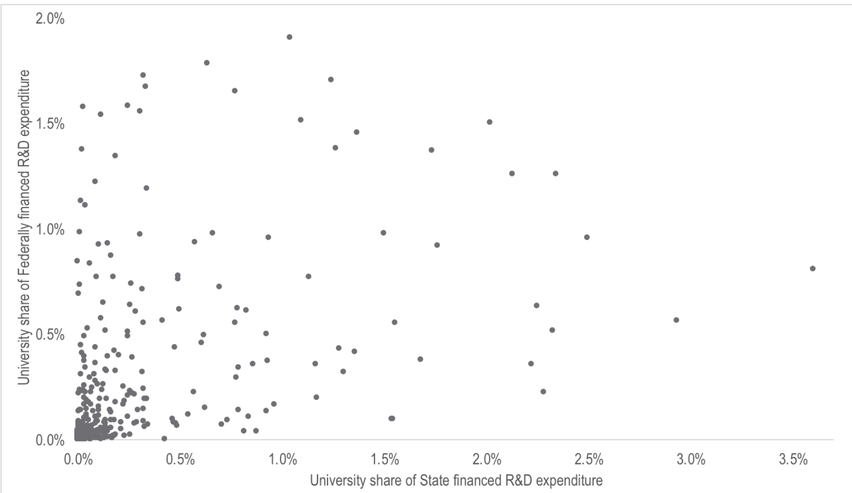
Figure 2: Federally financed R&D expenditures as a proportion of total expenditure at US research-intnsive universities, 2015 (data source NSF 2017)



Although state governments are still key funders for public universities, their role is diminishing, especially for funding facilities and research directly. For example, it is calculated that adjusted for inflation states spent $5.7 billion less on public universities in 2016 than in 2008 (SHEEO 2016). During the same period these universities educated around 800,000 additional students. States still provide support for research, but as Table 1 shows, this only accounts for around 5 per cent of reported expenditure in 2015. As one former, senior administrator and longtime observer framed it "states are still central to success of their public universities… they even play a part in funding research done at their flagship (institutions), but this is a case where periods of strong state support, such as in California, is the exception proving the rule" (Interview #21).

Not only is state funding designated for research a small component of expenditure, but its provision varies markedly across the country. Some states provide little while others the total each year amounts to hundreds of millions of dollars. While it is beyond the scope of this study to examine this in detail, there appears little evidence this funding is being given systematically as either offset for individual institutional lack of their success in gaining Federal funding, or as supplement to reward large Federal grants. For example, in 2015 there was no systematic relationship between the quantity of Federally financed expenditure on research universities reported to the NSF and that financed by state and local governments (see Figure 3 for an illustration of this), especially as at times state funds are directed towards politically earmarked research initiatives.[1]

Figure 3: Plot showing individual university share of total R&D's expenditure funded by the Federal government compared to its share of the total financed by State and Local government, 2015 (source NSF 2017)



Based on the NSF data on university research, two other sources of finance were neither as important as institutional or Federal funding. Nonprofit and foundation funding for research amounted to over $4.22 billion in 2015, while industry funded research was a similarly sized $4 billion. The former is particularly important for facilities and scholarships, and especially in the humanities and social sciences.

Table 2: Sources of finance for research at universities with high expenditure on R&D, 2015 (source NSF 2017)

	Total R&D Expenditure	**Federally financed**	**State/Local financed**	**Business financed**	**Non-profit and foundation financed**	**Internally financed**	**All other sources**
Number of high expenditure universities in each category ($100m+)	141	103	3	4	7	62	5
Total for high expenditure universities in each category ($b)	$61.40	$31.42	$0.54	$0.69	$0.87	$10.66	$0.55
High expenditure universities - Proportion of overall national total in each category	89.43%	82.97%	14.17%	17.25%	20.57%	63.79%	27.23%

The NSF survey data suggests those universities expending the most for research activity are the most dependent on Federal funds and the expenditure is concentrated in a subset of institutions. Only 141 universities reported over $100 million in 2015 for research, these are labeled the 'high expenditure' group here and as Table 2 shows, these accounted for the vast majority of total research spending (89.4 per cent), as well as the almost all of the Federal financing (82.9 per cent).[2] This group was also much more dependent than most universities on Federal funding, where it on average made up 70 per cent of expenditure. For this group, nearly a quarter of expenditure was from internal financing, with the NSF survey showing other sources such as philanthropy and business, only making up a few per cent of the total.

The Federal government as "dominant patron"

Measured by the NSF data on expenditure, research at US universities largely relies on Federal funding. This reflects the history of support. The scale and reach of American science grew significantly after the end of the Second World War when it became an object of Federal government policy. Driven by the public missions of ensuring national security, continuing the tradition of supporting innovation in agriculture and advancing the broader societal benefits coming from new knowledge, government became a central player (Dupré and Lakoff 1962, 11). The speed of technological development over the twentieth century became a driver for public and political consensus for public support for research to capture the spill overs from new knowledge and reap benefits that would not be realized without the intervention of government.

Acceptance of the broader benefits to American society, alongside the obvious private benefits for those able to utilize advancements, became the foundation for wide public support for research. Where government agencies before 1939 had viewed as ancillary much research without an agricultural focus, in the decades after the War there was a revolution in the breadth and organization of sponsored research in public agencies and American universities, which has been replicated in many other countries (Dupré and Lakoff 1962, 14; Gilpin and Wright 1964; Greenberg 1999). Following the publication of Vannevar Bush's report Science, the Endless Frontier in 1945, a growing consensus emerged of the need to provide consistently large scale public support for research.

