The U.S. Academic Research Enterprise (US-ARE): Possible Paths from the Pandemic

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Executive Summary

This white paper uses recent public data to identify what we can know systematically about how the COVID-19 pandemic is currently affecting the large, research-intensive universities that represent the core of the US-ARE. It uses those, admittedly preliminary and partial, findings to extrapolate about possible long-term effects of decisions that academic leaders, state and federal policy makers are taking right now. The descriptive story presented here isn't determinative, but it suggests that the pandemic poses unique dangers for the national and global research systems. A few themes bear emphasizing.

First, the difficulties universities face during the pandemic cannot be understood in a vacuum. They result from a long history of public disinvestment. That trend in turn increased these campus' reliance on tuition revenue and other sources of funds. Many universities were in challenging straits before the pandemic, which illuminated and exacerbated the effects of this already pronounced trend.

Second, federal and state policy-makers' efforts to address pandemic effects in higher education have been slow and partial. The options currently being considered are unlikely to be of an appropriately large scale or scope. Immigration policies and enforcement efforts pertaining to international engagements and collaborations only raise budgetary pressures.

Third, the pandemic is unique in the history of the US-ARE because it simultaneously pressures all aspects of university budgets. Costs in key areas are rising just as most sources of revenue decline. The result is that the "university finance balloon" is coming to lack the elasticity it needs to avoid destructive competition and its consequences.

Fourth and finally, the pressures of the pandemic highlight a key strategic dilemma for decision-makers at all levels. U.S. research universities are essential and make dramatic contributions to the health, wealth and well-being of the world because their capabilities can be turned to address known problems like today's pandemic and because their organization, funding, institutional commitments and missions keep them poised to help identify and respond to "unknown unknowns" in our future. In responding to the pandemic, decision-makers can choose between two reasonable strategies that current budgetary, political and social pressures stand to make mutually exclusive. On the one hand, decisions can be made that focus on exploiting existing capabilities as effectively as possible to achieve known high priority goals. On the other hand, efforts can be made to prioritize the diversity of fields, people, missions and connections that make US-ARE institutions a unique form of social insurance against our uncertain future.

That dilemma bites less in good times because of the typical, decentralized, organizational and funding model of universities and because of their history of public support. But today the most likely outcome I see is an increase in destructive competition among fields, units, missions and even institutions. More destructive competition can lead to increasing concentration, homogenization, and instability in the US-ARE system and, by extension, in the global research system that it helps to anchor. Deciding (intentionally or not), to pursue a focused exploitation strategy in order to address pressing pandemic questions, or even just to help insure a continued flow of limited federal research funding, seems likely to have dangerous consequences because it has the potential to: (1) limit the range of fields and topics funded; (2) make large scale

interdisciplinary research and teaching more challenging; (3) and to more thoroughly homogenize the academic research workforce.

Early evidence I present from NIH and NSF COVID-19 funding and from financial data on a key academic cost-center, libraries, suggest that the "perfect storm" of challenges that accompany the pandemic may make pursuing a focused strategy more likely and more fateful, with the result that the US-ARE could become less flexible, less diverse, less comprehensive, more unstable, less prominent on the global stage, and more isolated from the very communities and concerns we may wish for it to serve. This is not a certainty, but it seems a much more likely outcome to me if immediate decisions are not taken with attention to larger strategic goals.

Introduction

COVID-19 has had tremendous economic, social, and political effects across the world. In the United States, the last seven months have seen dramatically rising case and death counts, monstrous job loss, economic stagnation and ramifying social effects that will be felt for years if not decades. The nation's fragmented, failed federal pandemic response has increased widespread uncertainty while lengthening the period of the virus' greatest effects.

The white paper that follows uses recent, publicly accessible data to examine the current state of the United States Academic Research Enterprise (US ARE) during COVID-19 and to consider some possible paths that decisions by federal and state policy makers, as well as university leaders could take the system. I emphasize several major themes: (1) US ARE universities face unprecedented financial challenges during the pandemic that, for the first time in contemporary history, stress all aspects of the university mission and budget model at the same time; (2) Pandemic-related budget pressures come on the heels of at least a decade of other difficulties including accelerating state disinvestment in public universities and flat federal research spending; (3) US research universities, the core of the ARE in this country, are important because they act as a form of "social insurance" that helps keep the nation and the world poised to address unexpected problems or take advantage of unanticipated opportunities; (4) pandemic response decisions made by policy-makers and university leaders stand to damage US ARE institutions' ability to continue to play that important role.

Finally, (5) leaders face a key strategic challenge in pandemic response. They can focus what resources they have tightly on addressing both the pandemic and its associated budget effects or they can maintain broader efforts to support a diverse range of fields and research areas in order to maintain their longer-term capabilities to help address currently unknown future issues. There are, I believe, strong policy arguments for both approaches, so what is needed is to treat even urgent decisions as matters of policy and strategy as well as short term pandemic response. Doing that is exceptionally challenging now.

As many of the country's universities and colleges have reopened (and sometimes shut down again), the systematic toll of the pandemic on one of the world's great systems of higher education and research is becoming clearer. To better understand what is happening to that system, I focus on a very small, but essential component of American higher education that I call the U.S. Academic Research Enterprise (US-ARE). U.S. Department of Education (DoEd) data identify more than 6300 public, private, and for profit post-secondary institutions in the U.S. that enrolled more than 20 million students in fall of 2018. National Science Foundation (NSF) data for the same year report that about 10% of those (646) spent at least $150,000 on research.

Those U.S. colleges and universities spent a total of more $79.3 billion on research. That's $224 for each of the more than 323 million people who lived in the country in 2018. In the first of several themes that will animate my discussion, that research spending is highly skewed. Just 150 large public and private research universities account for 90% of that research spending. That 2% of U.S. higher education institutions represent the core of the US-ARE.

Research universities are very large and very complicated. Together they enrolled about 13% of all undergraduates and 36% of all graduate students studying in the U.S. Big research universities are the largest employer in 24 U.S. states. In 44 states, universities are among the top

five employers. In addition to the standard, tripartite, academic mission of research, teaching and public service, these institutions do other essential work. For instance, 47 of them run large hospitals that have been on the front lines of medical responses to the pandemic.

US-ARE universities, whether public or privately governed, together comprise the core of a national research system that I have argued is important in large part because it serves as a form of social insurance that allows the nation and the world to be better able to respond to unexpected challenges and to take advantage of unforeseen opportunities.[1] One needs only to look at the speed and the breadth of academic contributions to COVID-19 response and recovery to see a clear example. Their ability to do this work is a function of their complexity, their integration of multiple missions, and their traditional reliance on significant public support and subsidies to sustain capabilities for research and teaching that are found in no other sector.

US-ARE institutions are also the world's largest international hub for science and education. Their strength and resilience makes essential contributions that reach far beyond U.S. national borders. As a result, what happens to these institutions has immediate implications for the global research and education systems they do much to help anchor. It is too early yet to know what the full implications of COVID-19 will be for the US-ARE and by extension for global research and education. This paper uses public information from many sources to describe their state before the pandemic, glean hints as to possible effects from several "leading indicators" of how COVID-19 is changing the research component of the university's knowledge mission, and extrapolate to describe several possible post-COVID scenarios for the US-ARE and the individual institutions that it comprises.

The pandemic poses unprecedented challenges to all aspects of higher education and that fact exacerbates its possible effects on the academic research enterprise. The modern, Post-World War II, history of these institutions has no parallel to the difficulties they face today. The unique nature of these challenges highlights problems that have confronted the US-ARE at least since the Great Recession and, in some cases, for decades longer. COVID-19 did not cause many of the problems it worsens, but the decisions being made right now about how universities should respond to and recover from the pandemic will have substantial and potentially very long-term implications for individual campuses and for the health of the system as a whole. Federal actions, or lack thereof, have only made this situation worse and the conditions for decision-making in academia more uncertain.

Federal relief for higher education has been slow and piecemeal. Even the most aggressive plan being considered in Congress falls far short of the level of stimulus directed to research and higher education during the Great Recession. New actions by the Trump administration limit immigration, and add additional restrictions that especially strike non-US students. Likewise, recent executive branch moves to more rigorously police scientists and universities' engagements with non-US (particularly Chinese) organizations and researchers also worsen the situation. Caution is in order, but so is a systematic effort to think through what this situation might mean for the future.

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[1] Owen-Smith, Jason. 2018. *Research Universities and the Public Good: Discovery for an Uncertain Future.* Stanford, CA: Stanford University Press

Data alone is not enough to accomplish this, though better and more accessible data would help immensely. Even if available information were near perfect (it is not), relevant sources such as data maintained by federal and state agencies, often lag reality by years.[2] Fitting what we can know, relatively easily, right now, into a plausible set of future scenarios is an exercise in imagination disciplined by data and informed by a broad understanding of how these unique institutions work and what they do. I have spent more than 20 years researching, teaching, and writing about U.S. research universities. My recent book, *Research Universities and the Public Good: Discovery for an Uncertain Future* lays out the framework that animates my thinking here. Since 2015, I have been the co-founder and executive director of the Institution for Research on Innovation & Science (IRIS), a consortium of 35 U.S. research universities who share data for research and reporting to understand, explain and improve the public value of higher education and research. In this role I have learned how important good, accessible data are for thinking about complex institutions and their effects.

In what follows, I first summarize the framework that informs my analyses. I then turn to describe some of the challenges COVID-19 presents. Two unique strength of U.S. research universities are their complications and their breadth. These same features make them uniquely susceptible to damage both intentional and unintended. One of the things that's new and particularly challenging about the pandemic's effects is that they strike all aspects of the university's mission. The financial pressures that come with the pandemic follow and amplify more than a decade of difficult times since the Great Recession. But even that global downturn was not as devastating as the current situation because some, traditionally counter-cyclical, aspects of university finances were shielded. Enrollments increased as is commonly the case in recessions. Timely federal action under the American Reinvestment and Recovery Act (ARRA) pumped significant amounts of money into research. Thus far the pandemic has spared no part of the university.

Pressures created by COVID-19 render a fundamental tension in research policy and research leadership visible in stark ways. The strategic dilemma faced by policy-makers and academic leaders pits two potential research and funding strategies against one another in a fashion that is much more dramatic in this challenge environment. That tradeoff - between focusing resources and effort narrowly in order to fully and effectively exploit existing scientific capabilities for pandemic response and research revenue, and actively working to ensure the breadth and health of the research enterprise in order to support our ability to respond to future crises and opportunities - raises the possibility that short term decisions made with the best of intentions might have significant consequences for the future of the US-ARE.

To show how, I turn to available data that suggest what might be on the horizon as a result of the pandemic. The same data offer hints about how the pandemic is affecting the work of research and discovery. The picture these data paint now is necessarily partial, but I examine two "leading indicators" - COVID-19 specific funding from NSF and the National Institutes of Health (NIH) - in order to glean some sense about how things may play out for US Universities. Those findings provide a jumping off point for thinking through a set of possible post-pandemic scenarios and their implications. The medium to long term implications of the pandemic for research

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[2] Lane, Julia I. 2020. *Democratizing our Data: A Manifesto*. Cambridge, MA: MIT Press.

universities in the U.S. will depend, at least in part, on three interrelated concerns. Decisions made now will have implications for the breadth and variety of academic research, for the diversity and productivity of the academic research workforce, and for increased concentration and inequality in the ARE system. All of these, together, raise important questions about the kinds of strategic thinking that may be necessary to help ensure that today's decisions don't damage the US ARE's ability to serve as a central hub in the global research enterprise and a form of social insurance against a highly uncertain future.

The dangers I see are fractal, by which I mean they are mirrored at different levels of analysis. Individual universities are a microcosm of the larger system and decisions made about both (by academic leaders on the one hand and federal and state policy-makers on the other) stand to have analogous local and systemic effects. I sketch those in the context of the U.S. system before shifting focus to examine how the fate of the US-ARE might affect the global research system. The U.S. is still the largest and most central player in worldwide science and higher education. What happens here will ripple out to the rest of the world, creating opportunities for some nations but raising further uncertainty.

COVID-19 and the protracted shutdowns that have characterized US pandemic response are dangerous because the financial pressures they create remove essential flexibility from universities, creating tighter coupling across the organization and forcing tradeoffs that will have lasting effects. To understand why that is the case, and how the situation might play out, we must first lay some groundwork.

The US-ARE as a form of social insurance.

Universities and the larger research enterprise they anchor are essential because they represent stable (perhaps until now), publicly supported endowments of capabilities that are replicated nowhere else and that enable them to identify and help address unforeseen problems and opportunities that arise across the globe. The ability to identify and respond to "unknown unknowns" results from the unique organizational features of universities. They are simultaneously sources of new knowledge and skilled people, scaffolds that help support and shape local industries and communities, and hubs connecting far flung parts of the economy and the world.

The institutions' ability to be consistent sources of discovery and skill is a function of their broad knowledge portfolios and especially of their embrace of research and teaching in areas that may not seem to have immediate applications. At the most basic, being a source of knowledge and skill at the frontiers of what we currently understand means that universities must consistently produce new discoveries and must embed novices such as students and trainees in the details of that production as a means of teaching. In this framework, innovation is not something that happens *sui generis,* instead it results from the combination and recombination of existing pieces of knowledge, technology and skill. In other words, most new discoveries result from the integration of bits of what we already know to do new things or to do known things in a new way. Thus, one of the most important things that universities (and the public funds that sustain them) do is create and support extended networks of collaboration that investigators can use to search for and find the existing know-how they need to devise and test new understandings.

The capacities that are baked into the academic research workforce and the collaboration networks they create are what make universities effective sources of knowledge and skill. The same capacities allow them to pivot to address new and emerging problems like COVID-19. Being good sources requires that universities maintain the broadest possible knowledge portfolio, that the more or less independent pieces of that portfolio are connected to one another through chains of collaboration, and that the people and the networks that make up a university's unique knowledge fingerprint can access and use the widest range of historical and current knowledge possible.

This last thing happens in at least three ways: (1) often tacit knowledge at the the frontier of what we currently understand spreads through interactions and search in complex collaboration networks; (2) more established and potentially useful information and knowledge is readily accessible through the most open mechanisms possible including but not limited to publication databases, shared code and other research infrastructure; and (3) external points of connection between university researchers and the "outside" world create access to problems and the components of possible solutions from beyond the university's boundaries. While individual campuses are a microcosm of these features, the social insurance benefits of universities as a class really result from a system of institutions that each maintain (for reasons both idiosyncratic and strategic) different mixes of people and varied networks connecting them.

The particular external connections that make universities scaffolds and hubs also vary from campus to campus and locale to locale. Universities are scaffolds to the extent that their stability and breadth of mission allow them to connect to and support a wide range of local interests ranging from industry to activism, social services and healthcare. Because they are at least somewhat committed to the public interest and because public support makes them stable, important components of state and regional communities, universities can become the anchor tenants that help sustain and define their homes.[3] But critically different institutions and regions have different features.

A large, midwestern public university with historic ties to manufacturing industries can bring different capabilities and partnerships to bear than a more agriculturally focused rural land grant institution or a private university with deep local connections to high technology industries. Being committed to and embedded in their home turf makes universities more effective as universities but also helps ensure that the system they comprise is diverse enough that no matter what kind of problem or opportunity we face, some institution (or more likely several) will identify it and have the wherewithal to try to address it. Even more importantly, the fact that universities vary in terms of the composition of their networks and intellectual strengths means that efforts to address new problems will take multiple approaches.

When we pull back from the local focus to a more global view, we see that the very dynamics that make universities effective local scaffolds make them hubs that connect far flung parts of the economy and society. Large research universities are connected to a huge range of fields,

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[3] Agarwal, Aja & Iain Cockburn. 2003. "The Anchor Tenant Hypothesis: Exploring the Role of Large, Local, R&D-intensive firms in regional innovation systems." *International Journal of Industrial Organization*. 21(9): 1227-1253.

organizations, and sectors through collaborations and other formal relationships as well as through more informal connections forged as alumni leave to take up jobs and return. Their external connections make them shortcuts between more separated social and economic worlds. As we shall see these very connections place U.S. universities at the center of an increasingly globalized research system. Again, individual universities are made stronger by being well connected because external links provide means for new knowledge and resources to enter the institution and potentially find a foothold in their collaboration networks. Maintaining connections to multiple domains also ensures that universities will be among the first locations to identify new, emerging problems and opportunities, wherever they arise.

The system of universities is a form of social insurance against a deeply uncertain future because it is comprised of hundreds of internally diverse and broad knowledge portfolios connected by networks that help make the research capabilities of different campuses unique. Their stability and commitment to their homes means they represent a more or less permanent local endowment of skill and knowledge that is well adapted to the distinct mix of communities and industries that are a given institution's neighbors. Finally, their varied global connections mean that problems and the components of potential solutions flow to them from all over the world and from across the whole sweep of human activity. The fertility and effectiveness of this system thus depends on the range and diversity of universities participating in it, on their distinct capabilities and on the breadth and reach of their external connections. All three of these things are at risk as a result of the pandemic. To understand why we must dig into the complicated features of universities that enable them to be sources, scaffolds and hubs. The key to that is the flexibility, multiple interests, and synergies that are made possible by multiple missions that can cross-subsidize and inform one another.

