DRIVING U.S. COMPETITIVENESS THROUGH IMPROVED UNIVERSITY-INDUSTRY PARTNERSHIPS

Association of Public & Land-grant Universities

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Executive Summary

PROBLEM STATEMENT

Cross-sector research collaboration is viewed as one of the most important elements of a national innovation system. Collaborative university-industry R&D has benefits for universities, for industry, and for the U.S. economy. Collaboration can speed discovery and its application to important societal problems.

Collaboration is also costly; research partnerships require time and attention to reconcile differences in goals and to address other potential barriers. These costs and barriers may explain why university-industry collaboration is not more common given the importance of this collaboration to private sector innovation and long-term national economic competitiveness.

Industry R&D spending has soared over the past few decades; however, only about one percent of total industry R&D is spent on formal research collaborations with universities, and only 6 percent of university research funding comes from industry. Some argue that these trends point to a disconnect between industry and university research, making it more difficult to identify promising commercial applications, and slowing innovation and productivity growth in the U.S.

We aim to investigate the state of industry-university research collaboration and to identify methods and practices that might recouple university and industry research with the twin goals of solving important societal problems and generating renewed competitiveness for the U.S. economy.

RESEARCH QUESTIONS AND APPROACH

We set out to answer the following five research questions by conducting interviews with both university leaders working to improve industry R&D engagement and industry leaders working on university partnerships:

1. What kinds of industry R&D needs can best be met by academic institutions?
2. What are the barriers, enablers, and incentives for partnerships between academic institutions and industry?
3. What are the most effective mechanisms for securing, establishing, and expanding research collaborations between industry and academic institutions?
4. What might be the first steps to creating a more user-friendly, credible partnering infrastructure?
5. Based on these findings, what are some potential policy levers for advancing this agenda?

Because the nature of R&D relationships between universities and industries seems to vary by industry, we focused our interviews on specific research areas to enable a deeper understanding of how these issues might affect the most productive approach to stronger collaborations. The target industries included:

- Biotechnology
- Telecommunications, 5G, and Enabling Technologies
- Pharmaceutical and Therapeutics
- Computing and Quantum Computing
- Automotive Engineering

We performed 23 key informant interviews with individuals from 22 universities and 16 interviews with 16 companies. Each interview lasted about 45 minutes and loosely followed the interview protocol provided in Appendix B. The interviews were recorded to aid notetaking. While we acknowledge those we interviewed in the acknowledgements, we only attribute specific comments where we have been given explicit information to do so.

KEY FINDINGS

What kinds of industry R&D needs can best be met by academic institutions?

Interviewees mentioned the following R&D needs as important contributions that universities can make to industry:

- Access to unique research assets such as labs, equipment, and testing facilities that reduce the cost of research to industry.
- Opportunities to pursue federal funding and access the resulting technologies.
- Co-investment for basic and long-term research in strategic areas of importance to industry.
- Access to students who will help build the company's research talent pipeline.
- Clinical data that can be used to test and frame the benefits of new products to patients.
- Applied research, especially in cases where specialized university research can simulate an application environment.
- Knowledge sharing with global experts and the opportunity to learn about emerging ideas.
- Access to startups that can de-risk technologies until they are ready for further development by the company.
- Interdisciplinary solutions that approach the technical, market, legal, and policy elements that drive a preferred solution.

What are the barriers, enablers, and incentives for partnering between academic institutions and industry?

▶ BARRIERS

- Misalignment between the goals and incentives of industry research managers and university faculty is a frequent barrier. Some of this misalignment may be due more to perception than reality and might be addressed by direct communication clarifying how the goals and incentives might be aligned.
- Lack of capacity for pursuing and maintaining these relationships is an issue for both universities and industry.
- Misunderstanding of Facilities and Administrative (F&A) cost on the part of industry can sometimes generate a perception that universities are too expensive or that they are not genuinely interested in industry work.

- Lack of familiarity among faculty with industry's research needs or contracting process can impose a barrier that might be overcome for faculty willing to spend time learning how to work with industry.
- Industry misunderstanding a university's research mission might be perceived as a lack of respect and an unwillingness to treat a university as a research partner.
- Intellectual property policies can be a barrier, but they don't have to be.
- Lack of awareness or willingness among faculty to meet industry standards for regulatory compliance and data replicability might generate problems for industry's use of their research findings.