As Table 3 shows, most of this Federal expenditure continues to come through the Department of Defense ($70 billion in 2015 mainly for development), with the rest through other agencies (See Appendix 2 for a list). Federally funded research is conducted by a number of different organizations, including Federal facilities, private businesses and research universities. Researchers in Federal facilities accounted for around a third of the expenditure in 2014 and industry around a fifth (Hourihan and Parkes 2016, 3). Universities accounted for over a quarter of the expenditure, mainly funded through the NIH ($31 billion) and the NSF ($6 billion). This significant investment by the Federal government in university research dominates their expenditure more than any other source as the last section showed.

In 2015, overall direct Federal grants for R&D were over $132 billion (US Federal Budget 2016)[1], which was more than the nominal gross domestic product (GDP) of Hungary or Qatar that year (World Bank 2017). Though there has been a decline in Federal funding for research as a proportion of GDP since the height of the Space Race, this has been most pronounced in R&D performed by industry on the development as opposed to research side. Support for fundamental research, especially where carried out through universities has been relatively consistent as a proportion of the discretionary budget (see further sections in this paper for more detail).

The growth in US university-based research has been linked closely to the growth in Federal support. AAAS analysis finds "the only performers of federally-funded R&D to have exhibited collective long-run growth relative to GDP are the nation's universities" (Hourihan and Parkes 2016, 9). At the same time as universities have come to rely more heavily on the Federal monies, state governments have reduced their overall support for public universities.

The dependence on Federal funding is both a strength and weakness of university-based research in the US. A number of interviewees identified this as the central to its growing success over more than five decades. One senior administrator summarized this saying "the stability of the Federal funds, congressional consensus and the peer review system has undoubtedly been one of the keys to [US] success" (Interview #7). As will be explored further in this paper, there is no obvious single alternative to a continued reliance on Federal support.

The fact that US university research is a product of such large public investment is a structural constraint to the system, with some risk the Federal government reduces financing either directly or indirectly. An example of the former was the proposed reduction

[1] The NSF calculates this as slightly higher in 2015, based on the categories included (NSF 2017).

in mid 2017 to NIH facilities and administration funds which would have reduced this support by over $4 billion (Kaiser 2017), while the latter is exemplified by changes that will have an indirect impact on university capacity to fund research, such as the 2017 changes to the Federal Tax code, which are an additional strain on university finances and hence institutional contributions (APLU 2017). The strength and characteristics of Congressional support is explored in a further section of this paper.

At present, no other single source of funds is an obvious replacement for Federal funds, with limits to philanthropy and commercial sponsored research or increase in the amount of institutionally funded research. Direct foundation and individual gifts constitutes a growing source of support for research, and philanthropy has always been important for American universities. As one commentator put it, "no single force is more responsible for the emergence of the modern university in America than giving by individuals and foundations" (Hall quoted in Drezner 2011, 1). While this is demonstrably accurate for many elite, non-profit private institutions, the role philanthropy has played has been more modest for most institutions, especially public institutions. The capacity for many universities to internally support research activity is a function in many cases of their endowments, and indeed this internally support can itself be considered a form of philanthropy for science (for example Murray 2012). However, such characterization of philanthropy can obscure why universities provide internal funds for research, for example, the urge to excel.

Table 3: US Federal expenditure on R&D, millions of dollars, 2015 (source US Government Budget, 2016)

National defense:	
Department of Defense	65,666
Other national defense	5,062
Total national defense	70,728
Nondefense:	
General science, space, and technology:	
NASA	11,170
NSF	5,059
Atomic energy general science	4,159
Subtotal	20,388
Energy	2,785
Transportation:	
NASA	555
DOT and Other	779
Subtotal	1,334
Health:	
NIH	28,358
Other	2,557
Subtotal	30,915
Agriculture	1,870
Natural resources and environment	2,080
All other	1,958
Total nondefense	61,330
Total conduct of research and development	132,058

At times philanthropy or grants can bring additional challenges, even if on the margin. As one interviewee summarized it, "we cannot afford to take some philanthropic gifts, especially where they are for facilities [such as laboratories] which we will need to cover the cost of over their lifetime" (Interview #23). The possible inadvertent interference of donors with the integrity of research also becomes a difficult balancing act at times (David 2008; Gans and Murray 2012). One interviewee related several incidents during the last decade when philanthropic gifts were not able to be accepted, and one instance in particular involving tens of millions of dollars where "the Provost at the time felt [the university involved] could not meet the wishes of the donor" (Interview #1). While such examples are undoubtedly rare, or they would be more publicized, there is a challenge for universities in seeking to meet the wishes of those providing funds without compromising the science. The OECD summaries this challenge, saying "while private donations are widely welcomed, they can be oriented by personal interests and may be dissociated from public goals thus diverting research towards peripheral fields" (OECD 2016; also see Broad 2014).

Philanthropy is not always an alternative to Federal funds and is likely to remain an important supplement rather than major substitute. As one interviewee framed it "you can take the Gates Foundation, add Warren Buffett's wealth and other major philanthropists and you still only fund US research for a single year" (Interview #10). While this perhaps overstates the issue slightly, the essential observation holds that on present numbers philanthropy cannot be the chief replacement to mitigate a significant reduction in Federal funds.