The dire situation for research universities.

The things that I think distinguish U.S. research universities -- the diversity of their knowledge portfolios, their commitment to multiple sometimes conflicting missions, their varied internal and external networks, and their stability and commitment to place -- make them uniquely important components of the national and global higher education and research systems. Those very features are at risk as a result of a pandemic that will have the effect of tightening budgets across the full range of university activities. This tightening will force tradeoffs and increase conflicts between different aspects of the university mission, potentially damaging the very features I think we need to protect. To understand why, think about all the things that U.S. universities do.

They are major teaching institutions that are home to millions of undergraduate, graduate and professional students. They do the lion’s of share of US academic research across essentially the full range of human knowledge with work spanning the arts, the professions, sciences, engineering, and humanities. Many of them manage and run hospitals and clinics that are major components of the healthcare system of their states and of the nation. They maintain large, expensive physical plants that serve the needs of students and researchers alike. The common infrastructure represented by things like laboratories, museum collections, libraries, IT and regulatory systems create a shared platform on which teaching and research can occur. The fixed costs of that infrastructure are high and need to be covered despite pandemic shutdowns and slowdowns of work.

Universities are landlords and restauranteurs and often the home of highly professionalized and sometimes lucrative sports teams. Many maintain and support cultural and artistic productions, military training, or agricultural extension work. All have some aspect of their mission focused on public service. The list could go on, but the major message is that the complicated, sometimes messy and internally conflicting mix of missions and activities is a key source of their strength. But their success depends on public support that helps prevent internal competition for resources among different fields and activities from becoming destructive. Borrowing terms from organizational theory we can say that the institutions work because slack resources and loosely coupled activities enable multiple missions to create synergies rather than to force destructive tradeoffs.[4]

In other words, the stability and relative certainty of public support helps universities manage multiple missions without too much conflict, and the more or less decentralized organization of different activities means that while, for instance, the healthcare, research, and teaching missions can support one another, they are generally not completely interdependent. COVID-19 is changing all that because, unlike any other major economic shock, it has increased costs, and often decreased revenues across all aspects of the university mission. Fragmented, slow and in some cases absent government responses and associated financial pressures at both the state and federal levels only exacerbate these effects. As a result, I believe the pandemic will force decisions and tradeoffs that have the potential to systematically damage individual university capacities to be sources, scaffolds, and hubs. As that happens key features of the US-ARE system could also shift, with implications for the future of these essential institutions of the U.S. and of the world.

Revenues, Costs, and Pandemic Dangers

To get a sense of what this all means, we need to begin with a look at the financial model of U.S. research universities. The challenge is that there's not really just one. The diversity of universities as organizations is reflected in important variations in how they budget for and fund their activities. I draw on public data[5] to examine general financial information about the 150 U.S. research universities that represent the core of the US ARE. While these institutions vary in important ways - some are public, some private, some maintain comprehensive knowledge and teaching portfolios, others are more specialized, some have hospitals, others do not, some maintain a large agricultural focus, others do little to no agricultural research - their scale and complexity means they have more in common organizationally with each other than they do with other higher education institutions (such as colleges, regional universities, community colleges, or religious institutions) that generally have a more exclusive teaching focus. The first step toward understanding the dangers the pandemic carries for US-ARE institutions is getting a sense of how their budgets worked before the pandemic began. I thus focus my attention on

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[4] Cohen, Michael D. & James G. March. 1974. *Leadership and Ambiguity: The American College President.* New York: McGraw-Hill. Weick, Karl E. 1976. "Educational Organizations as Loosely Coupled Systems." *Administrative Science Quarterly*. 21(1): 1-19.

[5] The Integrated Postsecondary Education Data System (IPEDS) dataset maintained by the Department of Education's National Center for Education Statistics, NCES.

financial information from 2018 while realizing that the state of university finances then still bears the distinct marks of the Great Recession.[6] US Research universities were facing challenging times before the pandemic because they were just emerging from a "lost decade" of public funding.[7]

Budgets offer a concrete manifestation of organizational priorities and as such provide useful information about what universities focus on. The data I present are broken down to allow some of this variation to become apparent. Private non-profit institutions (schools such was Harvard, Stanford, Caltech, MIT, and Yale) and publicly governed universities (such as the University of Michigan, Iowa State, the University of Alabama, and the Universities of California and Texas) use different accounting practices. Thus, IPEDS reports their financial data separately, a practice I maintain. I also distinguish between universities that run academic medical centers and those that do not, because healthcare costs and revenues make up a sizable portion of the budget for institutions that have them and because healthcare in the pandemic carries unique difficulties. For the sake of simplicity, I first look at revenues and then turn to a discussion of expenses.

Revenue sources

Even when we consider only the top 150 research universities, we are talking about a large and expensive sector of the economy. The institutions that are my focus here spent about $289 billion in pursuit of their missions in 2018 and had nearly $330 billion in revenues. The work of the average institution cost nearly $2 billion but that figure masks wide variation. Let's begin by looking at the 103 public and private institutions that do not run hospitals.

Figure 1 presents the revenue sources these universities rely on. The area of each component of these figures is proportional to the percent of revenues they represent. I provide specific percentage labels for any revenue component that represents more than 10% of the total. The 71 public universities represented in Figure 1 had about $89 billion in revenue (Average = $1.3 bn, SD = $808 mn, min = $344 mn, max = $3.6 bn). The 32 private institutions had a total of $95 billion in revenue (Average = $3.0 bn, SD = $2.2 bn, min = $595 mn, max = $7.8 bn). Even the smallest of these are large organizations.

The figure highlights the wide range of things that universities do that bring in revenue. But they really depend on a smaller set of funding sources. Just four revenue streams account for more than 74% of funds to public universities in this figure: Tuition (28.6%), State appropriations (19.4%), Federal Grants/Contracts [8] (13.7%) and revenues from Auxiliary enterprises (12.6%). While the first three are pretty clear, the last may require a little unpacking. Auxiliary enterprises are businesses that are run by universities and that charge fees for services that are not a part of the core missions of research, teaching and service. Examples include things like residence halls,

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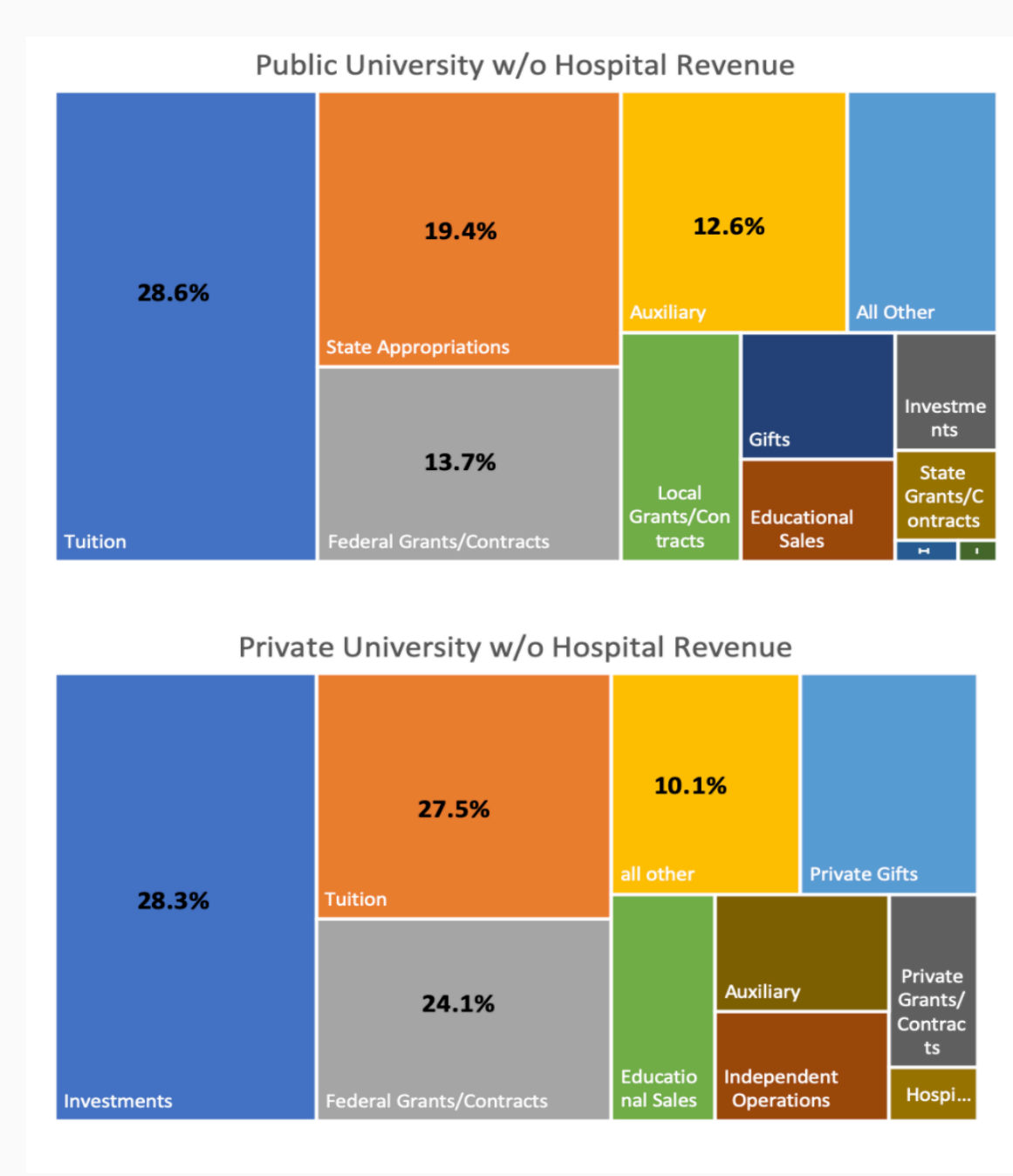
[6] https://www.acenet.edu/Documents/Talking-Points-Research-Relief-052720.pdf ↩

[7] https://www.cbpp.org/research/state-budget-and-tax/state-higher-education-funding-cuts-have-pushed-costs-to-students

[8] Federal grants and contracts capture the primary source of external research funds. We'll disaggregate that more in the next section.

food service, student health services, intercollegiate athletics, and college unions, college stores, and movie theaters.

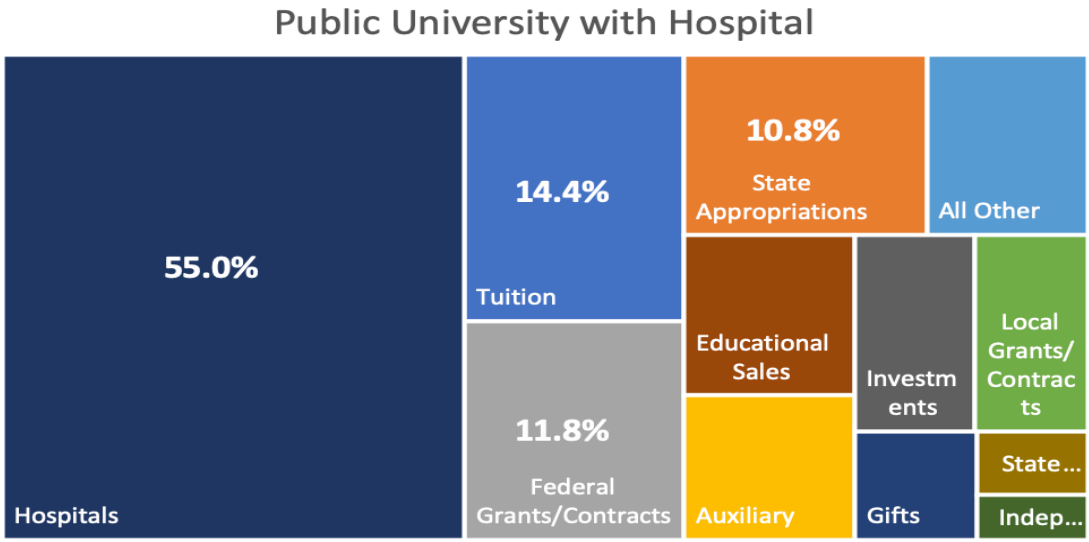


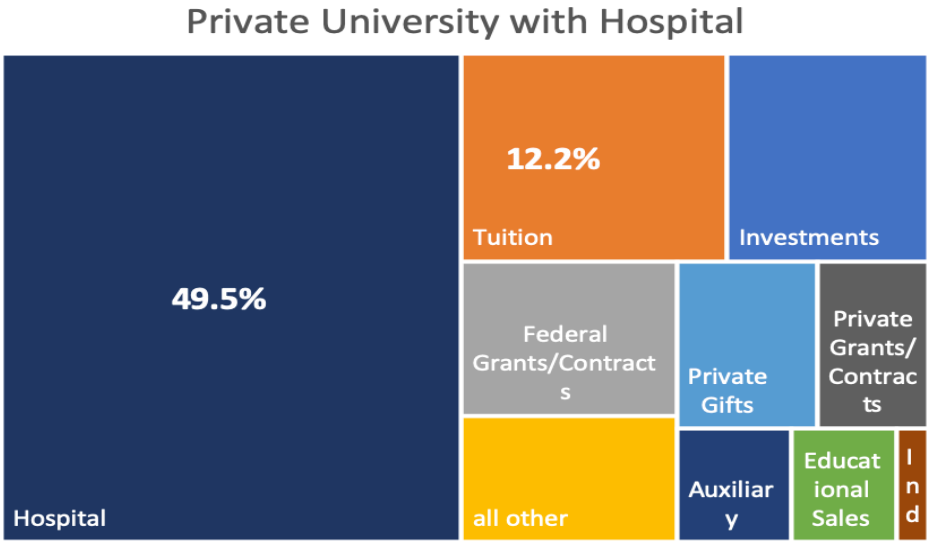
Gifts from philanthropic donors and revenue from investments (including endowment investments but also things like real estate ownership that generates rental income) together amount to about 7.3% of revenues for public universities without hospitals. This is the source of funds that most distinguishes private universities in this category from their public counterparts. These private institutions receive 90% of their revenues from their top sources. However, the

largest share comes from investment income (28.3%), followed by tuition (27.5%), and federal grants (24.1%). Philanthropic gifts represent another 9.5%.

The big message of Figure 1 is that public universities and private universities are about equally dependent on tuition dollars. Private universities draw about 38% of their revenue from investment income and private gifts. They also rely more heavily on federal grants and contracts (which represent 24% of revenues relative to just about 14% for public institutions). While public institutions do receive gifts and investment income, which represent about 7% of revenue, they rely more on state appropriations (19.4%), a source of public funding not generally available to private universities. Publics also rely more heavily on revenues from their auxiliary enterprises (almost 13% relative to a little less than 5% for privates). Those differences are important. While IPEDS data does not break auxiliary revenue down any further, most of the examples of these university operated business lines are focused on students in residence. While private institutions may have a little more of a cushion offered by investments and gifts, at public universities, the largesse of state legislatures and earnings from ancillary businesses are key.

The picture is somewhat different for the smaller group of institutions that also maintain hospitals. Figure 2 reprises Figure 1 for those 47 institutions.





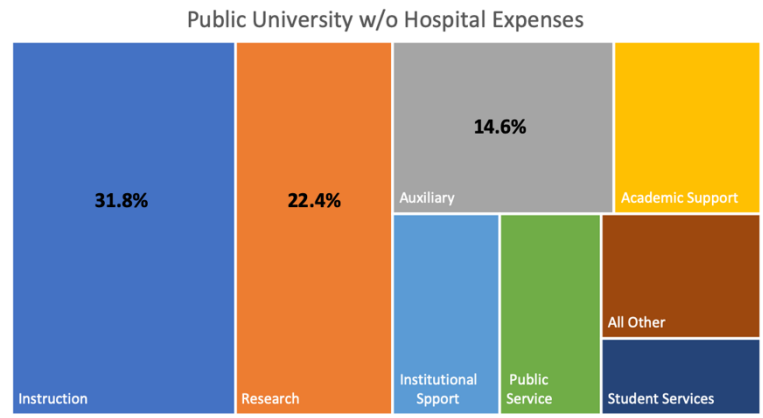
Two things are immediately obvious in Figure 2. First, having revenue from a hospital dramatically increases the overall size of the pie. As hospital revenues swell the denominator the overall percentage of funds represented by other sources of revenue necessarily diminishes. The 13 private universities and 30 public universities that maintain health systems are (not surprisingly) much larger than their peers without hospitals (Privates: Average = $4.7 bn, SD = $2.9 bn, min = $1.1 bn, max = $9.6 bn; Publics: Average = $3.3 bn, SD = $2.0, min = $648 mn, max = $9.3 bn). So, private universities with hospitals have more revenues, making their reliance on tuition seem smaller than it was for their peers in Figure 1.