▶ INCENTIVES AND MOTIVATIONS

- Student internships and employment opportunities are important incentives to both universities and industry.
- The opportunity to diversify a funding portfolio that is heavily weighted toward federally funded R&D can motivate university administrators to build partnerships with industry.
- A university's mission to conduct "public impact research" drives faculty to pursue opportunities to build industry partnerships that will lead to research applications that improve society and benefit the regional economy.
- University administrators want to support faculty interested in working with industry.
- Industry is motivated to seek out university researchers who can expose them to new discoveries that may have application in their target markets.
- Companies are embracing open innovation as a method for accelerating the scientific discovery required before market applications are possible.

▶ ENABLERS OF STRONG PARTNERSHIPS

- Goal alignment between partners and the ability to articulate mutual value are key elements of strong partnerships.
- Mutual trust and professional respect between industry and university scientists can provide the kindling for a larger organizational collaboration.
- University leadership that clearly articulates and supports an industry partnership strategy.

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- Faculty with industry experience are more likely to understand the motivations, culture, and environment of industry and envision commercial applications for their research.
- Partners with a long-term perspective on the relationship are more willing to invest the time required to build a strong partnership.
- Up-front investment in the development of mutually agreeable expectations for a project assessed using objective metrics can prevent misunderstandings.
- Effective structures for relationship management will benefit the long-term prospects for a partnership by delivering focused attention to each strategic relationship.
- Standard or simple agreements or templates that have already been approved by the university's general counsel can help potential partners quickly determine whether a formal relationship is possible.
- Multifaceted partnerships—those that involve multiple sources of benefit and points of contact—are more likely to have longevity, even in the event of tension or failure in one aspect of the relationship.

- Universities believe that having an internal company champion for the university partnership – particularly a champion with influence—can help the partnership gain leadership attention and attract resources.
- Geographic proximity encourages companies to reach out to universities for potential co-location opportunities and for exposure to students who, provided the opportunity, may stay in the area to start their careers.

What are the most effective mechanisms for securing, establishing, and expanding research collaborations between industry and academic institutions?

- University centers and institutes provide a focal point for communicating technology strengths to industry and offer strategic areas of focus for specialized research, investment, and support.
- Master agreements with general terms agreed upon ahead of time may be reserved for partnerships that have matured to the point where multiple projects are expected.
- Joint steering committees can help keep larger partnerships on track, maintain communication, evaluate the success of the partnership, and co-determine research direction.
- An effective alliance management function can assist both universities and companies in maximizing the value of their strategic partnerships.
- Interviewees have a mixed view of the usefulness of university-industry research consortia.

What might be the first steps to creating a more user-friendly, scalable partnering infrastructure?

- Universities better identify and communicate the research strengths that align with the strategies of companies of interest. Describe investments that signal a long-term commitment to advancing the science in the company's key technical areas.
- Potential partners demonstrate a mutual commitment to advancing the science in an area of shared strategic interest. A long-term vision for the partnership can flow from mutual commitment.
- Commit resources to centralized relationship management and to personnel with experience nurturing partnerships.
- Universities leverage industry interest in students to gain traction in a partnership that can grow into areas of mutual research interest. Grow the partnership

by identifying additional touch points that provide shared value and develop momentum and interest in the relationship. Leverage a company's interest in the university's brand.

- Identify common pain points in the contracting process and take steps to address them with input from key partners.
- Universities research the companies that are emerging in their strategic technical areas to identify those that might play a role in commercializing research in the future.
- Identify opportunities to bring potential partners into a government funding opportunity. Use the opportunity to start a conversation about how a partnership might generate mutual value.

Based on these findings, what are some potential policy levers for advancing this agenda?

- Enhance funding for translational research, for programs that explicitly support industry-university collaborative research, and for industry experiences for students.
- Expand partnerships between federal funding agencies and industry to co-fund university research in regionally, nationally, and internationally strategic areas.
- Maintain or increase funding for basic research.
- Work through conflict-of-interest issues to enable dual employment between the company and university.
- Incentivize regional collaborations among universities, industry, and state and local economic development organizations.