Another mechanism commonly proposed as a substitute for diminishing Federal funding is commercial research income (Audretsch 2014; Siegal et al 2007). As Table 1 shows, this only accounted for about 6 per cent of research expenditure in 2015 based on the NSF survey. Universities have periodically sought to build closer links with industry alongside developing spin-off business and commercializing their IP (Grimaldi et al 2011). The institutions examined for this study are all increasing efforts to find commercial partners willing to contribute to research or engage in contract research. Similar with relying on expanded philanthropy there appear limitations to commercial arrangements for research as general substitute for Federal funding, and it still only accounts for a small proportion of research expenditure at major research universities (see Table 4).

Several interviewees noted a limitation comes at times from the incompatibility between the research interests of faculty and that of industry partners. Specifically, there can be a difficulty in aligning faculty interests and capacities with the short term needs of industry. As one university president summarized it, "[My university] would probably need to drastically rethink our mission if we were to try to rely on commercial income as a primary source of support for research" (Interview #17). Ultimately this may be a problem of the two different cultures of science between universities and industry (Lacy et al 2014), each with different incentives, aims and approaches. This can be compounded by mismatched expectations between partners. To illustrate, one interviewee related that in their experience there has been at times a general concern by industry partners they "have already paid for research through their taxes, so are hesitant to pay what we would consider the full costs of the research" (Interview #18).

US university-based research relies on Federal government funding, and despite an important role for other sources of income, such as philanthropic and industry support, they are not yet an obvious replacement. As the evidence presented here shows it is reasonable to conclude the US Federal government will likely remain the "dominant patron" in short term at least. Several interviewees argued the extent these structural arrangements are significant for the future of research depends on features common to US university-based research as well as the politics around maintaining the current Federal support. These two dimensions are examined in the following sections.

3. SUBSIDIZING AND SUPPORTING RESEARCH WITHIN UNIVERSITIES

This section sets out the second major dimension affecting future support for university-based research identified through the interviews, being features of internal organization of university research and support, in particular for the STEM fields, as they have developed in a system primarily financed by the Federal government. Several trends were consistently cited by interviewees both inside and outside universities, including the rate of growth in the research activity which has increased the necessity of finding new research support, reliance on doctoral students for published research in the STEM fields, and reliance on cross subsidization between different university activities and different areas of research. These trends, while not the only ones or equally applicable to all universities, are cited as ongoing additional challenge to sustaining support for research.

As noted in the previous section, the scale of US university-based research has increased consistently since the 1950s as the Federal government funded evermore basic science. This growth, while it has meant more colleges are doing more research, has also been concentrated in an elite group. Several interviews argued that the increase in scale itself and the way it has been achieved has put extra strain on many of these institutions. In particular, the inconsistent cycles of Federal research funding, where as one interview described it "the 'boom and bust' mentality for many areas has an ongoing affect, where it is hard to scale down once an area has been scaled up" (Interview #23).

A recent example this was the growth in scale of laboratories and activity in response to the 1997-2003 boost of the NIH funding. This meant ongoing pressure for more resources to keep these running, leading a number of universities to diversify funds to keep facilities operational. The challenge as one interview summarized it is "universities respond to Federal incentives, such as an increase in funding, on the assumption that growth lasts… which is rarely the case" (Interview #23).

Table 4: Top 50 US universities by research financed by business and industry contracts, 2015, (source NSF)

Academic Institution	Business Financed R&D Expenditures (Millions USD)	Proportion of Total Financed by Business
Duke University	240.64	23.2%
SUNY, Polytechnic Institute	187.24	63.4%
Massachusetts Institute of Technology	150.00	16.1%
Ohio State University, The	119.27	14.6%
University of Pennsylvania	97.76	11.3%
Stanford University	90.18	8.8%
University of California, San Diego	84.67	7.7%
University of Texas M. D. Anderson Cancer Center	81.08	9.7%
University of California, Berkeley	75.48	9.6%
University of Texas at Austin, The	75.27	11.6%
Texas A&M University	71.56	8.3%
University of Utah, The	69.86	13.5%
University of California, San Francisco	69.10	6.1%
Johns Hopkins University	66.22	2.9%
University of Michigan	62.08	4.5%
Washington University in St. Louis	56.52	8.1%
University of California, Los Angeles	55.61	5.4%
University of Colorado	52.88	6.3%
North Carolina State University	52.84	11.3%
University of Alabama at Birmingham	48.54	9.4%
Harvard University	48.18	4.8%
University of Illinois at Urbana-Champaign	45.55	7.1%
Yale University	43.67	5.4%
Purdue University	42.50	7.4%
University of Washington	42.27	3.5%
University of Florida	41.38	5.6%
Georgia Institute of Technology	41.09	5.4%
University of California, Davis	40.95	5.7%
Cornell University	40.69	4.3%
Icahn School of Medicine at Mount Sinai	40.18	7.9%
Columbia University in the City of New York	39.63	4.6%
Vanderbilt University	34.67	5.4%
Pennsylvania State University, The	34.48	4.3%
University of Southern California	32.86	4.8%
Emory University	31.86	5.4%
Wichita State University	31.26	52.1%
Virginia Polytechnic Institute and State University	30.29	6.0%
University of Miami	29.84	8.2%
Scripps Research Institute, The	29.80	7.8%
University of North Carolina at Chapel Hill, The	29.00	3.0%
University of South Florida, Tampa	28.50	5.8%
SUNY, University Buffalo	27.08	7.1%
University of Chicago, The	26.20	6.2%
University of Minnesota	26.16	2.9%
University of Cincinnati	26.11	6.0%
Rutgers, The State University of New Jersey	23.74	3.6%
University of Wisconsin-Madison	23.71	2.2%
Carnegie Mellon University	22.83	9.4%
New York University	22.83	3.8%
Indiana University, All Campuses	22.36	4.1%