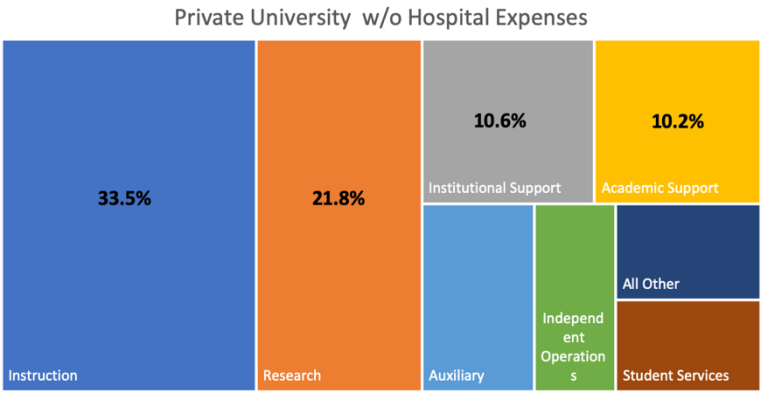
Second, hospital revenues make up a huge percentage of the funds that flow to these institutions (55% for public institutions, 49.5% for private institutions). We cannot over-estimate how much of a role health care plays in the finances of many USE-ARE institutions. This is also apparent when we shift our lens to examine expenses.

Cost Structure of ARE Universities.

The accounting systems used by private and public universities identify costs with activities that don't always align with revenue sources. For instance, research expenditures, which we will discuss in more depth soon, can be funded by federal sources, non-profit or business investments, state or local government grants and contacts, and the university's own money, which itself may be drawn from revenues as varied as tuition, state appropriations, gifts, auxiliary or hospital revenue and investments. The fact that the activities that account for costs don't exactly line up with sources of revenue speaks to one of the strengths I see in large research universities. The work of their various missions can be cross-subsidized, offering a degree of flexibility when one part of the institution faces external financial challenges. Relatively stable (and large) sources of funds such as investment income and gifts (in the case of private universities) and state appropriations (in the case of public institutions) add a degree of certainty to university budgets so long as the financial markets stay strong and public commitments to universities by their home states remain a priority.

These features are a strength in good times and can bolster institutions in bad ones. For instance, during the Great Recession, universities faced substantial declines in investment income and, for publics, in state subsidies. But at the same time, health care, tuition, auxiliary and grant income remained stable or even increased. Higher education enrollments tend to grow in recessions. Health care is also countercyclical. During the Great Recession federal stimulus funds added about $65 billion to research through the American Recovery and Reinvestment Act (ARRA). In other words, the closest contemporary analog we have to the pandemic recession saw costs rise as, for instance, increased enrollments required expanded instructional work. But revenues from those "business lines" would also have grown as more students paid tuition or as additional federal funds allowed more investigators to successfully compete for grants. There is no doubt that the last recession was a difficult time for universities but that period did not see downward pressure on revenues or upward pressure on costs across the board. That is precisely what universities are facing now.





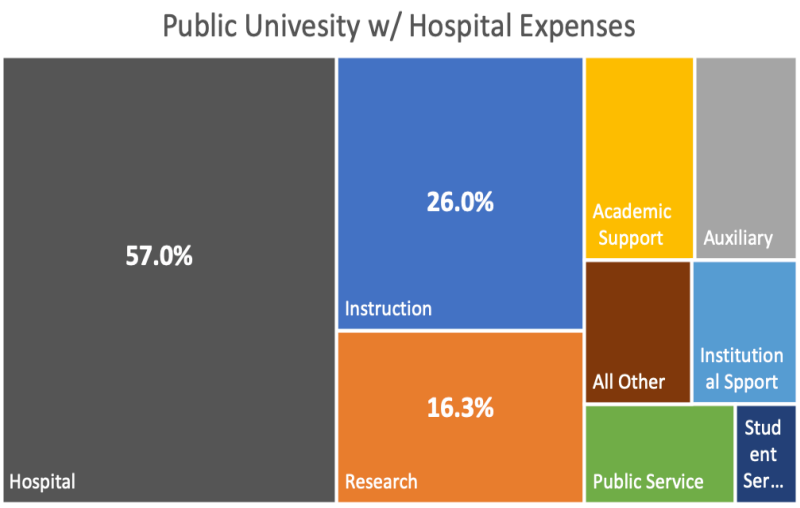
Consider Figure 3, which presents expense information for universities without hospitals.

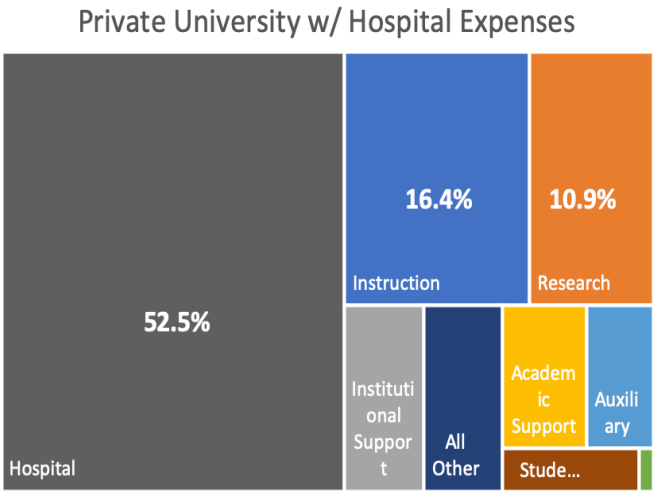
At both public and private institutions, instruction and research are the number 1 and number 2 costs, representing about 54% of expenses for public institutions and about 55% for private institutions. For public universities maintaining auxiliary enterprises represents the next most important cost, followed by costs of academic support, and the institutional arrangements (such as compliance and contracts offices or libraries) necessary to the university's research and teaching missions. Private universities spent less on auxiliary businesses and relatively more on academic and institutional support. The revenues presented in Figure 1 and the costs shown here don't align. Public universities require state appropriations and private universities require investment income to cover costs of instruction and research that are not fully defrayed by tuition or federal grants.

The story is similar, as Figure 4 shows, at universities with hospitals.

For both public and private institutions health care costs account for the majority of expenses. In both cases, they represent a greater percentage of costs than they do of revenues. Once again instruction and research are the next two most important buckets of expenses for both classes of institutions, and once again the relative costs of instruction are higher than their relative contribution to revenue. Here too we see how public universities depend on state subsidies and private universities depend on investment income to make ends meet in their complicated cost structure.

The overall picture here is one where external effects on university finances are something like squeezing a balloon. When outside forces, such as the Great Recession, exert pressure on one part of the institution, flexibility in another part can take up some slack to prevent the institution as a whole from failing. The at least somewhat fungible income from state appropriations and investments adds resources to the whole system. At least a portion of those are typically unrestricted, which means they aren't pre-committed to particular uses. Those funds add flexibility to the institution and allow a wider range of strategic cross-subsidies that can span different aspects of the university mission.





The General Fiscal Danger of COVID-19

COVID-19 has created a situation that is dramatically different than the Great Recession because it stands to remove all the flexibility from the university budget models. In the seven months or so since the U.S. began to shut down, university costs have increased for many major activities, and revenues from all sources are at risk. Weak federal responses to the pandemic have made things even more challenging by dramatically increasing the uncertainty university leaders face. To return to our earlier metaphor, squeezing the balloon during the Great Recession happened in a context where pressure could be released as the budget bulged somewhere else. The consistent constraints on most activities and revenue streams created by the pandemic means that budgetary pressures felt across the university may lead the balloon to pop.

How is that happening? Consider three major components of the university mission, research, teaching and, for a significant percentage of universities, healthcare. The pandemic shut down campuses starting in March of 2020. Guidance issued by the federal government allowed federal grants to continue paying research salaries even when laboratories were closed and work could not continue, but Congress and the White House provided only limited additional research support. Paying salaries when much work cannot happen is humane, but it also adds additional costs to externally funded projects that are not likely to be made up by new revenue absent intervention from the federal government that has been slow to arrive. Testifying before a U.S. Senate Committee in May, Francis Collins, the Director of the NIH, estimated that "something like $10 billion of NIH funded research . . . is going to disappear because of the way in which

this virus has affected everybody requiring this kind of distancing and sending people home"[9] Five major higher education associations in the US have joined together in letters urging Congress to provide $26 billion in research relief but relevant bills are making slow progress.[10]

Shutdowns generally occurred in the middle of the Spring semester. Sending students home necessitated a fast and costly ramp up of online teaching capability at most universities. Those additional costs continued through the summer as most institutions worked toward developing capabilities for hybrid and flexible provision of courses through a mix of online and face to face instruction. For those that decided to hold in person classes, the costs of additional testing, personal protective equipment, contact tracing, installation of classroom barriers and cleaning protocols also added to the expense. And these increased costs came at a time when tuition revenue remained uncertain. Even now as relatively high enrollment levels are being reported,[11] surging case counts in locales with large universities contribute to the cost of quarantining students who test positive for the virus while putting the semester at risk.[12] And auxiliary income is being lost as well, with some universities (such as the University of Wisconsin system and the University of Georgia system) reporting tens to hundreds of millions of dollars of losses due to cancelled events and foregone revenue from summer camps and other money making uses of their facilities.[13]

Mary Sue Coleman, the recently departed president of the Association of American Universities (AAU) estimates that large universities faced losses of $74-$153 million per campus for the spring semester alone. The American Council on Education (ACE) estimates that colleges and universities across the U.S. "have a total of $46.6 billion in increased student financial need and lost revenues, and an additional $73.8 billion in new expenditures to re-open in light of the

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[9] https://www.aau.edu/sites/default/files/AAU-Files/Research-Relief-Letter-8.3.20-FINAL.pdf

[10] https://www.acenet.edu/News-Room/Pages/ACE-Other-Associations-Outline-Key-Provisions-for-Student-and-Institutional-Aid-in-COVID-19-Emergency-Legislation.aspx

[11] A recent report finds that undergraduate enrollment overall declined by about 2.5% this fall, with public four year institutions suffering the least (0.4%) while private four years institutions took a bigger hit (3.8%). Across the nation, community colleges were hardest hit (8%) and graduate enrollments rose by almost 4%. https://www.studentclearinghouse.org/blog/undergraduate-enrollment-down-2-5-and-graduate-students-up-3-9-compared-to-sept-2019/

[12] https://www.nytimes.com/2020/09/06/us/colleges-coronavirus-students.html

[13] https://www.ajc.com/news/local-education/georgia-public-universities-propose-cuts-meet-state-budget-gap/XI59z6wLG557VBaHxg3iiI/. https://www.americanprogress.org/issues/education-postsecondary/reports/2020/06/11/485963/mounting-peril-public-higher-education-coronavirus-pandemic/#fn-485963-7

COVID-19 pandemic"[14] If we add up those estimates ($26 billion for research, $46.6 billion in student need and lost revenues, $73.8 billion in increased costs for reopening), which are almost certainly not comprehensive, we get a total of $146.4 billion. To put that back of the envelope estimate of university need into perspective, that number represents more than 50% of the total 2018 cost of 150 U.S. ARE Institutions.

But wait, there's more. Academic health centers (and hospitals generally) are also struggling with increased costs and decreasing revenues. Some academic medical centers are reporting revenue loss of 50% as elective health procedures were postponed or cancelled to slow infection and free up beds for COVID-19 patients. The same institutions also see increasing costs as they prepare for and treat often resource-intensive COVID-19 patients.[15] Taking a broader view, the American Hospital Association (AHA) projects that hospitals and hospital systems across the country will lose $323 billion in 2020 as a result the pandemic.[16] I haven't found an easy way to learn how much of that loss falls to medical centers associated with US-ARE institutions. However, academic medical centers are "the safety net health care systems in the United States" and also, because of their multiple academic missions "among the most expensive" healthcare systems in the country,[17] so it is reasonable to assume they face their fair share of extra costs, putting universities with academic medical centers in a particularly challenging situation.

Think back to our discussion of university revenues and the idea that a cost pressure squeeze on the university financial balloon could be managed by appeal to other, unaffected parts of the university. Not all funds are fully fungible. For instance, federal research grants always come earmarked to use for the particular project they support and can't be shifted unilaterally by the university. Endowment and gift income is often restricted by donors' intentions that money be put to a particular use. Despite such restrictions, there are sources of funds (notably tuition, state appropriations, and revenues from auxiliary enterprises) that can be used, to at least some degree, with greater flexibility. Both tuition and auxiliary enterprise revenue depend on students, and generally (at ARE institutions at least) residential students. As a result, uncertainties having to do with current and upcoming semesters loom large.

It would seem that research support from the federal government represents one stable, and potentially even growing source of revenue during the pandemic, while state appropriations represent another for public universities and at least some portion of investment income representing another for private institutions and a few particularly well-endowed publics. Let's take them in reverse order.

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[14] Op Cit. 10

[15] https://www.insidehighered.com/news/2020/05/04/university-affiliated-hospitals-suffer-huge-revenue-losses

[16] https://www.aha.org/system/files/media/file/2020/06/aha-covid19-financial-impact-report.pdf

[17] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7179061/

While some exceptionally well-endowed institutions, such as Stanford authorized significant draw downs of unrestricted income from investments, the focus of such expenditures was on student financial aid. In this case, the drawdown was accompanied by reductions in endowment uses for operating costs. Thus, using $150 million dollars of investment income to support students, while laudable "will lead to budget cuts for many units."[18] This ambiguously beneficial kind of decision may only be possible for the very wealthiest institutions.

A recent survey of 333 university endowment managers by the National Association of College and University Business Officers (NACUBO) found that the average endowment faced a 13.4% loss in the first quarter of 2020 and institutions with smaller endowments had larger losses in part because they were more heavily invested in U.S. markets, which have been particularly volatile. As a result, only 8% of respondents expected to increase spending rates from endowments. For most endowed universities spending must stay the same or decrease in the wake of COVID-19.[19] Even exceptional cases like Stanford's illustrate tradeoffs in the choice of how to make use of unrestricted funds. While supporting students they will still see operational cuts.

Public universities might seem to be in better shape given their reliance on state funding. But that too is mistaken. U.S. states themselves are facing dramatic revenue shortfalls and expanded costs. Most are legally prohibited from running a budget deficit [20] and must respond by cutting expenses. So public institutions face especial challenges. Take a recently published description of the pressures at Rutgers University, a public university system in New Jersey. Rutgers is one of the public US-ARE institutions. It serves about 71,000 students and expects to lose about $200 million in revenue during the pandemic. That figure is based on about $50 million of refunds for room, board, parking and other student expenses due to pandemic shutdowns, potentially dramatic tuition loss as international and out of state students (who both pay higher tuition and fees than New Jersey residents) may be less inclined or, in the case of non-US students, unable to travel for school. In addition Rutgers reports a $73 million dollar loss due to a freeze in this year's state appropriations as well as a $60 million revenue loss from cancelled procedures in the university's hospital[21]. In New Jersey and several other states, the pandemic has already resulted in large cuts to current state investments in higher education and the

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[18] https://news.stanford.edu/2020/06/12/trustees-approve-2020-21-budget-set-endowment-payout-light-covid-19/

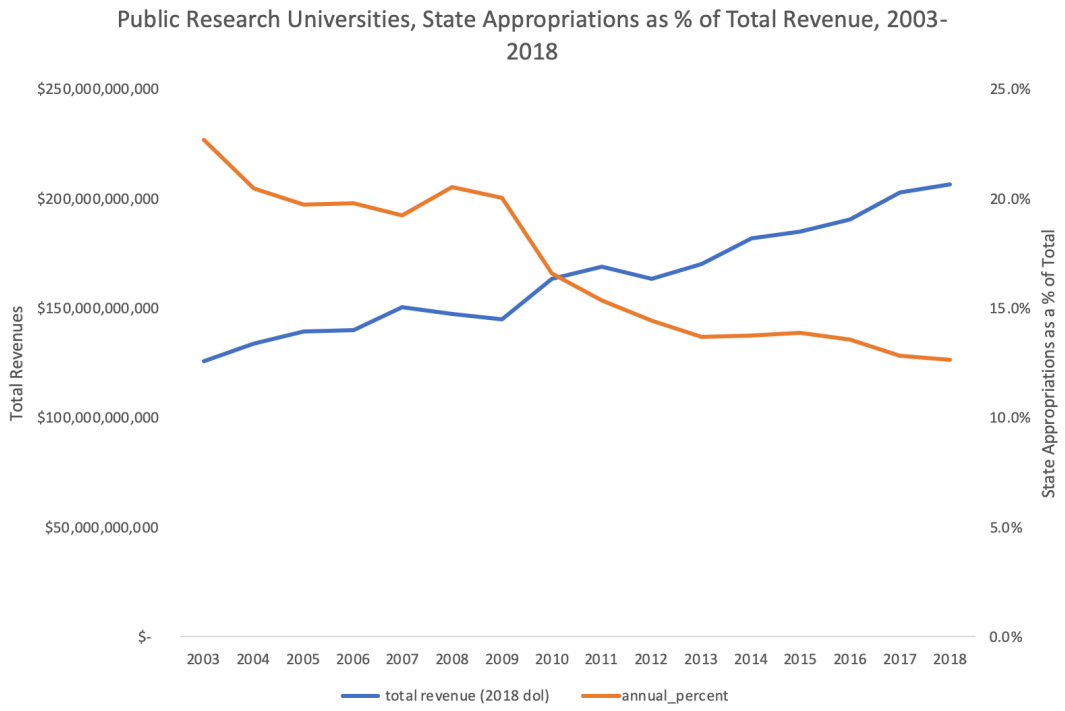
[19] https://www.nacubo.org/Research/2020/COVID-19-Research/Q1-2020-Endowment-Survey

[20] https://www.americanprogress.org/issues/economy/news/2020/04/17/483461/coronavirus-recovery-demands-substantial-durable-aid-state-local-governments/

[21] mycentraljersey.com/story/news/education/college/rutgers/2020/04/08/coronavirus-nj-rutgers-lose-200-m-revenue-due-pandemic/5119598002/

expectation of greater austerity measures to come as state governments report dramatic budget shortfalls[22].