ISSUES REQUIRING FURTHER EXPLORATION

- Many opportunities for improving university-industry collaborations have been identified in this report. APLU's Council on Research and its Future of Research Working Group are working together to prioritize them with assistance from APLU's Commission on Economic and Community Engagement (CECE).
- Industry-university working groups, for example, UIDP and the National Academies Government-University-Industry Research Roundtable (GUIRR), will consider taking up the highest priority issues and working collectively to identify solutions. UIDP has addressed many of these issues in publications cited in the footnotes of this report.

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Driving U.S. R&D Competitiveness Through Improved University-Industry Partnerships

U.S. COMPETITIVENESS AND UNIVERSITY-INDUSTRY R&D COLLABORATION

Collaborative university-industry R&D has many benefits for universities, for industry, and for the U.S. economy. Research collaboration allows for more complex research, transfers tacit knowledge among collaborators, and facilitates cross-fertilization of ideas, leading to insights that researchers or institutions working in isolation cannot achieve (Katz and Martin 1997). University and industry participants in collaborative research report a wide range of benefits, including more rapid transfer and commercialization of technology and enhanced knowledge for university faculty, students, and industry partners (Grey, 2011). Firms that cooperate with universities have higher innovation productivity and higher sales from innovative products; they use collaboration with universities to incorporate the results of fundamental research into their innovation and to pursue radical, rather than incremental, innovation (Belderbos et al. 2004).

More generally, collaboration among industry and universities can speed discovery and its application to important societal problems. Cross-sector research collaboration is generally viewed as one of the most important elements of a national innovation system, and its effectiveness influences a nation's ability to maximize the impact of its R&D investments (Grey, 2011).

But collaboration is also costly. The collaboration of universities and industries imposes costs of reconciling different missions and goals, motivations, management cultures, financial systems, and rules regarding intellectual property rights. Perhaps most importantly, partners in a collaboration must spend time aligning their research priorities (Katz and Martin 1997; Steinmo, 2015). These costs and barriers may explain why university-industry collaboration is not more common than it is, given the importance of this collaboration to private sector innovation and long-term national economic competitiveness. Thus, the potential for overcoming some of these costs and barriers is worth exploring.

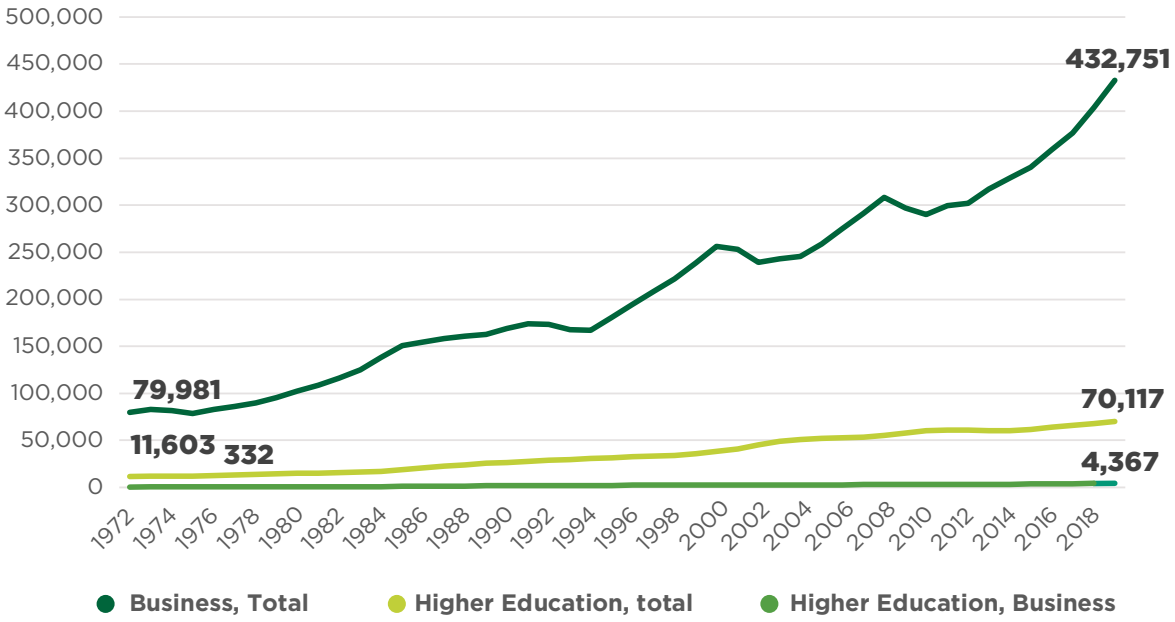
Industry-funded research is one (imperfect) indicator of the extent of university-industry research collaboration. Industry R&D spending, in constant dollars, has soared over the past 37 years, from about $80 billion in 1972 to over $430 billion in 2019—a quintupling of R&D effort. At the same time, R&D spending by U.S. universities grew from $11 billion in 1972 to about $70 billion in 2019—over six times the 1972 level. The amount of funding to higher education coming from business grew from 332 million to 4.4 billion (Figure 1). This represents about 1 percent of industry's total R&D spending.