The growth in research has also meant a greater total cost for supporting doctoral students, which continue to make a significant contribution to research. Several interviewees argued doctoral students and Post-docs are increasingly critical to viability of laboratories and this means pressure to train more researchers. One interviewee feared they were at times the unacknowledged “inexpensive workforce” (Interview #7). This is perhaps misleading, as increasing numbers of graduate students while not usually requiring the same salary as more expensive staff, such as Post-docs, are not without cost. The number of doctoral students in US universities increased by close to 20 per cent between 2006 and 2015, meaning they require more overhead and facilities support. The challenge here as one interviewee suggested is their “increasing their numbers strains university resources in ways not always visible to lead faculty; nor fully acknowledged by administrators” (Interview #27). The cost of supporting graduate students will likely grow, with interviewees arguing if legislation is passed such as the recent proposal to in-effect tax PhD remissions, it would eventually mean universities would need to dedicate more resources to supporting doctoral study will be revived (APLU 2017).

Increase in the costs of supporting laboratory groups, including through growth in graduate student and postdoc numbers, puts uneven pressure on facilities, especially as many institutions seek greater interdisciplinarity and the role of collaborations has become more important over recent decades (Lee and Bozeman 2005). One interviewee argued the assumption that international talent would be readily available to supplement local talent no longer holds, especially for the less prestigious universities in attracting earlier career academics (Interview #17). The competiveness of international universities and their remuneration structures, means talented researchers have many attractive options.

The changing scale of research too has exacerbated the effective subsidy provided for some areas of research from either other research areas or other sources of institutional revenue, such as tuition fees. Several interviewees argued there is nothing inherently wrong with cross-subsidization, but that it “causes an ongoing challenge” (Interview #23) for senior administrators in few ways. The first was the complexity can add to internal budgeting processes. One former dean and leading economist called transparency in university budgeting around research a “final frontier” (Interview #25).

Another was faculty misperceptions around where and how cross-subsidies were being made, with speculation there was little recognition by many within university communities that some of the most well-funded science federally was also the most expensive and required the largest subsidies, whereas this was often assumed to be the central source of subsiding other areas (Fethke and Policano 2013; Policano and Fethke 2012). For example, one interviewee argued some of the highest profile STEM areas in their university required some of the largest subsidies (Interview #25). The issue and complexity of cross-subsidy, compounds the challenge for research institutions in any change to Federal funding overheads and facilities for sponsored research, such as those proposed in 2017 by the Trump administration.

The preliminary findings from this study and the interview data endorse the widely made observation that there is an interaction between Federal and institutional funding structures, and that mechanisms and norms of internal university support have evolved reliance on the former all the more complex for universities.

4. CHANGING NATIONAL POLITICS OF RESEARCH SUPPORT

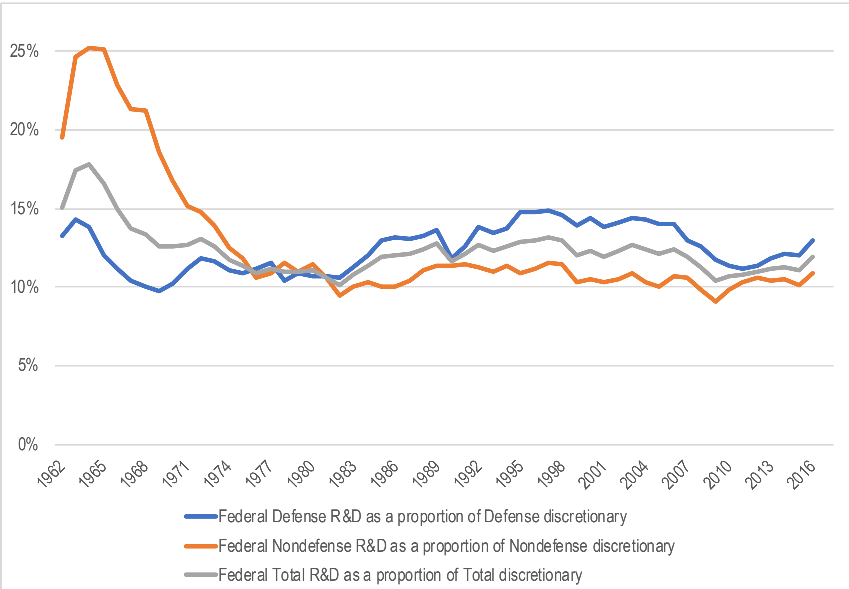
This section sets out the third dimension identified through the interviews affecting future support for university-based research, being the politics of support for research and primarily around Federal funding. Interviewees noted the wide but brittle congressional backing, growing contestation over different areas of science, such as climate science, and thin public engagement with fundamental research.