To make matters worse, state appropriations never really recovered from the Great Recession. In 2008 they had already been trending downward for decades. Consider Figure 5, which presents a view of state appropriations as a percentage of total revenues for the 150 US-ARE institutions based on data from IPEDS. Across the whole timeframe presented, total revenues for US-ARE institutions have consistently increased. But state appropriations have not kept pace as evidenced by a large decline that began in 2009. The trend seems likely to continue even further due to pandemic pressures on state budgets, which the federal government has been resistant to helping to allay.



The secular decline in state appropriations over the last decade has been accompanied by a dramatic increase in tuition rates at public universities. State appropriations for higher education remain well below pre-recession rates.[23] As tuition revenues became more important, public universities have become more dependent on out of state and non-US students. Right now, the U.S. federal government is, intentionally or inadvertently, adding to the pressure on tuition with proposed legislation, presidential executive orders, and customs enforcement guidance that limit

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[22] Ibid. https://www.americanprogress.org/issues/education-postsecondary/reports/2020/06/11/485963/mounting-peril-public-higher-education-coronavirus-pandemic/#fn-485963-7

[23] https://www.cbpp.org/research/state-budget-and-tax/a-lost-decade-in-higher-education-funding

access to non-residents, including non-US students, and require that foreign students take in person classes or be forced to leave the country. It is hard to see the latter as anything other than an attack on American higher education institutions that have come to depend on foreign students' tuition: "Over the last decade deep cuts in state funding for higher education have put put pressure on schools to admit more students who need less aid, which is why so many schools have come to rely on the revenue from foreign students who usually pay top dollar." The large research universities that are the core of the US-ARE are particularly reliant on foreign students. IPEDS fall enrollment data from 2018 tell us that while these institutions represent less than 3% of all higher education institutions, they enrolled 35% of non-US undergraduates and 62% of non-US graduate students.

So, state governments are likely not going to be in a position to more fully support the nation's public universities and, even if they were, all evidence from the last ten years suggests that they are not inclined to. Across the nation state funding for public higher education remains down nearly 9% from pre-recession (2008 levels).[24] Indeed, 41 states have yet to rebound to pre-recession levels of spending on higher education, and public institutions in every state have become more reliant on tuition as a result.[25] Tuition revenues from outside the US are also at risk, increasing the danger. The result of all this is that whether they also run health systems or not, public institutions are caught on the horns of a particularly nasty fiscal dilemma driven by longstanding trends in public support for their work.

Diving Deeper into Research Funding

With every other major source of revenue in at least some danger of decline, university leaders might be forgiven for imagining that federal research funds offer a lone, stable source of revenue. That may indeed prove to be the case, but I think it unlikely. As yet, only modest increases in research spending targeted specifically at COVID-19 relevant research have been forthcoming. Three currently pending bills in Congress would put anywhere from $10 billion (earmarked entirely to the NIH) to $26 billion (spread across many federal agencies into research relief). An early August letter from four higher education associations to Congressional leaders lays out the needs while noting:

"Without these funds, the consequences for our nation's university research and scientific enterprise are dire. [Federal Science] Agencies will be forced to choose between abandoning new research opportunities of national importance or discontinuing existing research projects that are not yet completed. This would undermine the public's investment in research and slow discovery and innovation, while at the same time jeopardizing a generation of

[24] https://www.cbpp.org/research/state-budget-and-tax/a-lost-decade-in-higher-education-funding

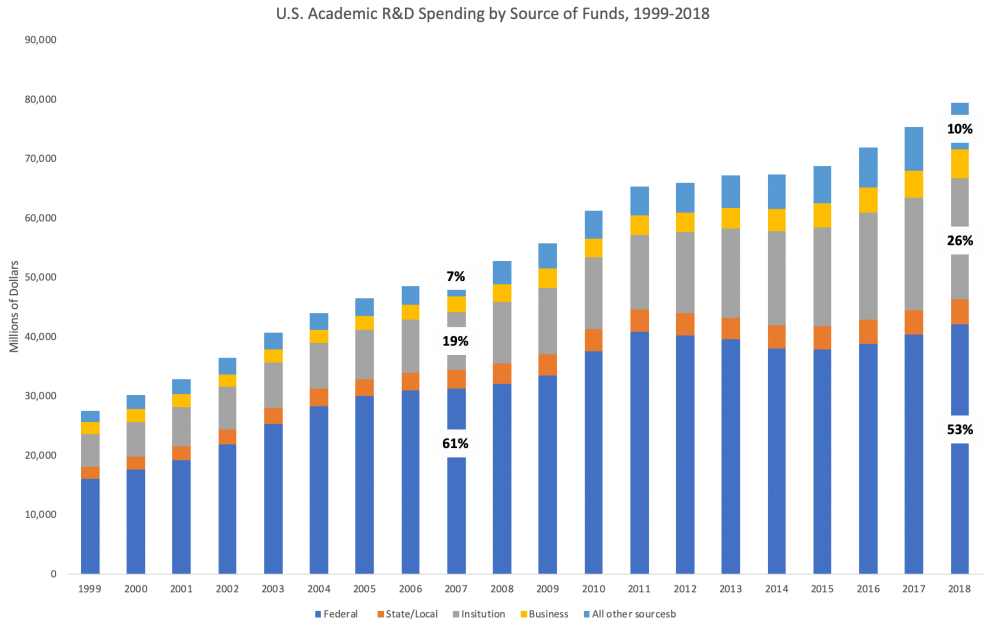
[25] https://shef.sheeo.org/wp-content/uploads/2020/04/SHEEO*SHEF*FY19*IB*PostRecession_Trends.pdf

scientists and engineers critical to America's innovation capacity and economic competitiveness for years to come. "[26]

The warning this letter makes explicit is warranted. Also note that the amount this influential group is asking Congress to provide is only about 40% of the research stimulus that was appropriated during the Great Recession. Even if Congress passes and President Trump signs the research relief bill that universities and their advocates prefer, it may be too little too late.

Such a shortfall would also come at a bad time. Like state appropriations, U.S. federal research spending in academe has stayed flat (in constant dollar terms) since the Great Recession. But academic research expenditures have been increasing overall.

Figure 6 draws on the 2018 Higher Education Research and Development (HERD) survey administered by the National Center for Science and Engineering Statistics, a unit within the National Science Foundation, to present a 20-year trend in academic research expenditures broken out by the source of funds.



This figure charts a fairly steady increase in overall research spending since 1999, but three things stand out. Notice the mix of funding sources. The tallest, blue, bar represents federal science funding. Orange and Yellow represent spending from non-profit (generally philanthropic foundation) grants and research funding from businesses respectively. The gray segment of each bar represents research spending from the institution's own pots of money. Total R&D spending by universities grew from $29.7 billion (in constant 2018 dollars) in 1999 to $79.4 billion in 2018. Until the mid 2000s, federal funding kept pace with that growth, reaching a contemporary

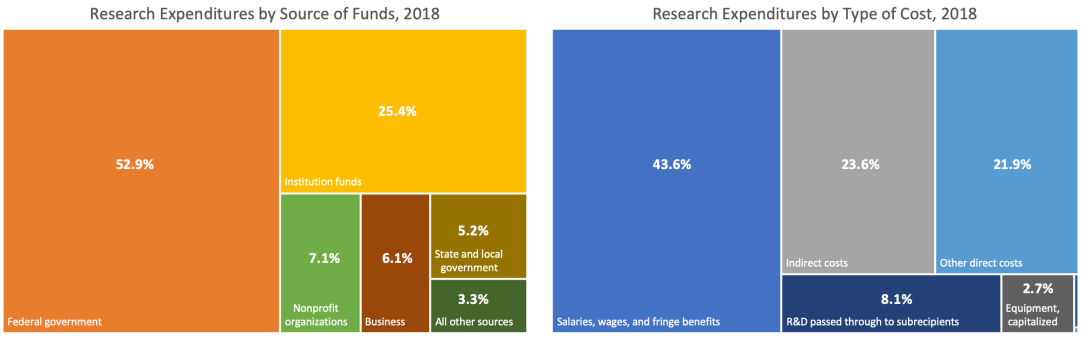
[26] https://www.aau.edu/sites/default/files/AAU-Files/Research-Relief-Letter-8.3.20-FINAL.pdf, https://www.aau.edu/sites/default/files/AAU-Files/Key-Issues/COVID-19/1ResearchReliefSenateLetter5-27-20Final.pdf

high-water mark of 63% of total spending in 2005. In 2007, the year before the Great Recession, federal funds for academic research represented 61% of the total. By 2018, that number was down to 53% after an almost ten-year period with little growth. Note that starting in about 2011, the blue portion of the trend is essentially flat, while the total continues to grow.

Other external sources haven't really taken up the funding that the federal government has allowed to stagnate. Business and Non-profit funds are important, even essential to contemporary university research, but each represents a very consistent 6-7% of the academic research portfolio over this time period. The real growth in research funding lies in institutional spending, universities investing their own money from other sources to support research. Between 2007, when institutional funds accounted for 19% of total research and 2018, when they covered 26% of research costs, the portion of research spending from university funds grew by almost 7%. That tracks very closely with the 8% decline in the proportion of federally funded research spending in this time period. In the decade after the Great Recession, more and more academic research came to depend on university revenues from other sources as federal, non-profit, and institutional funding stayed at a stable, essential flat rate.

In other words, US-ARE institutions confront increased costs and the potential for significantly reduced revenue after nearly a decade of ploughing more and more of their own money into supporting their research missions. There are only so many places those funds can come from. Gifts, tuition, state funds, investment income, auxiliary enterprises and sometimes hospital revenues could be used here. Public data are not sufficient to tease out which sources feed institutional research spending. The larger point is that it really doesn't matter. There is no source of revenue available to U.S. research universities that is not under significant strain.

Figure 6 presented data for research expenditures from the entire HERD survey. Figure 7 narrows focus again to look at where research funds come from and what they are spent on at the 150 US-ARE institutions.



This highly select subset accounts for about $70.8 billion of academic research spending. At those institutions, about 53 cents on every dollar of spending comes from the federal government, another 25 cents comes from institutional funds and the remainder is made up from non-profit, business, state and local, and other sources including non-US entities that account for about 2% of total research spending.

The plurality of research funds is spent to support people's salaries. Detailed spending data from 33 universities that share data with the Institute for Research on Innovation and Science (IRIS)

allow us to estimate that research grants paid salary to about 560,000 people in in 2018 and 2019. More than half of those (53%) were students or post-doctoral trainees, the potentially lost generation of scientists and engineers that higher education associations referenced in their letter to Congressional leaders. Less than 1 in every 5 (17%) are faculty. The remainder are professional and research staff who are paid by the direct cost portion of grants.[27]

That last sentence requires a sidebar, because the second largest bucket of research costs for ARE institutions is "Indirect Costs (IDCs)." Every federal and some business and non-profit grants have two basic components. Direct costs are the amount a given research investigator can spend to accomplish the research work they propose. IDCs, in contrast, go directly to the investigator's institution. They represent a portion of grant dollars that funders allocate to reimburse universities for the costs of supporting the research funded by grants. For federal grants, universities negotiate an indirect cost rate with the federal government at regular intervals. At my institution, the University of Michigan, that rate is about 56%. In other words, if I want to spend $100,000 dollars to pursue a new research project. I have to write a grant to a federal science agency for $156,000. My university would use the indirect cost portion of the grant to pay for all the kinds of things that researchers need but that aren't covered under the direct cost portion of grants. This might include but is not necessarily limited to the cost of contract offices and sponsored projects offices, compliance units dedicated to oversight of human or animal subjects research, costs associated with specialized physical plants, access to articles and databases through the library system, heat, light, and even square footage. Indirect costs are critical in that the represent reimbursements of investments universities make that enable research.

No wonder, then, that they constitute nearly 24% of research spending. But you have likely noticed that 24% is significantly less than the 56% rate that I cite for my university. There are several reasons for that. First, and most simply, the indirect rate at my university is 56% of direct costs (it's more like 36% of total costs, which are the sum of direct and indirect funds). But 24% is still far less than 36%. That's because universities don't recover all that they spend in indirect costs from the federal government. It also happens because many businesses and foundations pay much lower indirect rates (often as little as 0%). Thus, a university research funding portfolio made up from multiple sources will necessarily include less in indirect costs. One important component of increasing institutional spending is expenses incurred to pay for unrecovered indirect costs on federal or non-federal grants. Indeed, foundation funding or business funding with low or no indirects generally loses money for a university. A declining portion of federal funds and increasing reliance on institutional spending only makes this problem more challenging during the pandemic.

A smaller chunk of US-ARE research expenses flow from one university to another research organization as subcontracts (8.1%). Such subcontract relationships are one important way that the growing trend in large, multi-institutional team science is supported. While space keeps me from paying much attention to this here, it's useful to think about the complications inter-institutional collaborations face as different regions of the country labor under differently timed

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[27] https://iris.isr.umich.edu/wp-content/uploads/2020/04/IRISresearchspendingfactsheet4-20_final.pdf

outbreaks and as individual universities make independent decisions about shutdowns and reopening.

The final major component of research expenses is the cost of the goods and services (equipment and "other direct costs") necessary to research. Together these two types of expenses represent just about 25% of total research spending for ARE universities. That's where short-term cost savings can be realized given federal guidance that allows salaries to continue being paid. But purchases of goods, services and equipment represent a relatively small fraction of what universities spent to support research work. So what cost savings there are to be had are relatively small in comparison to shortfalls many universities are reporting. More importantly, that spending is a necessary component of research work, and those funds flow out of universities to the businesses and other organizations that make up the research supply chain. When viewed from a more national or even state perspective, economizing on vendor purchases may be a bad idea in the midst of a massive recession and it doesn't free up funds that could be used for other purposes.[28]

Remember that indirect costs are reimbursements for money already spent by research institutions. If they are not sufficient, they leave a funding gap that must be filled from other sources. In the time of COVID-19, as institutional spending is becoming a larger and larger component of the overall research spend, increased costs of instruction, research, and healthcare and decreased revenues from state appropriations, tuition payments, auxiliary enterprises, medical centers, and investments mean that the university research mission as well as the people, organizations, industries and regions that have come to depend on it are in grave jeopardy.

Libraries: An important cost center

Recall that the recombinant view of research that animates my thinking suggests that one of the most important things a university can do is maintain and make accessible to researchers the broadest possible range of existing knowledge. A lot of the work of research happens through interactions with collaborators and skeptics alike, but a huge amount of important knowledge resides in the ever-increasing corpus of research literature. Books, academic articles, archives and databases are key inputs to and often central outputs of research so most campuses maintain a large, and expensive collection of scholarly works in their libraries. Libraries are one of the cost centers that universities maintain to support their teaching and research missions, so it makes sense to do what we can to consider the implications of COVID-19 for their health.

IPEDS routinely reports data on library collections and expenditures, which lets us get a sense of what the dangers are. This information does not include any details of revenue so, let's talk about expenditures. Figure 8 sets the stage, presenting rates of change in total expenditures on libraries and costs specific to maintaining subscriptions, databases and other key parts of their collections. The 896 library branches maintained by US-ARE institutions represent a relatively small (~$6.3 Billion in 2018, the most recent year for which these data are available), but important cost

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[28] Chhabra, Yulia, Margaret Levenstein & Jason Owen-Smith. 2019. "The Local Impact of Science Spending: Evidence from the American Recovery and Reinvestment Act." Working paper, University of Michigan.

relative to the entire US-ARE. And a significant portion of those funds are used to maintain access to scholarly research for faculty, students and other affiliates of the university.