During these same years, the percentage of university research funded by the private sector has varied, starting at 3 percent of the total university spending on R&D and reaching its highest point at 7 percent in the mid-1990s. Today, about 6 percent of university spending on R&D is paid for by industry. This has occurred while federal funding has fallen as a share of university R&D, and while institutions are spending more of their own resources (Figure 2).

As a percentage of GDP, federal funding in R&D has declined by over 60 percent since the 1970s (Figure 3), while competitor countries invest larger shares of their GDP in research (Atkinson and Stewart, 2011).

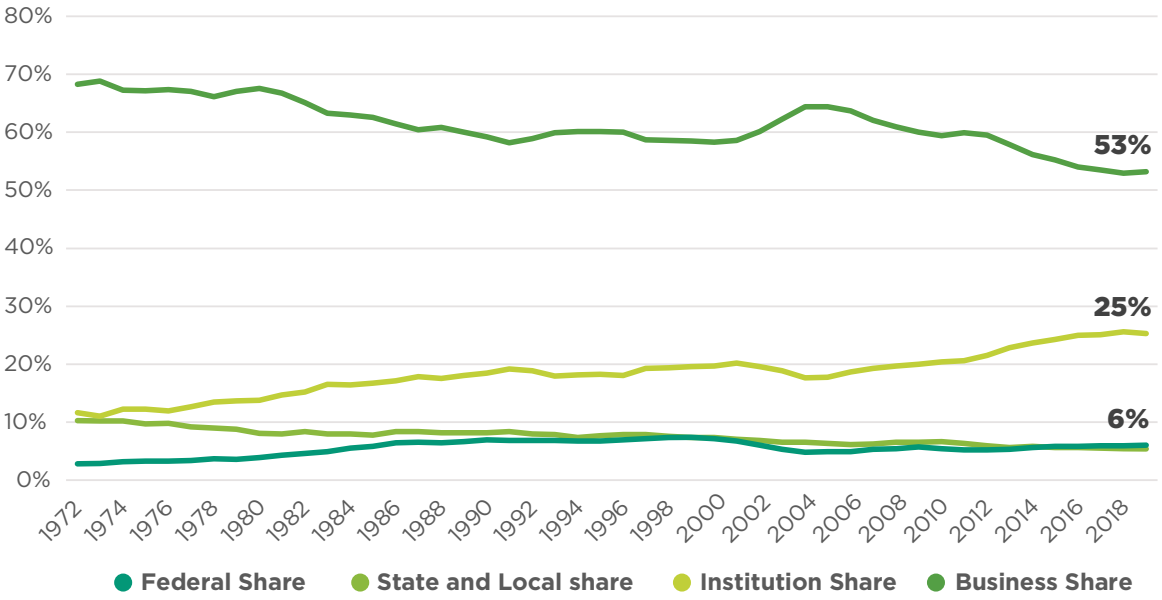
Figure 1. U.S. R&D Expenditures by Performing Sector and Source of Funds, 1972 - 2019