Wide but increasingly brittle congressional support

A common observation made by interviewees from both inside and outside universities was the wide and sustained support for research across Congress. In particular, research “holds a special place, and despite criticism at times, there really are no anti-science members” as one longtime political observer and former Chief of Staff to a congressional Committee on Science framed it (Interview #32). Congressional support for funding basic research has been consistent since the 1950s, despite some prominent incidents, such as Senator William Proxmire’s long running ‘Golden Fleece’ awards attacking public support for some research projects (Irion 1988), or the demise of the congressional Office of Technological Assessment in the mid 1990s (Kieper 2005). Several interviewees pointed out that despite occasional episodes of hostility, it has likely had little practical effect on overall support for research and most members of congress rated support for research as one of the most important tasks of the Federal government.

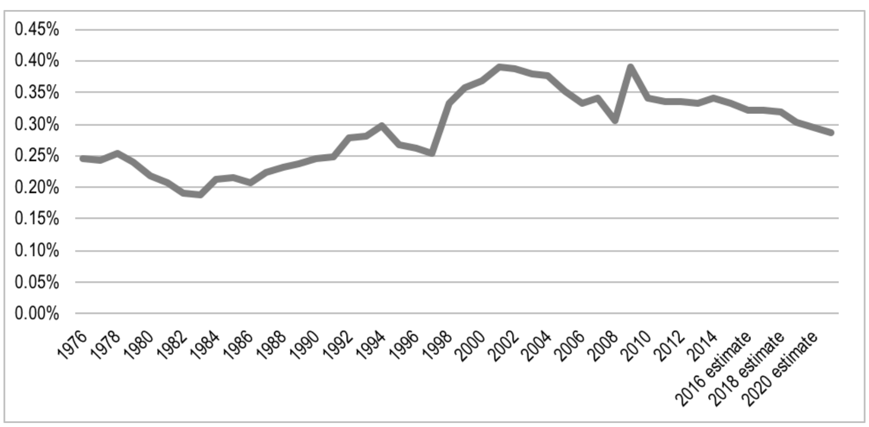
The longstanding strength of this support is apparent when considering the mechanism through which basic science and research is funded as part of the Federal budget. Research is financed through the discretionary portion of the budget which Congress must authorize each year and has remained a steady proportion of this since the end of the Space Race (see Figure 4). This has particularly been the case for fundamental research. Where reductions have been made these have largely been to development and applied research.

Figure 4: Research as proportion of discretionary Federal budget (source US Government Budget 2016; and adapted from Hourihan and Parkes 2016)



Individual science funders have also had their budgets reliably maintained. For example, the NSF received about 0.4 per cent of the discretionary budget in 1976 and has consistently grown to now account for 0.7 per cent (US Government 2017). Yet, the amount classified as 'general science and basic research' remains a modest proportion of the overall Federal budget as Figure 5 shows.

Figure 5: General science and basic research funding as proportion of total Federal budget (source US government budget 2017)



As many interviewees pointed out, this past success is not necessarily a reliable guide to the future, with several arguing it is more precarious than appears due to diminishing discretionary Federal funds. Hourihan and Parkes summarize this problem:

> Discretionary spending is the part of the federal budget determined annually through the appropriations process… discretionary spending – especially that for defense – once occupied a more prominent place in the budget. Over time,

> however, the federal budget has come to be dominated by mandatory spending, which is made up mostly of the major entitlement programs – Social Security, Medicare, and Medicaid – as well as numerous other transfer payment programs. Mandatory spending is known as such because it is written directly into authorizing legislation, is not subject to annual changes by appropriators, and is mostly – but not entirely – on "autopilot." (Hourihan and Parkes 2016, 2).

While research has held up as a proportion of the discretionary budget over the last 40 years, if the discretionary budget decreases overall so too does the available funds for science. As one interviewee put it, "research may be an inadvertent casualty of a discretionary budget under extreme pressure" (Interview #12). Another said, "there is no sign the squeeze [on the discretionary budget] is going to let up soon and only looks to be getting worse" (Interview #9).

The central argument here being, while support for research is broad it is ultimately more brittle than many commentators are ready to admit. Several interviewees noted deep support in Congress and among Federal political leaders tends to be confined to some areas, specifically biomedical research, pointing to the ongoing support for the NIH above other agencies, which was once again demonstrated in early 2018. Interviewees argued, however, even for those areas where support is deep the politics will become more complicated as greater pressure is put on the Federal budget (Congressional Budget Office 2017).

The immediate effect of a diminishing discretionary budget on congressional support is hard to gauge. As one interviewee noted, Congress only requires a limited number of members to maintain funding "so long as the right people, e.g. committee heads, support it and no one opposes, research will continue to do well" (Interview #32).

Several interviewees were concerned Congressional support will quickly diminish where the public sees less of a priority for research and members will make an electoral calculus unfavorable to its ranking above other areas of policy (Interview #31). Public backing for publicly funded research (explored in the next section) may not be enough where other policy choices are more pressing. Many of the demands are well known, an aging US population, the growing cost to Medicaid and social security expansion put increasing pressure on public funds. Mandatory measures now account for nearly two-thirds of the total budget.