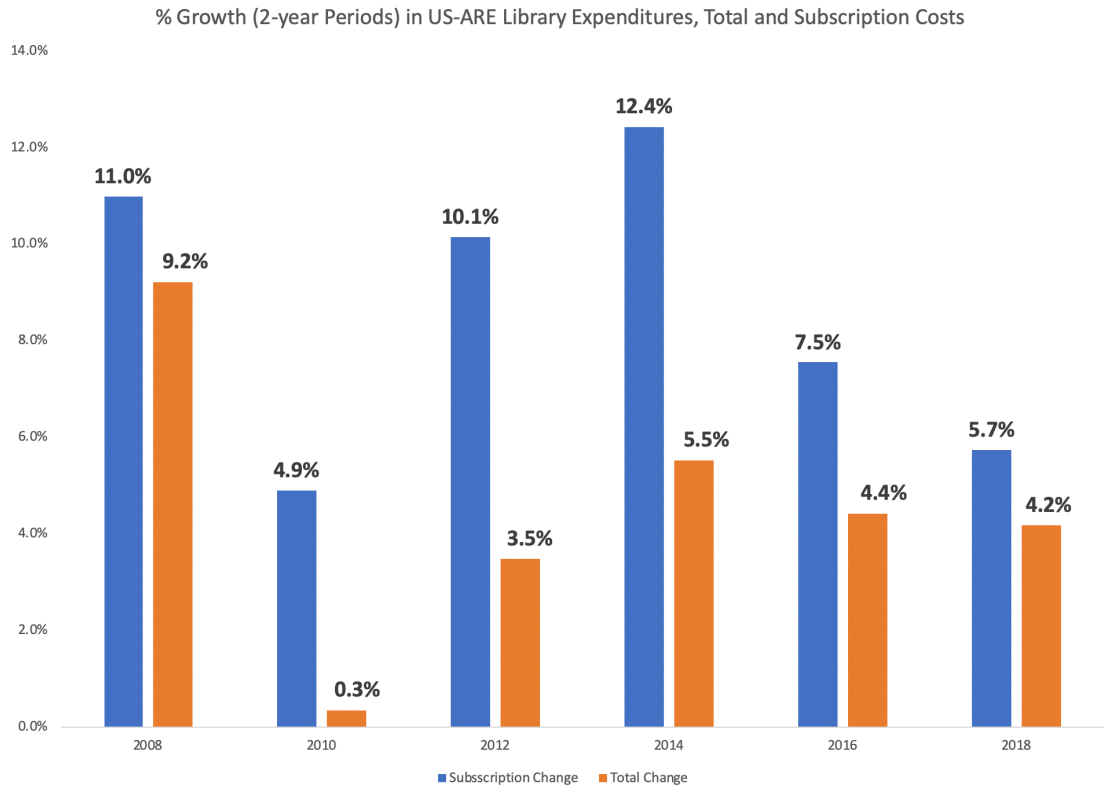
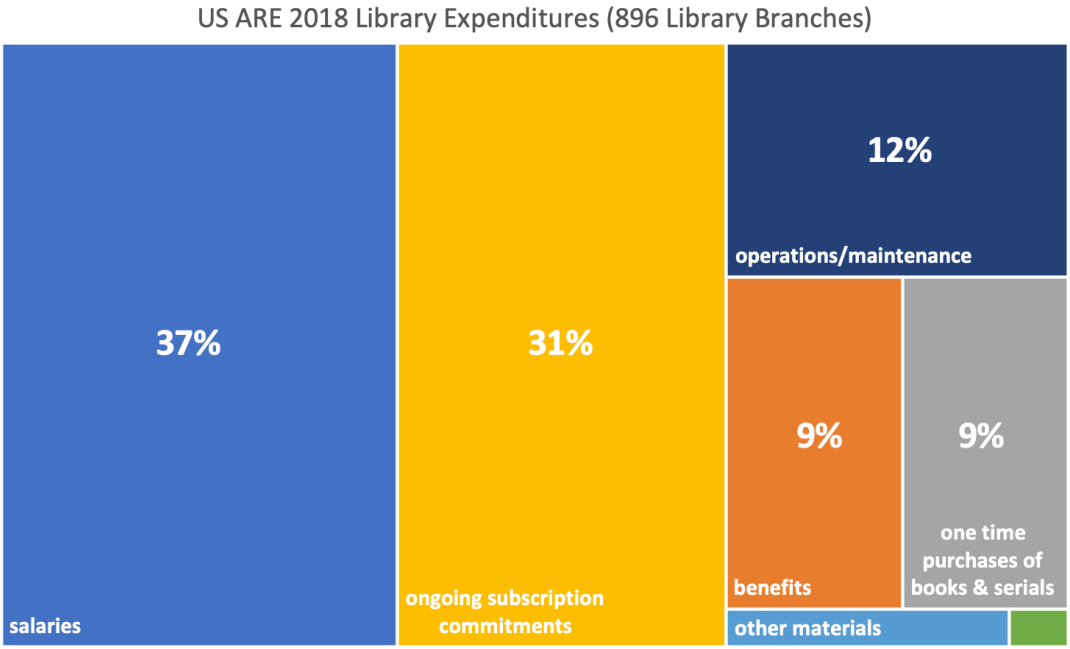


Figure 8 shows us the rate of change (across two-year periods) in total costs and subscription costs. We see that both costs grew every year since 2008. Even in 2010 during the last recession, total library costs (the blue bar) grew by about 5%. During that recessionary year universities did not invest much new money at all in new subscriptions. Across all years the rate of growth of subscription costs was lower than the overall rate. However, the overall growth of libraries slowed in 2016 and again in 2018 while subscription cost growth remained fairly steady. The story here isn't as clear as it was with state appropriations or research trends described above, but two things appear to be clear. During a recent, lesser, recession libraries dramatically slowed their acquisition and maintenance of ongoing subscriptions. In recent years the rates of growth for this cost and overall library spending are getting closer and closer. Maintaining access to a broad range of expensive scholarly materials may take more of a hit as universities look to cut costs during the recession.

Figure 9 helps illustrate why by digging more deeply into the cost structure of US-ARE libraries as it stood in 2018.



We see here that subscription commitments and one-time purchases of books and serials make up about 40% of library expenditures. The lion's share, 46%, goes to salaries and benefits with operational costs representing another 12%. If universities seek to maintain as much of their workforce as possible through the pandemic, deferring maintenance or cutting operational costs seems unlikely to reduce overall amounts significantly. That leaves subscriptions as a place that libraries might make significant cuts, as the 2010 data in Figure 8 suggests they did the last time a major financial shock hit.

The human toll.

What does all this mean? The capsule version is that the revenue and cost structure of research-intensive U.S. universities has been under strain at least since the Great Recession. The pandemic, for the first time in the history of the contemporary US-ARE, simultaneously stresses every source of university revenue while increasing the costs of some of the most important core activities. State governments seem unlikely to be able or to want to make up the gap for public universities. Most institutions (public or private) with endowments are facing shortfalls due to market instability. Federal relief for research could bolster budgets for science agencies and the university research infrastructures their grants help sustain. But those funds are uncertain in a highly polarized political environment during a presidential election year. The largest amount being proposed ($26 billion) is only a fraction of what may be needed and about 60% less than the research stimulus funds made available in the last, arguably less severe recession. Finally, other federal actions - such as limits placed on visas for foreign students, or requirements for in person classes to maintain residency - put even greater pressure on institutions that came to rely more and more on tuition from non-residents as state appropriations declined. The situation is not auspicious.

But the view I present from a financial perspective may be more rosy than the actualities universities and their leaders face. If we shift toward thinking about the people who universities support and train, we add another dimension to the challenges of COVID-19. My brief in here is research and the institutions that anchor the US-ARE. So I'll focus there. Recall that the majority of people whose salaries were paid by grants are students and trainees. Early evidence from a set of 10 university members of IRIS suggests that in early months the pandemic, loss of research jobs fell most heavily on students (who accounted for about 62% of a decline in research jobs on campus in March-May 2020 relative to employment rates in the same period during 2019). It seems clear that students and trainees are particularly at risk of delays and departures due financial challenges associated with COVID-19. That vulnerability seems likely to extend to early career faculty and those who rely significantly on "soft money" from research grants to cover their salaries.

Systematic data are hard to come by, but new research points to another important feature of the pandemic as it pertains to the US-ARE's research workforce. It's obvious, but it's also important to note that the financial pressures universities face come on the back of massive economic, social and political upheaval. This is not simply a financial crisis. Widespread shutdowns that span sectors, unprecedented job loss, and ongoing anti-racist protests, coupled with new health risks mean that even a financially healthy university will face challenges having to do with the human toll the pandemic exerts on its faculty, staff, trainees and students.

While all parts of a research university's budget are coming under strain during the pandemic, some fields and some people face greater challenges due to shutdowns than others. Laboratory work and human subjects research that required face to face interaction ceased almost entirely, while much research work in other fields was easier to continue remotely [29]. Field research and clinical trials also suffered.[30] Lost time, missed participant targets, and interruptions to time sensitive research designs endanger human subjects research across social, behavioral, and biomedical fields. Likewise, laboratory research that relies on animal models faces its own set of costs and challenges due to the need to manage research animal colonies during shutdown and re-opening. A recent report by the US Congressional Research service offers a thoughtful discussion of these trends.[31] Likewise a compelling white paper released by the Council on Government Relations (COGR) presents estimates of research impacts based on an economic model along with a series of five case studies that suggest US institutions face a 20-40% decline in research productivity, hundreds of millions of dollars in revenue loss and additional costs on each campus. In describing a new "pandemic normal" the paper's authors conclude:

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[29] https://www.nature.com/articles/s41562-020-0921-y

[30] https://www.sciencemag.org/news/2020/07/clinical-trials-rebound-after-covid-19-crash-can-enrollment-gains-continue; https://science.osti.gov/-/media/hep/hepap/pdf/202007/07-Hildreth*Narain-Community*Gathered*COVID-19*Impacts*for*HEP.pdf?la=en&hash=F6FE69EFB66A99207380F4286B3AB94185CEAB8A; https://www.aip.org/sites/default/files/aipcorp/files/peril-and-promise-final.pdf

[31] https://crsreports.congress.gov/product/pdf/R/R46309

Until a vaccine is widely available, research universities and other research performers are facing an existential threat. Not only are research finances tenuous, the uncertainty of tuition status, students returning to campus, and safely operating the institution are real threats. Further, immigration issues hover over our research workforce development, which jeopardizes the top minds from the around the world coming to the United States and contributing their diversity and expertise to the United States research enterprise.[32]

Regardless of their fields, emerging evidence success the pandemic's professional and scientific repercussions fall harder on some groups than others. People at career stages that include significant time limitations (students, post-docs, and junior faculty, for instance) are at greater professional risk as the pandemic drags on than are more established, tenured faculty. Those faculty and staff who depend on soft money for their salaries (a demographic that has been growing, especially in biomedicine)[33] but whose work has been delayed or sidelined may also face more serious challenges. Even though universities have begun re-opening their on campus and human subjects research, careful attention to safety through density limitations, health screening, and other measures mean that even the most successful campuses may remain at less than their full research capacity for a long time in many fields. [34] Future slow or shutdowns may remain a significant possibility as campuses face additional outbreaks due to the start of residential, at least partially in person, semesters. As summer turns to fall, an expected surge in COVID-19 cases may also result in further delays and closures. The uncertainties and interruptions raise the possibility of a "lost generation" of trained researchers across "science, engineering, social and behavioral sciences, education and the arts."[35]

Beyond concerns based on field and career stage, larger social and political dynamics surrounding the pandemic suggest the possibility of widely varied effects across groups of researchers. Recently published survey results suggest that in addition to those working in "bench science," women researchers and those with young children are facing particular challenges due to school closures, lack of childcare.[36] All of these groups report substantial declines in the ability to work on their research in the early months of the pandemic.

Other research is more mixed. Early reports from NIH uncovered no persistent gender gap in new grant applications.[37] However, as the pandemic continues, remote public school, uncertain reopening and lack of access to childcare may have more lasting effects on female scientists. Indeed, several recent studies have demonstrated gender inequities in publication and authorship

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[32] https://www.cogr.edu/sites/default/files/Research*COVID*August2020*COGR*FINAL.pdf. P. 17

[33] Stephan, Paula. *How Economics Shapes Science*. Cambridge, MA: Harvard University Press.

[34] Op cit. 34.

[35] https://science.sciencemag.org/content/368/6496/1190.summary

[36] https://science.sciencemag.org/content/369/6504/609

[37] https://nexus.od.nih.gov/all/2020/07/28/an-early-look-at-applications-submitted-during-the-pandemic/

that offer support to survey findings about lost work time and productivity.[38] New immigration and travel restrictions place additional burdens on foreign born researchers as well.[39] While research has been slower to address the effects of the pandemic on the productivity and careers of under-represented minority (URM) researchers, working scientists in several fields have sounded the alarm that the unique challenges faced by underrepresented groups during the pandemic seem likely to exacerbate already existing disparities across gender, race, ethnicity and nationality.[40] One result of COVID-19 interruptions and the possibility of a lengthy and uncertain period of "pandemic normal" in the US-ARE, could be the "gutting" of hard won but still far from complete gains in diversity.[41]

Possible paths from the pandemic.

Systemic budgetary challenges, the possibility of a protracted period of uncertainty, and already apparent professional effects on important swathes of the US academic research workforce paint a gloomy picture for the US-ARE. The prospects are bleaker if significant federal research relief fails to materialize and if the pandemic remains poorly controlled or gets worse through the winter, putting another semester at risk. But how might all these various pressures play out and what might be done to mitigate the damage?

Even the small section of the global and US research and higher education systems I attend to here is complex and defies easy prediction, but the trends and conditions I have documented suggest some possible paths the US-ARE might follow. At this point, the implications of different trajectories are beyond our empirical reach, so we must turn back to the broader framework for understanding the workings and the public value of U.S. research universities.

I have argued that a large part of the continuing, long-term value of the academic research enterprise derives from research universities' unique ability to identify, and respond to unexpected problems and unforeseen opportunities. US-ARE institutions can play this role individually, but the capabilities the whole system they make up are what can realize the promise of a knowledge infrastructure.

The choices policy makers and university leaders make during the pandemic and a potentially lengthy recovery matter. But the ways in which seemingly isolated decisions might ramify

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[38] https://gh.bmj.com/content/5/7/e002922; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7304994/; https://www.nature.com/articles/d41586-020-02183-x; https://www.insidehighered.com/news/2020/08/20/womens-journal-submission-rates-continue-fall

[39] https://www.aip.org/sites/default/files/aipcorp/files/peril-and-promise-final.pdf

[40] https://www.nature.com/articles/s41559-020-1233-3; https://www.nap.edu/download/25585; https://penntoday.upenn.edu/news/rooting-out-systemic-bias-neuroscience-publishing

[41] https://www.nature.com/articles/d41586-020-02288-3

through the system as a whole are less clear. My work on U.S. research universities leads me to believe that decisions about how to approach the research enterprise during the pandemic and after will have lasting effects to the extent that choices made now stand to alter the characteristics of individual campuses and the ARE system in more sustained ways.

I see several broad directions this could go. They are not exhaustive, nor are they likely to happen in isolation. Rather the "perfect storm" of challenges that ARE universities face suggests that multiple overlapping and potentially mutually reinforcing consequences may result from even well-intentioned moves.

Important characteristics of the US-ARE

A large part of what makes both individual research universities and the US-ARE system effective and consistent producers of new knowledge and skilled people, sources, has to do with the range of missions, constituencies, and fields of research they maintain. The ability to manage internal tensions that emerge when missions, fields and interests collide is aided because: (1) multiple revenue streams including often countercyclical sources of funds typically insulate universities from immediate fiscal pressures while (2) stable public investments enable universities to operate in a fashion that keeps competition among its components from becoming destructive. Finally, (3) a large diversely-organized system of publicly subsidized universities ensures that (a) campuses will be differently positioned in local, national, and global networks enabling them to individually and collectively serve as hubs to identify problems and opportunities that emerge outside their boundaries; (b) stable, sufficient public support, resulting commitments to public service, and deep connections to place help make certain that they can act as long term endowments of skills, knowledge and capabilities for the nation and the world while serving as scaffolds for the development of regional communities and industries; and (c) that the networks and institutional supports they develop with varied portfolios of external and internal funding and partnerships make them a consistent source for recombinant discovery and high skill training.

The holistic financial pressures that result from the pandemic strike a time when a decade of declines in public support for universities and growing public distrust of academe had already stretched these institutions thin. In this context, an academic and scientific system that (at least for this particular set of institutions) has been driven by competition for resources, visibility, and priority both within individual institutions and across the nation and the globe may become destructive. Think about how the financial pressures we discussed above might play out in terms of internal competition. Most U.S. universities operate on some form of decentralized budget model. The most common variant of that model is what is been called responsibility centered management (RCM).

This is not the place for a detailed description but the basic, generic idea is that this is a budget model that allows different parts of the university to pursue distinct and potentially conflicting missions by seating much financial responsibility at the level of units (such as colleges) within the institution. That kind of decentralized model works fairly well when times are good by insuring that parts of the institution can go their own way while allowing a central administration to set general strategic directions, invest in campus wide capabilities and use returns from one part of the institution (for instance a fraction of net tuition payments) to subsidize the work of units that are important but may not be able to generate sufficient revenue on their own. The

clearest examples of this might be when departments (such as those that teach many important foreign languages) with relatively low enrollments are subsidized by universities who decide that, for instance, maintaining teaching and research in a wide range of languages is essential to their larger mission. A similar thing happens with research activities where, for instance, use of external grant money (in the form of indirect costs) to sustain core facilities makes it easier for others on campus to also access the tools for their own research.