Millions of constant 2012 dollars



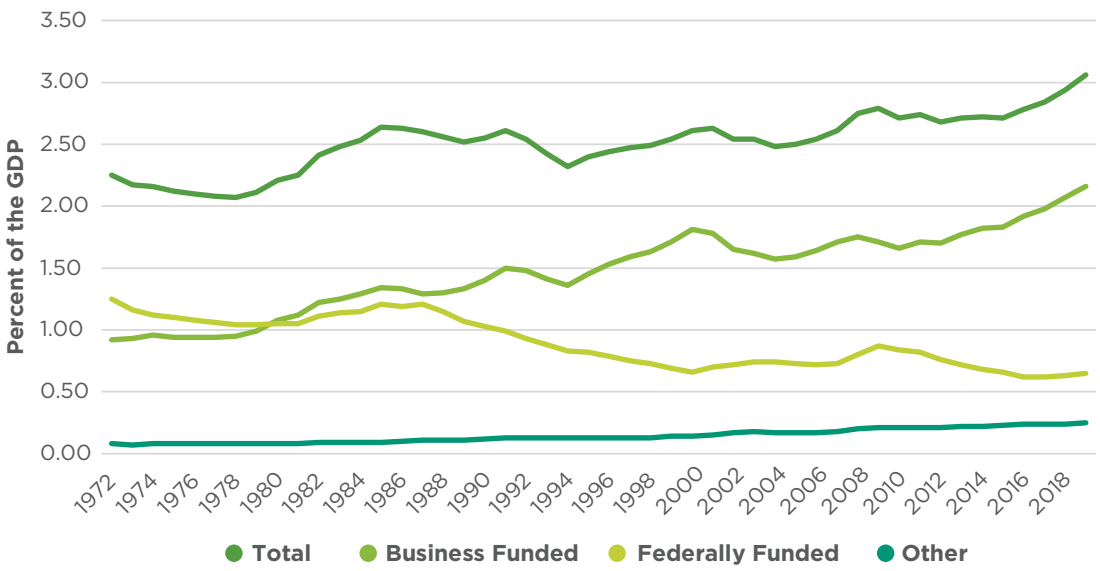
Source: National Center for Science and Engineering, National Patterns of R&D Resources, Table 2.

Figure 2. U.S. Higher Education R&D Expenditures, Share by Source of Funds FY 1970– 2019



Source: National Center for Science and Engineering Statistics, Higher Education Research and Development Survey (HERD).

Figure 3. Ratio of U.S. R&D to Gross Domestic Product, by Source of Funding for R&D: 1972 to 2019



Source: National Science Foundation, National Center for Science and Engineering Statistics 2019. National Patterns of R&D Resources: 2017–18 Data Update. NSF 20-307. Table 1. Alexandria, VA. Available at http://ncses.nsf.gov/pubs/nsf20307.

Spending is not the only issue of concern. Arora and his colleagues (2019) argue that one factor slowing innovation and productivity growth in the U.S. is the decline in internal corporate R&D, which, until the decline of large corporate R&D labs in the 1980s, was *complementary* to university research *and* more likely to identify promising commercial applications. Corporations have increasingly sourced ideas and inventions from universities and from startups—essentially outsourcing their R&D. This decoupling of university and corporate research, according to the authors, has been less effective at turning these ideas into commercial products.