One interviewee noted congressional support for research could be viewed as a trade-off between the agreed benefits it provides and its cost in political capital (Interview #13). R&D initiatives and projects which are publicly popular and which experts agree have tangible benefits are more likely to be supported than those where there is public controversy over benefits. For example, deeper political support for biomedical initiatives reflects the public popularity and often demonstrated improvements to health outcomes which has come from much NIH funded research. "Medical research does not require congress to expend as much political capital as for other, more controversial areas, as everybody supports a new cure for cancer" was how one interviewee framed this argument (Interviewee #10). Future prioritization by members of Congress for research in the discretionary budget will likely depend on the broader question of whether current public support and engagement can be maintained.

Public support for Federally funded research

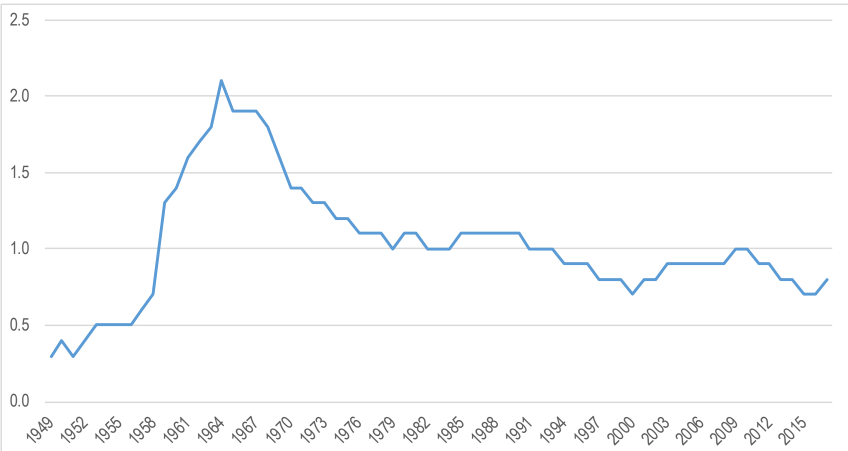
A number of interviewees noted the historical popularity with US voters of publicly funded science. Public opinion research has consistently shown both the support for its government financing and the belief that through this funding it is providing benefits. For example, PEW found in 2015 that 67 per cent of US adults said science generally has a positive effect on the US. Moreover, 71 per cent of those surveyed supported Federal funding of it. As Figure 6 shows, Federal support for R&D as a proportion of GDP reflects this support and has been stable since the end of the Space Race.

While this underlying US public support has existed since before the Cold War, a number of interviewees questioned whether it could be maintained (also Wang 1999). A Pew (2015a) survey shows that when the public are asked to rank what Congress's priorities should be, support for scientific research is near the bottom, ranked alongside global warming and global trade as the least important things for Congress to focus on. The public are also divided on whether science needs defending. In 2017 the March for Science sought to "champion robustly funded and publicly communicated science and role it plays in everyday lives". Yet only 48 per cent of the public surveyed said they supported its goals.

One interviewee also pointed to the potential problem of public misperception around the different roles government and industry play for university-based science (Interview #30). Misunderstanding of the difference between basic, applied and development often meant that the public thought that industry would be able to compensate if government stepped back from financing fundamental research.

There was concern voiced during interviews that the social contract for university-based science was becoming more fragile than during the Cold War (see also Guston and Keniston 1994). This development, interviewees speculated, was part of the broader breakdown in trust between universities, government and public. The growing hostility toward higher education for some sections of the US public is well documented, as part of the turn against those labelled as 'elites', with some indication this wider issue is starting to be reflected in public debate over university research (Wermund 2017; PEW 2017). This is fueled by the growing cost of tuition and doubt about the promises universities make about their capacity to deliver a higher standard of living for their graduates (for example Caplan 2017).

Figure 6: Federal support for R&D as a proportion of US GDP, 1962 to 2017 (source US Government Budget, 2016)



There is a partisan element to this trend, with one survey finding 58 per cent of those who identify as Republicans said universities have a negative effect on the US at present. Moreover, as Wermund (2017), notes "less than half of households making less than $75,000 a year who identify as Democrats have confidence in higher education" (see also Pew 2017).

The fear articulated by several interviewees was summarized by one who argued the hostility would become "directed towards pure science simply because it is mainly a university activity" (Interview #37). Public support for research is critical to future congressional support but that this is given is far from certain. How future support for research plays out where it must compete for a smaller discretionary budget is further complicated, several interviewees argued, due to contestation over certain areas of science, and hostility more generally to where it is enacted.

Growing contestation over some areas of research and the partisan divide

The contestation over public support for some areas of science is well documented, most recently for climate science (Stokes et al 2015). Controversy over science has had clear impacts, for example the debate over climate change has resulted most recently in changes made to the EPA which some commentators have argued undermines environmental protection (UCSUSA 2017). There have been repeated calls by prominent public voices to defund research into contested areas of science. Despite the controversy, interviewees pointed out the direct impact of political contestation of science is unclear, with some effects, such as less use of the terms such as 'climate' in grant applications for some schemes, seemingly limited. This is not just limited to grant applications, a similar recent controversy emerged over the Centers for Disease Control and Prevention (CDC) being asked to avoid certain words in its 2019 budget request, including 'evidence-based' and 'science-based' (Cohen 2017).

What is clearer is that controversy over some areas of science has a partisan element. Many more members of the Republican party have been vocal in demanding that climate research not be funded (Cragg et al 2013; Foran 2016). This divide is reflected in public opinion, with one PEW survey showing only 11 per cent of conservative Republicans saying climate scientists understand the causes of climate change very well and 57 per cent saying the scientists' conclusions are based on a desire to advance their careers. Whereas for this liberal Democrats this was 54 per cent and 16 per cent respectively.