This kind of decentralized approach generally includes mechanisms to subsidize mission critical but not necessarily revenue generating areas (ranging from cost-centers like libraries to smaller fields and more esoteric research areas). But the balance of the whole depends on the premise that all the different sources of revenue don't take a hit at once. When they do, as they are now, the elasticity of the financial "balloon" is reduced and competition among different university goals, approaches, and units becomes more zero sum. These conditions are exacerbated by uncertainty and may be felt first in greater difficulties with standing up and supporting initiatives (whether research or educational) that span multiple areas. Interdisciplinary research and teaching in areas (such as entrepreneurship or design) that often span multiple schools are in danger.

Something similar happens at the level of the system as a whole. Here too there is decentralization at work. Individual universities make choices about how much of their institutional resources to invest in particular activities. While these universities averaged about 26% institutional spending the actual range reported in NSF data runs from 1% at Wake Forrest University (a private institution in North Carolina) to 69% at the State University of New York's Binghampton campus. They collaborate with each other in ways large and small. The subcontract portion of university research expenses offers one way to think about that. Relatively stable patterns of faculty hiring in many fields create another set of connections while also representing a consistent pattern of stratification and inequality that also characterizes the system [42] . As the intellectual and resource requirements of modern research have gotten more complex, research teams have grown in all fields and multi-institutional collaborations have become both common and important.[43] According to the U.S. National Science Board's 2020 *Science and Engineering Indicators*, U.S. researchers authored or co-authored 548,848 articles in 2018. Fully 76% of those articles had authors from multiple institutions. About 60% of those articles reported work by teams that spanned multiple US institutions.[44] In other words, US-ARE

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[42] https://advances.sciencemag.org/content/1/1/e1400005

[43] Jones, Benjamin F. 2009. "The Burden of Knowledge and the "Death of the Renaissance Man:" Is Innovation Getting Harder? " *The Review of Economic Studies*. 76(1):283-317. Wuchty, S. Et al. 2008. "The Increasing Dominance of teams in the Production of Knowledge." *Science*. 316:1036-1039. Leahey, Erin. 2016. "From Sole Investigator to Team Scientist: Trends in the Practice and Study of Research Collaboration." *Annual Review of Sociology.* 42:81-100.

[44] https://ncses.nsf.gov/pubs/nsb20206/data#supplemental-tables, Table S5a.32. I'll return to a more detailed discussion of international collaborations in a later section.

universities depend on one another in many ways, but centralized planning across the national research enterprise is nearly non-existent.

Like the different fields and units that make up a university, the different institutions that make up the ARE system also compete vigorously for funds, for students and faculty, and for scientific visibility and priority. The rivalries and competition can be intense, but are usually not damaging. This is common in highly networked, knowledge-intensive sectors where a rival on one project or topic can be a collaborator on another so there's a strong incentive toward non-destructive competition.[45] In the sciences and engineering a huge area for competition is in the pursuit of research funding. As an example, think about the U.S. federal funding system. The majority of US-ARE institutions' research spending is drawn from federal sources, but the plural is important there. The U.S. does not have a single centralized funding agency or plan. Instead it has many federal science agencies with different missions, different budgets and different review and evaluation processes. This means the system itself supports decentralization and offers many different routes for universities and their investigators to compete for the grant support they need. However, this means that decisions made by different congressional appropriators and the leadership of different funding agencies could have outsized effects on competitive dynamics of the US-ARE. As is the case with faculty hiring, however, the US research funding system is characterized (even within the large, research intensive, universities that make up the ARE) by a relatively stable hierarchy, that also helps to structure competition.

Path 1: Destructive Competition and Concentration

Like many things in the world of research, funding is highly skewed, with a small number of institutions receiving a relatively large percentage of federal funds. The US-ARE universities themselves represent less than 3% of US higher education institutions, but they do 90% of funded academic R&D. Within this group, there is still a high degree of stratification. The average ARE university spent $472 million on research in 2018. But there were fifteen universities that spent more than $1 billion. Those institutions (10% of ARE institutions and 0.2% of all higher education institutions) conducted 27% of all funded academic R&D. On most campuses the same is true of organizational units and fields of research, with the biosciences and engineering generally accounting for the lion's share.

One possible outcome of an extended pandemic period is that the fiscal pressures I describe will lead university leaders, state and federal policy makers to make decisions that have the effect of increasing the intensity and destructiveness of competition among fields and units within institutions and among institutions within the larger system. This seems particularly likely to happen if federal policy makers choose, perhaps quite reasonably, to concentrate any new research funding or funding relief further in areas of biomedical science that are especially relevant to today's pandemic crisis. At the university level it could occur if fiscal pressures remove flexibility from the university budget model and university leaders focus the institutional

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[45] Powell, Walter W., Kenneth W. Koput & Laurel Smith-Doerr. 1996. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology." *Administrative Science Quarterly.* 41:116-145.

research funds they do have on supporting units and fields capable of generating significant external research revenue.

Increased, more zero-sum competition is likely to have several pernicious effects. At the system level it is likely to result in greater concentration as universities with more substantial and established infrastructure in relevant fields receive the lion's share of new funding. Greater concentration in turn will likely reduce the diversity of networks and approaches in the system as a whole, especially as universities that rely heavily on institutional research funding and that might be less well equipped to pivot toward large scale infectious disease and emerging pathogens work fall behind in access to federal funding.

At the university level, leadership decisions about how to allocate limited institutional support for research and a general lack of flexibility across the budget may result in disinvestment in smaller, less immediately pandemic-relevant, or revenue intense research fields or in smaller, less revenue generating teaching areas. The former may be a particular danger if academic leaders perceive federal research funds as a stable or growing source of funding and direct their discretionary funds to support research fields and units that seem positioned to benefit from federal investments in research to address the pandemic.

Path 2: Homogenization and Narrowing Capabilities

The second path is a corollary to the first. Destructive competition and increased concentration are likely to result in more homogenous, decoupled and thus narrower research universities. That trend would also render the ARE system as a whole less likely to be able to identify and address unexpected or emergent problems and opportunities.

By homogenization, I mean three things. First, disinvestment in fields that are less immediately relevant to today's problems, or that represent knowledge and teaching capacity essential to the university mission but less likely to generate significant revenue, would result in universities that maintain and expand a narrower slice of human knowledge. Second, the combination of shifts in support for some fields, and the larger social, economic, and political pressures of the pandemic may lead to a dramatic loss of demographic diversity in the U.S. academy. Women, under-represented minority, and early career scholars face particular challenges and may require additional support to sustain and advance their careers. US funders and institutions seek to expand the diversity of academe for many good reasons. The most pragmatic are simply based on the idea that talent is evenly distributed across the entire population and that limiting access to large swathes of the population thus damages the overall capabilities of universities. I also believe higher education has a moral obligation to support the greatest possible development of human capacities. Third, at the level of the system as a whole, both forms of homogenization could narrow the range of paths that people can take into academic research, exacerbating both of the first two forms of homogenization.

Path 3: Increased isolation and instability

Across the ARE, decreasing diversity in the mix of fields, the reach of collaboration networks, and the range of connections to external partners and communities will make the whole less able to serve as a form of social insurance. It may also limit possibilities for the international and

inter-institutional collaborations that are an increasingly important part of contemporary academic research.[46]

To the extent that women, URM and younger, less established scholars bring to the academy different network connections, personal histories, community ties, and interests homogenization of the academic research workforce will further narrow the knowledge capabilities of universities and potentially make them less able to work effectively as scaffolds and hubs, reducing both their ability to identify and to respond to unexpected problems and solutions.

Even relatively short-term concentration and homogenization of research and teaching capabilities or declining diversity in the academic research workforce could thus have significant and lasting consequences to the extent that the ARE might lose important people, capabilities, and connections. One possible result would be increasing isolation of key academic research capabilities from large economic sectors and varied communities.

The same dynamics, coupled with the last ten years of state disinvestment, and stagnant federal research funding, also have the potential to render individual universities and the system as a whole less stable. Greater reliance on a smaller range of funding sources and more limited public investments could result in a boom and bust cycle as societal need and leaders' priorities change. To the extent that such dynamics have the effect of tying larger parts of the university to the business cycle, we might expect universities to lose both their documented ability to pursue research and teaching that lies outside the ambit of businesses and for-profit colleges, and to face even greater difficulties when the next recession or pandemic arises. As a result, the multiple competing missions, longer term vision and public service orientation of these important institutions are at risk.

An Overarching Tension

The paths I have sketched seem plausible to me given what we know about academic finances, research and the recent history of challenging times for U.S. universities. They are not exhaustive, nor might they be all bad. Increased competition and growing concentration at the system level, for instance, might open greater possibilities for institutional mobility in highly stratified US-ARE. Likewise, a tighter band of investments in a small number of fields, existing knowledge infrastructure and established investigators with proven track records makes a lot of sense in the midst of a pandemic when the overarching goal is to solve todays problem's as quickly and effectively as possible.

All three paths result from a larger tension that cannot be resolved empirically. In the world of research, the tension can be conceptualized in terms of focus and flexibility. Focusing resources and attention in a fashion designed to help us solve known problems of widely recognized importance, such as this pandemic, represents one effective policy choice. Maintaining the flexibility and range of individual universities and the diversity of the system as a whole represents an alternative choice that emphasizes the ARE's unique capability to serve as a societal investment in the ability to address our highly uncertain future.

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[46] I return to a discussion of International collaborations in a later section.

I happen to be partisan of flexibility, stability, and diversity in the academic knowledge enterprise. But I certainly recognize the value of focus. The larger point is that leaders and policy-makers are reaching decisions now under extreme pressure and in the face of dramatic uncertainty. Those decisions can, through mechanisms like those outlined above, have substantial, long term consequences for the US-ARE and with it for the global research and higher education enterprises. What's important, then, is recognizing that this is a strategic choice being faced at multiple levels of decision-making and to decide accordingly. We want to avoid emerging from the pandemic having undermined long term capabilities we value in order to address admittedly critical and challenging but hopefully shorter-term needs.

We are only months into what seems increasingly likely to be a sustained crisis (at least in the US). Many important decisions have been made or are being considered right now. It makes sense, then, to do what we can to glean empirical hints as to what has actually happened in the US-ARE over the early months of the pandemic. This is a challenging thing to do and I am under no illusions that truly systematic analysis of a system as complex as this is possible in the short term. One major challenge is simply a lack of good, broadly accessible, data. In my role as director of IRIS I am working to help remedy that for the US-ARE. For now, though, the best that I can do is try to distill some signal from current data that might offer a few leading indicators of where things are going.

Leading Indicators

The key challenges COVID-19 poses to the research (and other) capabilities of the US-ARE and component institutions are both fiscal and socio-political. Regardless of the state of university budgets, large swaths of the U.S. economy are shut down, with predictable and increasingly apparent consequences not just for academics but for everyone. The pandemic's full fiscal effects are unknowable right now. But some recent data may provide a bit more insight into what is to come. I focus closely on two "leading indicators," new federal funding for COVID-19 related research from NSF and NIH. I draw up to date (through the end of July, 2020) data from the NSF's Fastlane system and the NIH Exporter.[47]

These datasets are interesting for the purposes of identifying early empirical evidence of concentration and homogenization. First, they are recent and represent the effects of new research priorities and of initial federal appropriations for pandemic research. Second, the funding data offer a view of US research across biomedicine from NIH and of a wider range of disciplines ranging from education, social and behavioral sciences to engineering, physical and geological science from NSF. Third, most research universities in the U.S. appear to have exempted research that is directly relevant to COVID-19 from shutdowns and spending freezes. Thus, patterns we see here offer some insight into the effects broader pandemic-related upheavals have on the academic research workforce. Finally, as was the case during the Great Recession, the NSF and the NIH pursued different strategies for allocating specially appropriated funds. One, NIH, which made COVID-19 grants for a much larger amount of overall funds,

[47] https://www.fastlane.nsf.gov/jsp/homepage/awards_funds.jsp, https://exporter.nih.gov/

pursued something like the "focus" strategy I describe above. The other, NSF, opted for a strategy that more closely reflects the "flexibility" model.

COVID-19 Research funding from NIH and NSF

The U.S. Congress has thus far appropriated new funds for COVID-19 related research in three different bills.[48] Those appropriations directed about $3.6 billion to NIH. The NSF received about $75 million.[49] NIH is made up of 27 different institutes (ICs), which each focus on different disease or bodily system. Congress can direct appropriations to particular ICs, which means we can glean a sense of the strategy federal policy makers are pursuing with these funds. Within NIH $1.53 billion went to the National Institute for Allergy and Infectious Diseases (NIAID) for basic research, drugs and vaccines. Another $1.59 billion was earmarked for rapid testing and administered by the Office of the Director (O/D) and the National Institute of Biomedical Engineering and Bioengineering (NIBIB). $306 million went to the National Cancer Institute (NCI) for serological testing, and $103 million went to the National Heart Lung and Blood Institute (NHLBI) for therapeutics and longitudinal studies.[50] Clearly, federal policy makers are following something akin to the "focus" strategy for the bulk of funds appropriated to these two agencies. Because appropriations are made to the NSF as a whole and then apportioned to directorates with different scientific foci, the federal strategy is not as easily discernible for those funds. However, an analysis of the early COVID-19 grants made by these two agencies suggests that the agencies themselves took very different tacks with different implications. In order to provide a baseline against which to understand how COVID-19 awards are playing out, I compare them to all new awards made by these agencies in the prior year (2019).

Funding Strategies and Concentration at NIH and NSF

Public data allowed me to identify $736.1 million of NIH COVID-19 awards. The vast majority of those funds (94.2%) were from the three bills described above. I also identified a "baseline," comparison group comprised of all new NIH awards made through standard grant mechanisms in 2019, which totaled $6.9 billion.

COVID funds were allocated via 427 grants to 160 U.S. research organizations. Baseline funds were dispersed through 14,930 grants to investigators at 1721 research organizations. COVID-19

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[48] The three are: (1) the Coronavirus Preparedness and Response Supplemental Appropriation Act (enacted 03/04/2020); (2) the Coronavirus Aid, Relief, and Economic Security (CARES) Act (enacted 03/27/2020); and (3) Paycheck Protection Program and Health Care Enhancement Act (enacted 04/24/2020).

[49] https://www.sciencemag.org/news/2020/06/nih-grapples-researchers-rush-claim-billions-pandemic-research-funds

[50] Some caveats are necessary. These funds represent a snapshot at one point in time, early in the pandemic. They represent only about 20% of the COVID-19 funds appropriated to NSF. As we shall see, the COVID-19 funds tracked in this sample do not include substantial funding from the NIH Office of the Director or the National Cancer Institute. As a result the patterns I identify here may well change and should be taken with some care.

grants were larger (average = $1.7 million) than baseline awards (average = $464,000). Already we see some early evidence of concentration of funds in a smaller number of grants and institutions. There's also evidence that NIH's COVID-19 grant strategy differs significantly from its routine practices as evidenced by the baseline grants.

Evidence about NIH Funding Strategies

Before we get to some possible consequences, let's think about what these data tell us about the NIH's strategies. There are three dimensions we can use to gain some insight. These data include information about the "activity" a given grant represents, the "award mechanism" used, and the IC that administers the grants. The activity data allows us to distinguish between new awards and what the NIH calls supplements, which are expansions of funding for existing awards. Award mechanisms identify different types of grants, for instance the "R01" award is the NIH's flagship research project grant. R01s can be contrasted with larger, more complex awards administered through "U" series cooperative agreements or "P" series program project grants. Because of the way the NIH is organized, the IC that administers the grant offers a very high-level indication grants' topics.

Table 1 presents a slice of summary data that compares baseline and COVID-19 grants in terms of activities and mechanisms.

NIH Funding by Mechanism and Activity, % of funding (dollars)				
	Baseline Grants		**C-19 Grants**	
	$ Amount	% Total	$ Amount	% Total
Activity				
New Award	$ 6,856,189,805	99.0%	$ 25,452,243	3.5%
Supplement to Existing Award	$ 63,422,433	0.9%	$ 709,778,523	96.4%
Mechanism				
"R01"	$ 2,494,184,067	36.0%	$ 49,517,710	6.7%
"U" series cooperative agreement	$ 1,294,679,028	18.7%	$ 2,494,184,151	72.5%
Total # of Mechanisms	84		25	

The difference is stark. Where standard practice at NIH hugely favors new applications and awards (99% of total $), COVID-19 awards were disbursed overwhelmingly as supplements (96% of total $). Mechanisms are more complicated, because there are a lot of them. Here I simply present information on the two most common from each set of grants. More than 1/3 of baseline grants (36%) went to R01, investigator initiated research projects, the NIH's flagship grant. About 73% of COVID-19 awards were allocated through "U" series cooperative agreements.

What does this tell us? NIH's baseline practice favors more or less open competition among new applications and award mechanisms targeted to focused research projects. In contrast, COVID-19 awards emphasize larger grants (about 3.7 times larger on average) made as extensions to some of the largest and most complex types of existing awards. In other words, NIH's COVID-19 grant strategy appears to be an exemplar of the focused approach I describe above. Or, at least, the route to get significant COVID-19 funding from NIH thus far has been to be an established investigator with a very large-scale grant for which you pursue a supplement.