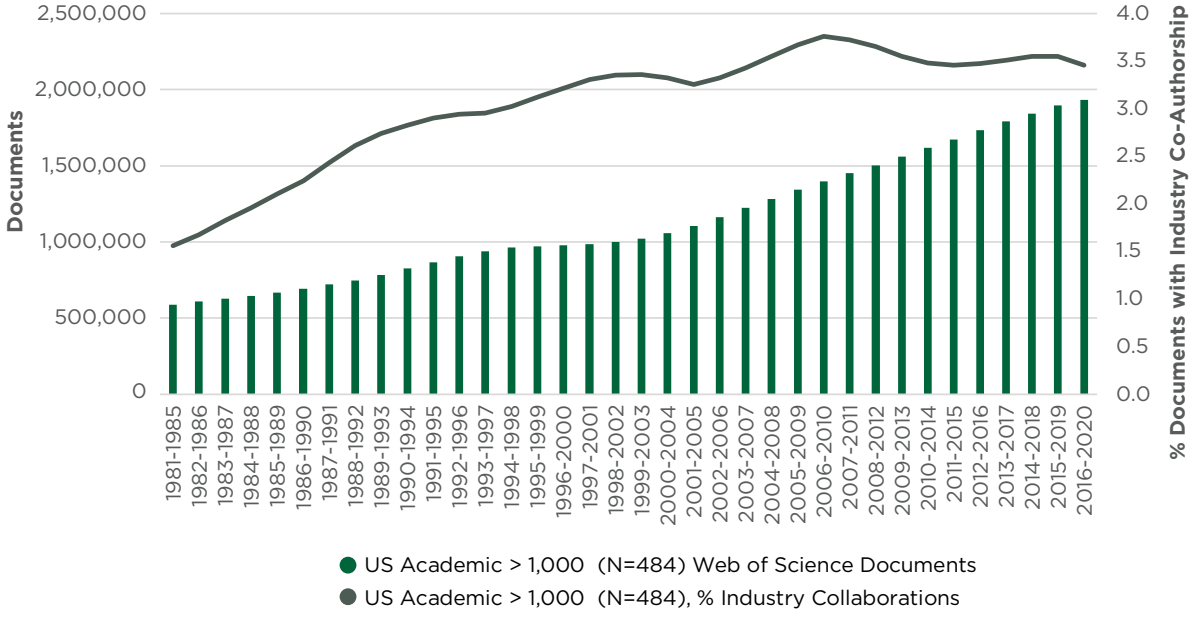
Universities have spent a great deal of time and attention over the past two decades improving the processes and effectiveness of launching *new* businesses based on university intellectual property. They have put less systematic effort into forming reciprocal partnerships with established, R&D-intensive industries to ensure that their market understanding infuses university research. With these partnerships in place, fundamental research is more readily translated into applications that advance technology—particularly in technology areas key to industrial competitiveness.[1] We also have not arrived at a common vision for what a strong system of cross-sector research collaboration can accomplish, what it should focus on, how to incentivize it, or how it should be funded.

1 Critical technologies in the U.S. Innovation and Competition Act include artificial intelligence and machine learning; high performance computing, semiconductors, and advanced computer hardware; quantum computing and information systems; robotics, automation, and advanced manufacturing; natural or anthropogenic disaster prevention; advanced communications technology; biotechnology, genomics, and synthetic biology; advanced energy technology; cybersecurity, data storage, and data management technologies; materials science, engineering, and exploration relevant to the other focus areas.

Public research universities in the United States were originally primarily funded by state governments, giving them a decentralized and place-based nature that, in many cases, led to a focus on the needs of their states and localities (Rosenberg and Nelson,1994). While the share of general funding from state governments has fallen, the focus on state and local economies has not; in fact, state governments rely on universities as engines of state and local economic growth. To foster continued growth, many state governments have invested in programs that encourage universities to direct their research toward locally important industries. Stronger collaboration between industry and universities is one way to encourage that alignment (Atkinson & Stewart, 2011), but the commitment varies a great deal across states (Atkinson, 2018). Part of our goal is to examine the potential to incentivize alignment between university and local industry research goals.

Funding is certainly not the only indicator of collaboration between universities and industries. Industry and university scientists collaborate on research and publications, even in cases in which funding is not exchanged. Sometimes those collaborations result in publication (although often they do not, for reasons we discuss later). The figure below shows the trend in overall co-publications between university and industry scientists. Overall, the percentage of industry co-publication with academic scientists peaked in 2006-2010 at just under four percent; they have seen a slight decline since then. Analyzing the data by discipline shows that co-publication is highest in disciplines related to telecommunications and lowest in the life sciences (see Appendix A for detailed co-publication data by relevant discipline.)

Figure 4. Number and percentage of publications with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.



OPPORTUNITY AND OBJECTIVES

We set out to investigate trends in university-industry collaboration, make a case for greater collaboration, and demonstrate methods and practices that can "recouple" university and industry research, with the twin goals of solving important societal problems and generating renewed competitiveness for the U.S. economy. More specifically, the key questions to be addressed in the study were as follows:

1. What kinds of industry R&D needs can best be met by academic institutions?
2. What are the barriers, enablers, and incentives for partnering between academic institutions and industry?
3. What are the most effective mechanisms for securing, establishing, and expanding research collaborations between industry and academic institutions?
4. What might be the first steps to creating a more user-friendly, credible partnering infrastructure?
5. Based on these findings, what are some potential policy levers for advancing this agenda?