The fear articulated by several interviewees was not the direct effect of a partisan controversy and contestation, rather it was that attacks on climate science may have a wider impact of diminishing support for science and research more generally, which makes it more difficult for congress to support. The "politics of climate science risks framing all science in the public mind" (Interview #37).

The politics of support for research, primarily around Federal funding, is characterized by wide though brittle congressional support but where Congress has diminishing capacity in the discretionary budget to continue to fund at the present levels. The public support enabling Congress to act is put further under strain through a growing contestation over different areas of science, such as climate science, and thin public engagement with fundamental research, and at times outright hostility to the institutions in which it occurs.

5. HOW ADVOCATES AND UNIVERSITIES ARE RESPONDING

Interviewees were each asked about how governments, advocates and universities were responding to many of the issues raised. This section of sets out examples of how different institutions are reacting to the perceived challenges and politics around support for university-based research in the US. As this paper presents preliminary findings, a brief summary of key approaches and strategies follows.

Universities are pursuing multiple strategies to meet diminishing Federal funding. Many interviewees spoke of growing efforts to seek philanthropic and foundation support to replace lost Federal funds. While many private universities have long had sophisticated infrastructure for seeking these sources of funds, public universities are increasingly investing resources in administration and leadership to diversify support for all disciplines. As noted in section 2 of this paper, most non-Federal sources of support, especially philanthropy, are likely to supplement rather than directly substitute in many instances, as they rarely are available on the same terms as public funds, nor provide the same degree of discretion to university leaders in their use. Endowments too are increasingly important, but there is still some way to go for public universities. Of the universities having endowments over one billion dollars, still only a small fraction are public universities (NACUBO 2017).

A number of senior university administrators spoke of their universities pursuing efficiencies through better internal transparency and accounting structures, or efforts to constrain growing teaching costs and therefore free up resources for other purposes, such as research. This was matched with specific policies to ensure the limits and strengths of non-government research support were always considered. For example, explicit policies to seek full costs for projects and infrastructure and so avoid partially funding infrastructure as has occurred in the past in some instances. Several institutions noted their desire to seek long term relationships with a small number of commercial partners, one citing local corporations that provide opportunities for faculty which could develop “organically” (Interview #18). Another institution cited efforts to build international linkages and leverage international opportunities both for collaboration but also for funding, for example by leveraging European Research Council collaborations to fund research.

Regarding the broader issue of political support for research funding a number of interviewees indicated there is a growing recognition by universities and other commentators that public and political support for research is more fragile than it has been over the last five decades. In particular “university leadership are realizing we haven’t done a great job in recent years of explaining to the broader public what we do on our campuses and why we do it” (Interview #24). To address this there are coordinated activities underway to rebuild public and political constituency for fundamental research, for example the April 2017 March for Science jointly organized jointly by the AAAS, alongside individual university outreach directly to state and federal legislatures. One interviewee pointed to efforts to recognize where strong support exists in Congress and foster it through high profile public events, such as the Golden Goose Awards, which celebrate scientific achievements (Interview #10). There have been growing efforts to encourage faculty (and graduate students) to engage with politicians at national and state level, one example cited was a regular program to take groups of graduate students to meet state legislators. Interviewees noted that representative groups are increasingly important for advocating on specific national issues, with a recent example being the importance of lobbying when indirect costs for the NIH were threatened (Interview #10).

Interviewees cited many examples of how institutions and advocates are seeking to respond to the issues for the future of research support. However, one key insight shared by them was summarized as follows “nobody, no university, has found the magic bullet yet for [these issues], and that is what is getting people concerned in this current environment” (Interview #23).

6. CONCLUSION

One of the great strengths of the US research system is its foundation in a long standing social contract (Vest 2007; Guston and Keniston 1994). This has been characterized by strong public trust that providing significant funds to scientists and researchers will produce societal wide benefits. Research universities have become the chief drivers of fundamental research, even though governments continue to exert a significant influence on where and how it occurs through funding and regulation (OECD 2016).

The interviews undertaken for this study reveal the complexity of the relationship between public, government and researchers, and the challenges to the sustainability of research it generates. Central to this is the ongoing reliance by US university researchers on public funds. Federal support for fundamental science has fared well over many decades compared to other areas of discretionary spending, and given this, it is a reasonable conjecture the system will be stable for the immediate future.

The longer-term prospects, however, are far less certain. Unrelenting pressure on the discretionary budget from social and health spending means it remains to be seen if research spending can continue to hold up in the face of growing demands on government finances and a slowing revenue base. The available evidence suggests it is a fair assessment it will be unsustainable over the longer term, an appraisal shared by the experts interviewed for this project. What a world beyond current structures might look like is harder to assess at present, and a topic on which interviewees shared little agreement. The institutions most exposed are those without endowments or revenue sources to smooth any serious volatility in Federal funds, and especially those with the least capacity to quickly build diverse support streams. This implies many small to medium sized research universities may be at risk, even where flagship universities still prosper. The US science state has deep roots but is perhaps more unstable than many who contribute to its success appreciate.