Looking at the distribution of funding across ICs offers further, though still somewhat ambiguous hints. Table 2 compares baseline and COVID-19 grants by the specific institute that administers them. I present information for all IC's that made at least one COVID-19 grant. Ten institutes did not, which by itself indicates a higher degree of concentration by field that is driven largely by the decisions of federal appropriators. The outcome of this is that ICs concentrated in areas that may be relevant or even important to the pandemic might have made few, or even no COVID-19 grants thus far. Consider the National Institute of Mental Health (NIMH), which surely focuses on illnesses of importance during the pandemic.[51] NIMH awarded about 6.5% of baseline dollars, a total of about $445 million, but is so far absent from COVID-19 funding. Likewise, absent from COVID-19 funding to date are the National Institute of Child Health and Development (NICHD) and the National Institute of Minority Health and Health Disparities (NIMHD).

	C19			Baseline	
IC	dol	% tot		$	%tot
National Institute of Allergy and Infectious Diseases (NIAID)	$ 389,355,867.00	53%		$ 644,956,060.00	9%
National Heart Lung and Blood Institute (NHLBI)	$ 236,432,100.00	32%		$ 642,297,302.00	9%
National Institute of Biomedical Imaging and Bioengineering (NIBIB)	$ 52,689,493.00	7%		$ 122,289,269.00	2%
National Center for Advancing Translational Sciences (NCATS)	$ 18,553,903.00	3%		$ 92,631,639.00	1%
National Institute of Drug Abuse (NIDA)	$ 8,226,190.00	1%		$ 521,304,313.00	8%
National Institute of Aging (NIA)	$ 8,159,397.00	1%		$ 923,555,816.00	13%
National Institute of General Medical Sciences (NIGMS)	$ 5,912,044.00	1%		$ 480,889,185.00	7%
National Cancer Institute (NCI)	$ 5,283,739.00	1%		$ 684,022,970.00	10%
Office of the Director (OD)	$ 3,485,277.00	0%		$ 227,981,586.00	3%
National Institute of Deafness and other Communication Disorders (NIDCD)	$ 2,540,055.00	0%		$ 62,636,076.00	1%
National Institue of Environmental Health Sciences (NIEHS)	$ 1,785,183.00	0%		$ 68,942,767.00	1%
National Institute of Dental and Craniofacial Research (NIDCR)	$ 1,481,043.00	0%		$ 87,251,651.00	1%
National Institute of Neuroligical Disorders nd Stroke (NINDS)	$ 1,360,669.00	0%		$ 601,807,758.00	9%
National Library of Medicine (NLM)	$ 362,792.00	0%		$ 16,723,872.00	0%
National Human Genome Research Institute (NHRI)	$ 168,829.00	0%		$ 55,807,620.00	1%
National Institute of Nursing Research (NINR)	$ 161,500.00	0%		$ 27,628,516.00	0%
National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)	$ 133,505.00	0%		$ 321,211,089.00	5%
Totals	$ 736,091,586.00			$ 6,925,175,789.00	

I take a twofold message from Table 2. First, due to federal policy maker's priorities in appropriating new COVID-19 research funds, NIH Grants for COVID-19 are, at least thus far, much more highly concentrated than is the typical for the baseline pattern of funding. NIAID and NHLBI account for 18% of baseline funding but fully 85% of COVID-19 funding. Second, this table suggests not just increased concentration in a few funding areas, but also often sizable shifts away from the typical distribution of NIH funds across institutes. For instance, the NIA, which administers the largest share (13%) of baseline funds has made only about 1% of COVID-19 related grants.

The picture of NIH COVID-19 funding strategy that emerges here is very skewed toward a focused approach that emphasizes directed efforts targeted at established infrastructures, investigators and teams. Federal policy makers shaped that strategy through the power of the purse by appropriating funds to particular areas of research. NIH administrators made choices that further focused biomedical COVID-19 research efforts by seriously emphasizing supplements to existing, generally larger and more complex, award mechanisms rather than new applications. The result of these two intersecting choices is that the route to substantial COVID-19 support from the National Institutes of Health is to have an established, large scale grant from

[51] https://www.nejm.org/doi/full/10.1056/NEJMp2008017

one of just three ICs and to pursue a supplement to pivot some of the work of that existing grant toward today's virus.

Concentration in NIH COVID-19 Funding

I suggested that a focused strategy can be an effective way to achieve targeted goals but also has the potential to create less positive unintended consequences. These preliminary data allow us to get a sense of how baseline and COVID-19 funding from NIH compare on two dimensions of interest. While the high-level view presented above includes some suggestion of concentration in a few general areas for COVID-19 funding, Data about the universities, PI teams and individual investigators receiving the funds can also offer some interesting insights.

Let's start with the universities that received COVID-19 funds and think about what they can tell us about possible effects of this strategy on concentration in the US-ARE. Table 3 presents some basic information about concentration in COVID-19 and baseline NIH funding.

Concentration NIH Funding Amount		
	Baseline $ (N=1762)	c19 $ (N=160)
Total	$ 6,925,175,789	$ 736,091,586
Top 12	23.3%	76.1%
Top 25	38.1%	87.0%
Top 50	55.0%	94.2%
Top 100	72.5%	98.6%
Top 150	81.6%	99.9%

This offers a very simple, but telling view. It can't be determinative, because, of course, there are huge differences in the scale (both in terms of dollars and the number of institutions receiving grants) across the baseline and COVID-19 cases. With those caveats in place, though, we can see that both are highly skewed. But the fact that, for instance, just 12 institutions received 23% of baseline funding while 12 institutions received 76% of COVID-19 funding only offers some degree of support for this idea. That set of institutions represents less than 1% of those who received baseline funding but about 7.5% of those receiving COVID-19 funds, so this is not really an apples to apples comparison. An alternative is to calculate the Herfindahl-Hirschman Index (HHI), a common measure of market concentration. As I calculate it this measure would equal 1 if all NIH funds went to a single institution and 0 if the NIH more or less equally funded a large number of organizations. For baseline funding HHI is 0.008. It is an order of magnitude higher for COVID-19 funding at 0.083. That's not a huge degree of concentration but on a standard measure it's much higher than is typically the case for NIH funds.

It's also useful to look at the institutions that received the most COVID-19 funding. Concentration represents a type of inequality (less than 8% of institutions received 76% of pandemic research funds), but changes such as those I've been describing can also create opportunities for mobility. If concentration increases overall but different sets of universities dominate, then this might reflect a change that increases the overall diversity of the system.

Table 4 reports information on the top 25 universities by COVID-19 NIH dollars.[52]

NIH Org	University?	awd cnt	awd $	Covid Rank	Baseline rank	base-c19
UNIV OF MASSACHUSETTS MED SCH WORCESTER	1	4	$ 112,626,009	2	55	53
UNIVERSITY OF CALIFORNIA LOS ANGELES	1	12	$ 94,463,072	3	14	11
EMORY UNIVERSITY	1	14	$ 60,078,819	4	15	11
VANDERBILT UNIVERSITY MEDICAL CENTER	1	10	$ 13,676,194	8	25	17
SAINT LOUIS UNIVERSITY	1	2	$ 12,782,217	9	188	179
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO	1	13	$ 11,064,411	10	4	-6
ICAHN SCHOOL OF MEDICINE AT MOUNT SINAI	1	11	$ 8,848,143	12	19	7
BAYLOR COLLEGE OF MEDICINE	1	3	$ 8,129,529	14	32	18
JOHNS HOPKINS UNIVERSITY	1	16	$ 8,077,532	15	2	-13
STANFORD UNIVERSITY	1	8	$ 7,382,840	16	10	-6
UNIVERSITY OF MARYLAND BALTIMORE	1	5	$ 6,994,205	17	47	30
NORTHWESTERN UNIVERSITY	1	2	$ 6,904,853	18	81	63
ALBERT EINSTEIN COLLEGE OF MEDICINE	1	2	$ 5,328,577	20	58	38
UNIVERSITY OF MINNESOTA	1	3	$ 5,212,901	21	18	-3
NEW YORK UNIVERSITY SCHOOL OF MEDICINE	1	9	$ 4,637,986	23	29	6
YALE UNIVERSITY	1	8	$ 4,217,139	24	6	-18
UNIVERSITY OF PITTSBURGH AT PITTSBURGH	1	8	$ 3,441,592	26	5	-21
WASHINGTON UNIVERSITY	1	6	$ 3,072,453	27	12	-15
UNIVERSITY OF CALIFORNIA, SAN DIEGO	1	8	$ 3,023,487	28	13	-15
ROCKEFELLER UNIVERSITY	1	5	$ 2,850,321	29	87	58
NORTHWESTERN UNIVERSITY AT CHICAGO	1	7	$ 2,572,615	30	21	-9
OREGON HEALTH & SCIENCE UNIVERSITY	1	6	$ 2,534,744	31	26	-5
WEILL MEDICAL COLL OF CORNELL UNIV	1	5	$ 2,352,167	32	40	8
UNIVERSITY OF TEXAS MED BR GALVESTON	1	7	$ 2,285,553	33	97	64
UNIVERSITY OF WISCONSIN-MADISON	1	7	$ 2,265,928	35	23	-12
Top 25 Univs total		181	$ 394,823,287			

While the raw dollar amounts and award counts are interesting, the remaining three columns are particularly useful for our purposes as they provide an indication of upward or downward mobility. Column five lists the numeric rank of each institution in terms of amounts of new pandemic research funding. The next column, "baseline rank" presents the same information for baseline NIH funding. The University of Massachusetts Medical School at Worcester, for instance, was the number 2 recipient of COVID-19 funds but was ranked 55th for baseline funding. This represents a case of mobility. Something about the existing scientific capabilities, people, infrastructure and grants at this institution positioned them to receive $112.6 million for COVID-19 work. The last column of the table captures such movements by the simple expedient of subtracting an institutions' COVID-19 rank from their baseline rank. If that number is positive (as it is in the dramatic case of St. Louis University) it represents upward mobility. If it is negative (as is the case for the University of Pittsburgh) it reflects downward mobility. If, in a hypothetical world, funding got more concentrated but the same set of universities dominated both tranches of funding, this column would be full of zeros and small number changes.

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[52] While NIH awards grants to many different types of institutions, most notably teaching hospitals and independent research institutes, I focus only on university recipients here. As you can see from "COVID-19 Rank" column in Table 4, there are numerous non-universities in the overall top 25. The #1, and #5-7 recipients of these funds are not universities. In order they are: the Research Triangle Institute ($114.7 million), Family Health International ($57.4 million), the Fred Hutchinson Cancer Research Center ($45 million) and Massachusetts General Hospital ($18.9 million). The overall concentration measures I present were calculated on the complete set of institutions receiving NIH COVID-19 funding.

COVID-19 funding allocated following a highly focused strategy does seem to have resulted in increased funding concentration, but it did so in a fashion that led some universities to receive more funding than might be expected given their recent history with the agency while others that had been very successful did not. This is an indication that concentration itself, particularly when we're seeking to address a really pressing, known problem, is not necessarily a bad thing. But it does raise questions about whether choosing such a strategy might leave us less well positioned to address the next major challenge or opportunity we face.

In fact, some of the institutions whose work could be very important to COVID-19 were not the largest and most active players in recent NIH funding overall. Some very large performers of overall NIH research (for instance the University of Pennsylvania, ranked #1 for baseline funding but #40 for COVID-19 funding), may not be as important to pandemic response on this dimension. This is actually an indication of the value a diverse ARE system made up of larger and smaller universities with different mixes of scientific capabilities and connections has for addressing emergent problems. In short, increasing concentration in NIH COVID-19 funding was accompanied by more mobility than is typically seen in year-to-year changes in overall research funding rankings. The challenging question that needs to be considered is whether choices made to effectively address COVID-19 under conditions of increasing budgetary pressure, social and economic upheaval could limit the ARE system's ability to address the next crisis.

Funding Strategies and Concentration at NSF

The National Science Foundation could not have taken a more different approach to allocating its, much more limited, COVID-19 funding than NIH did. Part of this is the result of federal decision-making. The US Congress appropriates money to NSF as a whole not to its individual components as it does with NIH. As a result, decisions inside the foundation may be less directly constrained. NSF had a lot less money to spend, but it allocated that money through its Rapid Response Research (RAPID) funding mechanism, which is based on a new application, capped at $200,000 and limited to 1 year.[53] In other words, to get new NSF COVID-19 funding an investigator had to write a (shorter than standard) new proposal for work to be done in the short term. Funding limits also meant that the funds that were available were likely to be spread across much wider range of projects. It's also notable that NSF spans a wider range of fields than NIH. While the latter emphasizes biomedical and related research, the former funds basic science in fields ranging from anthropology to zoology.

This approach comes closer to the "flexibiilty" model I described above and thus provides an interesting contrast with NIH. As a starting point, NSF awarded much less money ($132.8 million) than NIH through more (894), smaller (average = $148.5 thousand) grants. This is a smaller amount than the average for the 8300 odd baseline grants made by NSF in 2019. Those grants were more than twice as large as COVID-19 grants ($342.0 thousand) on average.

How have early NSF COVID-19 funds been allocated across fields? I used the high-level organization of a science agency and a comparison between COVID-19 and prior year baseline

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[53] Though "Well justified proposals that exceed these limits may be entertained." https://www.nsf.gov/pubs/2020/nsf20052/nsf20052.jsp

funding to to take a look. Table 5 presents breakouts of NSF COVID-19 and baseline funding by what are called directorates. Directorates are the broadest units within NSF. They focus on funding different areas of science and engineering.

NSF Directorate	C19 $	C19 $ %	Baseline $	Baseline %
Engineering (ENG)	$ 31,411,196	23.7%	$ 721,015,663	20.5%
Social, Behavioral and Economic Sciences (SBE)	$ 29,053,737	21.9%	$ 164,840,329	4.7%
Biological Sciences (BIO)	$ 24,760,692	18.6%	$ 431,789,937	12.3%
Computer and Information Sceince and Engineering (CISE)	$ 21,475,170	16.2%	$ 616,643,415	17.5%
Mathematical and Physical Sciences	$ 10,163,915	7.7%	$ 561,941,932	16.0%
Education and Human Resources (HER)	$ 9,406,744	7.1%	$ 558,406,213	15.9%
GeoSciences (GEO)	$ 4,402,895	3.3%	$ 396,780,451	11.3%
Office of the Director (OD)	$ 2,121,786	1.6%	$ 68,082,427	1.9%
Grand Total	$ 132,796,135		$ 3,519,500,367	

NSF has 7 directorates.[54] All of them awarded at least some COVID-19 funding. The top 4 granted 80% of COVID-19 research funds. NSF appears to be spreading its money out more broadly across fields than NIH did. There are also some very notable shifts relative to the baseline. MPS, EHR, and GEO were all responsible for a far smaller percentage of COVID-19 funding than they were at baseline. ENG, BIO and especially SBE awarded a higher percentage of COVID-19 funds than baseline. Funding for COVID-19 research in the social behavioral and economic sciences saw a particularly large jump. SBE made grants for 22% of COVID-19 research but only about 5% of baseline funding.

What does a strategy that seems more oriented toward fast support for a broader range of fields and approaches seem to mean for concentration in the US-ARE? Table 6 provides some insight.

Concentration (Funding Amount)		
	Baeline (N=1375)	C19 (N=278)
All	$ 3,519,500,367	$ 123,826,823
Top 12	15.7%	21.7%
Top 25	28.9%	36.3%
Top 50	47.0%	54.6%
Top 100	66.9%	75.1%
Top 150	76.4%	86.1%

As was the case with NIH, baseline funding allocated vastly more money to a much wider range of organizations. In general terms, it's notable that while NSF made COVID-19 grants worth around an order of magnitude less than NIH, it gave more awards to more organizations (NSF=278, NIH=160), further evidence of the flexibility strategy. NSF award spending is still very concentrated but the raw differences reflected here are much different for those in Table 3, which provides analogous data for NIH. The HHI concentration measure bears out some of this intuition. COVID-19 NSF spending (HHI = 0.008) manifests very similar concentration across organizations to baseline spending (HHI=0.006).

Table 7 presents the top recipients of new NSF COVID-19 awards along with their baseline rank and rank mobility.

[54] The Office of the Director also controls and distributes funds.