Following the election of President Donald Trump in 2016, commentators voiced concern for the hostility shown by the administration toward science. Some of the risks the new administration's actions present may indeed be real and pressing, and pose a genuine threat to the science effort, but they are likely a consequence not cause of deeper issues. To foreground the actions of one administration downplays the combination of structural and political factors at play. The shock Trump appears to have brought to many institutional leaders, senior administrators and the research community hints at a more complex set of challenges to be faced if universities are to continue to be the center for fundamental research.

For the future of US pure science and research, two factors are likely to be decisive. The first is whether the strength of the public backing for funding university-based fundamental research continues, and the second is how those same universities respond if, and in the assessment of many, when this support erodes. While public and congressional support for funding pure science is widespread, there are signs this could diminish. It is less clear for many people than it once was what the societal benefits are of university-based fundamental research and hence why it should be a Congressional priority. A growing partisanship around some areas of science carries risks. High profile partisan attacks and threats to defund specific areas Federally, such as climate science, weakens the legitimacy of all publicly supported research. The answer as to why government should support often opaque research above other priorities such as health is not straightforward.

Given the precarious prospects for the current scale of public support, the response by universities themselves become all the more critical if the US' fundamental research is not to be undermined. Universities are expanding efforts to diversify sources of support away from pubic funds. However, based on the preliminary findings of this study there are legitimate questions around whether the response to date will be sufficient to mitigate a serious decline. There remains much work to be done by institutions to build their capacity to diversify sources of support. Federal funding is so much a linchpin that greater effort will be needed to fully utilize philanthropy and commercial income, if these are to ever be more than supplements.

Exacerbating the challenge is how universities have internally managed their research efforts historically, and alongside this how they have responded to system incentives. Universities have "not been in the habit of turning down funding", even if it is not clear where the full costs are going to be met from (Interview #1).

Science and research has a strong authority enjoyed by few other human activities. University research in the US has largely been a publicly funded exercise since the 1950s. While this makes it intrinsically political, it is different to most areas of public policy, and as one longtime political observer put it, "it is unlikely any members of Congress are genuinely "anti-science" (Interview #32). Despite the special status of publicly supported science, some stark conclusions are perhaps unavoidable. There is a risk public trust will further erode and the social contract for science breaks down. In such circumstances, it is likely researchers would be less able to attract support from government or other benefactors. Universities are still a long way from finding convincing answers should this come to pass. What seems clear, is that if the system is to remain viable, universities will need to make greater efforts to rebuild trust and understanding with the US public and litigate anew their raison d'etre at the center of US research.

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APPENDIX 1: LIST OF INTERVIEWS (DE-IDENTIFIED)

Interviews, by ID, role (de-identified) and organization (de-identified)

ID	Position	Organization
1	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
2	Analyst	University - public
3	Analyst	University - public
4	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
5	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
6	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
7	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
8	Analyst	Other organization
9	Senior Administrator (Vice Principal or equivalent)	Other organization
10	Senior Administrator (Vice Principal or equivalent)	Other organization
11	Senior Administrator (Vice Principal or equivalent)	Other organization
12	Senior Administrator (Vice Principal or equivalent)	Other organization
13	Analyst	Other organization
14	Analyst	Other organization
15	Senior Administrator (Vice Principal or equivalent)	Other organization
16	Senior Administrator (Vice Principal or equivalent)	Other organization
17	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
18	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
19	Analyst	Other organization
20	Senior Administrator (Vice Principal or equivalent)	Other organization
21	Senior Administrator (Vice Principal or equivalent)	Other organization
22	Other	Other organization
23	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
24	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
25	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
26	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
27	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
28	Analyst	Government
29	Other	Government
30	Other	Government
31	Other	Government
32	Senior Administrator (Vice Principal or equivalent)	University - private
33	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
34	Senior Administrator (President, Vice-Chancellor or equivalent)	University - private
35	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
36	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public
37	Senior Administrator (President, Vice-Chancellor or equivalent)	University - public

Appendix 2: US Federal government research granting agencies

The following agencies are major funders for science in the US:

U.S. Agency for International Development (USAID)
Corporation for National and Community Service (CNCS)
U.S. Department of Agriculture (USDA)
U.S. Department of Commerce (DOC)
U.S. Department of Defense (DOD)*
U.S. Department of Education (ED)
U.S. Department of Energy (DOE)*
U.S. Department of Health and Human Services (HHS)*
U.S. Department of Homeland Security (DHS)
U.S. Department of Housing and Urban Development (HUD)
U.S. Department of the Interior (DOI)
U.S. Department of Justice (DOJ)
U.S. Department of Labor (DOL)
U.S. Department of State (DOS)
U.S. Department of Transportation (DOT)
U.S. Department of the Treasury (TREAS)
U.S. Department of Veterans Affairs (VA)
Environmental Protection Agency (EPA)
Institute of Museum and Library Services (IMLS)
National Aeronautics and Space Administration (NASA)
National Archives and Records Administration (NARA)
National Endowment for the Arts (NEA)*
National Endowment for the Humanities (NEH)*
National Science Foundation (NSF)*
Small Business Administration (SBA)
Social Security Administration (SSA)

(source NSF)

*key funders for US university research.

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[1] Linear regression analysis shows no statistically significant relationship between the two at a 95 per cent level of confidence.

[2] The high expenditure list correlates closely with membership of the AAU. The criteria for ‘high expenditure’, while partly arbitrary, serve to illustrate the concentration of research expenditure at a smaller group of universities. Of the 609 universities, half reported over $10 million expenditure in 2015.