Organization	C19 awds	C19 $	c19_$_rnk	base $ rank	base-c19
Regents of the University of Michigan - Ann Arbor	20	$ 3,354,054	1	1	0
Arizona State University	23	$ 2,924,146	2	12	10
University of California-San Diego	15	$ 2,889,078	3	7	4
Pennsylvania State Univ University Park	14	$ 2,126,734	4	2	-2
New York University	13	$ 2,103,458	5	32	27
Virginia Polytechnic Institute and State University	12	$ 2,036,089	6	28	22
University of Maryland College Park	14	$ 2,018,089	7	33	26
University of California-Irvine	13	$ 1,986,537	8	23	15
University of Washington	14	$ 1,939,808	9	6	-3
Northwestern University	10	$ 1,876,065	10	17	7
University of Texas at Austin	14	$ 1,823,781	11	10	-1
Northeastern University	14	$ 1,780,189	12	21	9
University of Georgia Research Foundation Inc	10	$ 1,680,365	13	38	25
Columbia University	11	$ 1,671,100	14	8	-6
Yale University	9	$ 1,588,053	15	54	39
Purdue University	12	$ 1,503,807	16	16	0
Cornell University	10	$ 1,454,856	17	18	1
University of Southern California	9	$ 1,432,355	18	29	11
Stanford University	8	$ 1,423,385	19	43	24
University of Florida	11	$ 1,312,080	20	14	-6
University of Minnesota-Twin Cities	7	$ 1,234,872	21	9	-12
University of Wisconsin-Madison	7	$ 1,222,858	22	11	-11
University of California-Los Angeles	7	$ 1,220,669	23	26	3
Georgia Tech Research Corporation	10	$ 1,151,429	24	4	-20
University of Utah	6	$ 1,134,685	25	39	14
Top 25 total	*293*	*$ 44,888,542*			

As we should expect, the distribution of award amounts is much narrower than it was for NIH. There's some evidence of mobility, but more organizations moved up than dropped down. I am tempted to attribute this to the shift in the distribution of funds across research areas and the flexible strategy NSF seems to be pursuing. Those two factors could have allowed universities with less emphasis in the physical and geosciences and more, for instance, in the social and behavioral sciences to compete effectively for increased funding in that area. Perhaps more importantly, NIH's strategy of picking big winners based on prior and ongoing success left more universities that usually would have done well a bit more out in the cold. In the NSF model, that doesn't appear to be the case.

The focused NIH strategy seems to me to a totally reasonable one for the seemingly pretty narrow but very very important goals that animated federal appropriators. The focus reflected in those appropriations - testing, therapeutics, and vaccines - are pretty concrete. The more flexible approach that NSF pursued likewise seems appropriate to turn a wider range of fields and institutions toward what we might expect to be less clear and concrete goals. This difference mirrors a standard distinction that has long been of interest to management and organizational scholars. In those terms, NIH is pursuing a strategy that seems oriented toward effectively "exploiting" existing capabilities to achieve identified goals. In contrast, NSF's strategy seems better suited to the "exploration" of new possibilities.[55] The latter seems to me to be a necessary

[55] March, James G. 1991. "Exploration and Exploitation in Organizational Learning." *Organization Science.* 2(1): 71-87.

approach if our goal is to maintain an ARE system that can continue to serve as a form of social insurance, as is clearly happening now.

Neither of these strategies is wrong on its face. Both may well turn out to be correct for their purposes. What's interesting is the balance of the two and how long it persists. The differences in the scale of NIH and NSF COVID-19 funding and in their strategies for using those funds raise the possibility that we might shift too far in the direction of exploitation in our pursuit of a solution to the pandemic. That's an incredibly important goal, so I don't think it's a place where we want to exert too much caution. What I think policy makers and, on different scale, academic leaders should do, though, is make decisions that also attend to maintaining the flexibility, competitiveness, and diversity of knowledge portfolios as much as possible. At the very least, we should make decisions fully aware that we may end up trading some of our ability to address an unknown future crisis in order to raise our chances of solving this one.

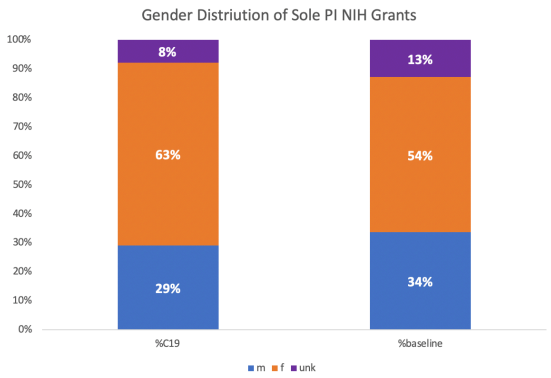
These dynamics aren't playing out in isolation. Lots of factors -- pressures on university budgets, the social and economic challenges that are striking some parts of the academic research workforce much harder than others, serious uncertainty in decision-making, possibilities for destructive competition, a long history of declining or stagnant public support -- are pressing decision-makers towards a more focused strategy. Going hard at that approach in today's world seems likely to have other consequences that will affect universities' ability to be good long term sources, anchors and hubs.

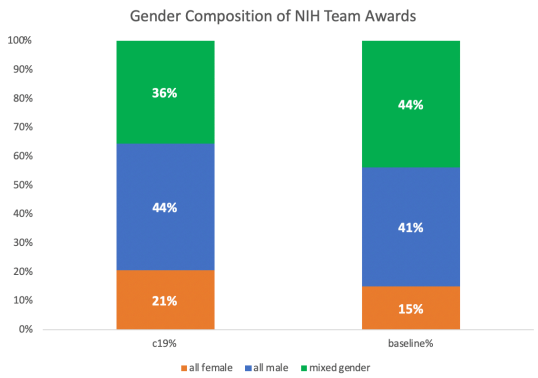
Homogenization: Investigator Gender at NIH and NSF

It's difficult to get an empirical handle on that possibility in anything approaching real time given limitations of current data and its dissemination. But we can find some evidence in the demographic characteristics of NSF and NIH Principle Investigators (PIs). Unfortunately, the up to date public data I have access to includes very little information about individuals. Gender, race, ethnicity, rank, age, family status and other important characteristics aren't available. But we do know the names of lead and co-PIs for both funding agencies. Thus, I use an established tool, Ethnea, that was created by computer and information scientists to induce people's gender and ethnicity from their names. I focus on gender here because it’s simpler and because the algorithms Ethnea uses are better at accurately predicting it. Names in some languages and cultures are less likely to carry strong gender markers. Some names -- such as "Leslie" -- are gender ambiguous even when they do. So Ethnea returns three categories, Male, Female, and Unknown. For some purposes I will eliminate the unknowns. I don't find it particularly enlightening to look at aggregate gender distributions in this case. Instead I focus on individual grants and ask what percentage of them include male and female PIs in different combinations. This allows us to account for the possibility that the team structure of grants changed with COVID-19.

NIH PIs

COVID-19 NIH grants are slightly more likely to have more than one listed PI. Sole PI grants are 78% of those funded during our baseline 2019 period, but 67% of COVID-19 grants are sole PI. Women are much more likely to be the sole PI on a COVID-19 award than on a baseline award. Mixed gender PI teams also declined for COVID-19 awards with all male teams growing slightly and all female teams growing more dramatically. Figure 10 presents this information.





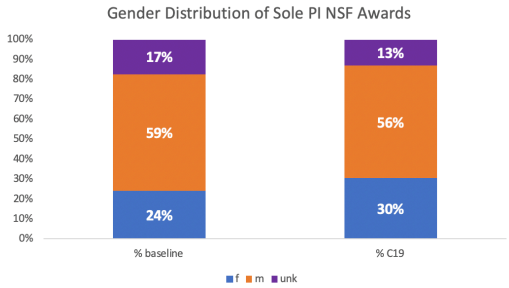
For sole PI teams, I keep PIs of unknown gender in the mix. I eliminate them to examine the gender composition of teams. Across baseline and COVID-19 funding, sole PI grants are mostly awarded to women, but the percentage of grants made to a single woman increases and the percentage of grants made to a single man decreases relative to baseline. Team grants show a somewhat different pattern. Mixed gender teams decreased from 44% (for baseline funding) to 36% (for COVID-19 funding). Both all male and all female teams became more common, but the growth in teams made up entirely of women grew about twice as much during COVID-19.

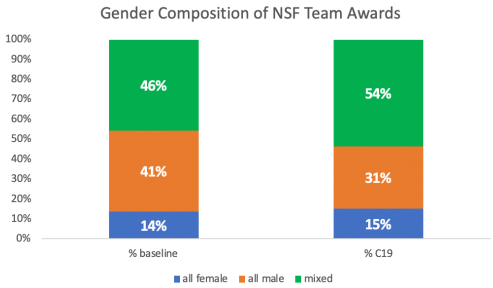
Across the entire corpus of NIH grants, then it appears that women are not being awarded a smaller proportion of grants. Instead, the pressures of the pandemic appear to push women to submit more grants alone, or in all female teams.

NSF PIs

The story for NSF is more complicated, because there are pronounced differences in the gender distribution of the fields represented. Social and behavioral sciences, overall, have a much higher percentage of women faculty who might submit proposals than, for instance, engineering. So the kinds of shifts we saw in funding by directorate may drive much of the gender composition story.

Figure 11 begins by comparing overall NSF team composition measures.



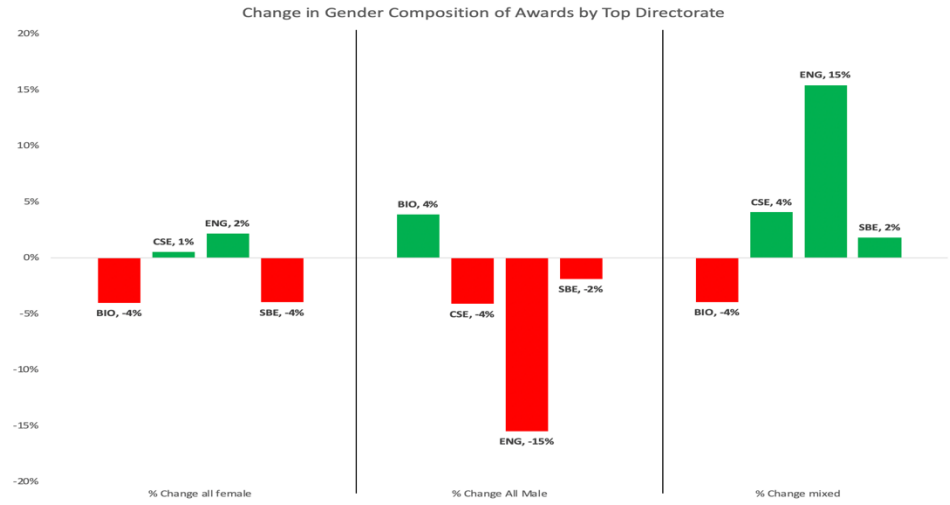


Here we see that grants to sole, women PIs increased a bit, while male sole PI grants decreased. This runs in the opposite direction of NIH awards, though the shifts are smaller. The gender

composition of team awards also changes but here we see all female teams stay about the same, all Male teams decrease significantly and mixed gender teams grow for COVID-19 awards.

It would seem, on the face of things, that NIH awards see continued participation of women at high rates while shifting toward sole PI and all female teams. Female NSF PIs also continue to be awarded COVID-19 funds at a relatively high rate, but rather than a shift to all female teams, we see pretty dramatic growth in mixed gender teams.

But how much of this is a function of increases in the relative rate of social science funding during COVID-19? Engineering, Biosciences, Social, Behavioral and Economic Sciences, and Computer & Information Science awards saw the greatest relative increase in COVID-19 awards. Figure 12 highlights changes in the gender composition awards from those directorates.



There's much impacted in this figure. But the big trend is that COVID-19 awards were slightly more likely to go to female teams for CSE and ENG, and somewhat less likely to do so for BIO and SBE. The areas of research that have fewer women seem to have seen a slight increase in grants to female PIs. The change is matched by much larger declines in all male engineering grants and increases in CSE, SBE, and especially engineering grants to mixed gender teams. While there's not a blindingly obvious story here. This suggests to me that we may be seeing more male fields increase their inclusion of female PIs while more female areas of science stay about where they were. The combination of those two things is a dual source of the overall rise in female and mixed gender teams.

These two explorations are far from comprehensive, but they are suggestive. At NIH a more focused, knowledge exploitation strategy resulted in greater concentration and a shift in collaboration patterns that hints at the beginnings of greater gender segregation. At NSF, which adopted a more flexible, knowledge exploration strategy, we also see increases in sole PI grants to women accompanies by a pretty unequivocal rise in mixed gender teams. That seems to be driven at NSF by two factors. First, more traditionally male fields at NSF look more prone to award COVID-19 grants to female and mixed gender teams, while more traditionally female fields stay closer to their standard gender distributions. Because the NSF increased relative funding to the biosciences and social sciences significantly during COVID-19 a part of the changing gender distribution is a result of broadening the range of areas of being investigated at that agency.

Overall, then, it seems that the early months of COVID-19 were not accompanied by a wholesale departure of women from the PI role. Though this seems likely to change as the pandemic drags

on in the US. Instead, I suspect that broader pandemic pressures, such as those created by school and childcare closures, pushed women to work alone more in general and at NIH in more female teams. At NSF, where grants were much smaller and focused on new applications, we see a rise of mixed gender teams. The portion of that rise that might be attributable to within field changes may be due to NSF's focus on smaller grants with shorter and easier to write proposals. The larger share of the NSF changes, however, seems to be attributable to the shifting distribution of funding across broad areas of science. In other words, NIH awards show us that in the early days of a pandemic that puts more pressure on women's professional work, a knowledge exploitation strategy seems associated with increasing gender segregation but not an overall decline in women's participation. The opposite is true of the more exploratory and flexible strategy at NSF. But more than anything else, that demonstrates the ways in which concentration of funding in a new set of fields has effects on workforce homogeneity.

The US-ARE and the Global Research Enterprise

I've now spent an immense amount of time and energy to examine what is happening in the United States Academic Research Enterprise. But the changes at work in the US are also important for the global research system. That's true for several reasons. First the US-ARE is still the largest segment of global academic R&D. Second, US-ARE institutions have traditionally trained a large share of graduate and post-doctoral researchers from other nations. Third, and maybe most importantly, as the global research system has become more integrated through increasing international collaboration, US-ARE institutions and scientists remain central.

Some data produced by the National Science Foundation allow us to see that centrality very clearly. The 2020 edition of *Science and Engineering Indicators,* a biennial report on the state of U.S. science and engineering, includes high level bibliometric data on collaborative scientific publications. It also tracks international collaborations between individual countries represented in the author affiliations of team science papers.[56]

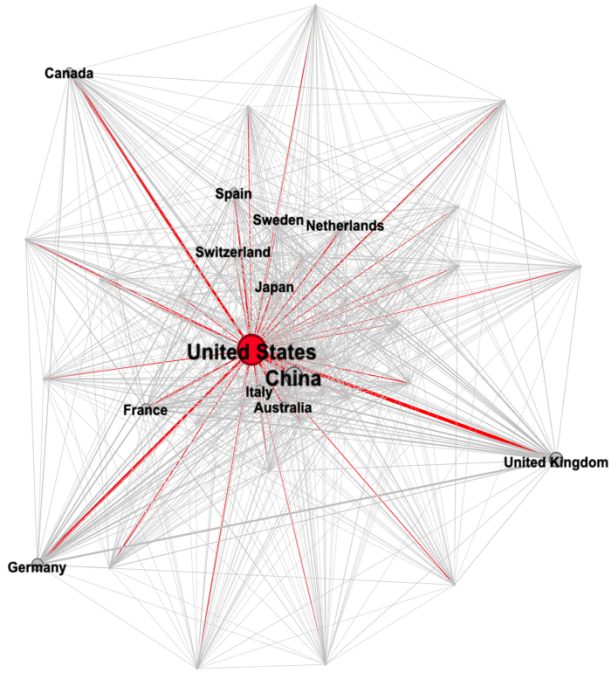
	Int'l Collabrative Articles	% Total
United States	215388	37.4%
China	126868	22.0%
United Kingdom	99924	17.4%
Germany	82089	14.3%
France	60916	10.6%
Canada	51287	8.9%
Australia	50584	8.8%
Italy	50243	8.7%
Spain	42137	7.3%
Japan	36050	6.3%
Netherlands	33713	5.9%
Switzerland	29476	5.1%
Total	575857	

Table 8 draws on these data to identify the nations that are most active in internationally collaborative papers.

This table is based on 2018 publication data. Nearly 576,000 scientific articles published that year had authors from more than one nation. That's about 23% of the more than 2.55 million new papers published in that year. US research collaborated on about 37% of those international

[56] National Science Board. *Science and Engineering Indicators, 2020*, table S5a-33

papers. Chinese scholars co-authored another 22% and research in the UK, Germany, and France all played roles in more than 10%.



If we treat these data as a collaborative network where nodes are nations and ties represent the number of articles their scientists author in common, we get a more nuanced sense of the role different nations play in the global academic research system.

Figure 13 presents an image of that network. In this image, the size of nodes and their labels is proportional to the total number of scientific articles with at least one author from that country. Wider ties represent a greater degree of collaboration between two nations' scientists. I emphasize the US role in the international collaboration network by highlighting their ties in red. The center of the network is dominated by the US and China. If fiscal pressures on US-ARE institutions, decisions about how to respond by policy makers and university leaders, and government actions (or inaction) have significant effects on the structure and functioning of the US-ARE, then Figure 13 strongly suggests that those changes are going ramify out internationally in very short order because of the key role that US researchers and institutions play in the global collaboration network. If one result of pandemic policy and decision-making is to narrow the scope and future flexibility of the US-ARE, Chinese researchers and institutions seem poised to take up any slack.