APPROACH

The study team has observed that the nature of R&D relationships between universities and industries varies by industry due to the differences in research timelines and the importance of protecting intellectual property, among other issues. Therefore, we wanted to focus our interviews on specific research areas to enable deeper understanding of how these issues might affect the most productive approach to stronger collaborations. We chose specific industries/technology areas based on their research intensity, the potential to accelerate commercialization with improved university/industry collaboration, and their policy relevance—that is, their importance to the nation's competitiveness and defense. The target industries include:

- Biotechnology
- Telecommunications, 5G, and Enabling Technologies
- Pharmaceuticals and Therapeutics
- Computing and Quantum Computing
- Automotive Engineering

The project team identified universities with significant research activities in each area—particularly where the institution is emphasizing partnership with industry—while also

trying to maintain some diversity with respect to the size and geographic location of universities.

We also identified industry representatives in each technology/industry area—particularly those who have experience working with universities.

We performed 23 key informant interviews with individuals from 22 universities and 16 interviews with 16 companies. Each interview lasted about 45 minutes and loosely followed the interview protocol provided in the Appendix B. We recorded these interviews to aid in notetaking. While we acknowledge those we interviewed in the acknowledgements, we only attribute specific comments where we have been given explicit information to do so.

KEY FINDINGS

What kinds of industry R&D needs can best be met by academic institutions?

Our interviews revealed agreement between industry and universities in the following statements about the type of industry R&D needs that universities can best meet.

Factors mentioned most often by both universities and industries

Unique research assets. Some universities said that their unique and specialized equipment and facilities attract industry when those assets can legally be offered as a fee-for-service to industry. Industry interviewees agreed with this statement, and it seemed especially important for smaller companies or for companies exploring new research areas. These companies might not want to invest in state-of-the-art equipment until they are sure it will have a positive return on investment; testing the equipment at the university is one way to demonstrate the ROI. In some cases, especially for a small firm, it may simply be cheaper to use university facilities, even in the long run, than to obtain their own equipment.

THE PENN STATE MATERIALS RESEARCH INSTITUTE provides an example. Industry researchers can apply to use the equipment in the materials characterization lab, the nanofabrication lab, and the 2D crystal consortium. The user identities are kept confidential. Some instruments allow for remote access, opening the lab to users who are not geographically proximate. Penn State reports that the companies using the lab vary in size, from small startups to Fortune 500 companies. An increasing number of biosciences companies are using the equipment to explore technologies that cross over from biology to materials science. The use of the equipment sometimes translates later into more extensive research as the company becomes familiar with the faculty working in the labs.

THE UNIVERSITY OF WASHINGTON has a unique research center with Boeing. The Boeing Advanced Research Center (BARC), represents a new paradigm in the execution of industrial research. Boeing-employed affiliate instructors work in dedicated lab space side-by-side with faculty and students on joint research projects in the manufacturing and assembly of aircraft and spacecraft structures. Projects focus on finding ways to make airplane assembly and manufacturing more efficient, automated, and streamlined. Areas include machine learning, 3D printing techniques, designing lift devices, and robot control interfaces. The overall goal of BARC is to foster:

- collaborative basic and applied research,
- translational research and development, and
- student education-related activities.

GEORGE MASON UNIVERSITY'S CENTER FOR APPLIED PROTEOMICS AND MOLECULAR MEDICINE and its Center for Infectious Disease Research are two centers that have conducted a large body of collaborative work with industry players of all sizes ranging from startup to large-cap companies. Researchers from these centers and collaborating multidisciplinary faculty utilize two of Mason's premier biomedical research buildings, including a regional biocontainment laboratory with a dedicated aerobiology suite and a multidisciplinary biomedical research building equipped with a College of American Pathologists/Clinical Laboratory Improvement Amendments (CLIA) laboratory and a microfabrication facility. Mason faculty and their partners leverage these facilities to work jointly on Biosafety Level 2 and Biosafety Level 3 pathogens, develop and test new platform technologies, conduct unique clinical trials, and perform diagnostic tests, while supporting joint commercialization of new innovations.

Access to federal funding opportunities. Universities and industry also report that industry likes to partner with universities to gain access to federal funding opportunities and to the technology developed with this funding. This statement was confirmed by industry representatives who noted the power of leveraging federal funding to supplement the budgets of industry-university research partnerships and to expand the breadth of the partnership to include the government agency. The new three-party partnership can result in richer outcomes and serve broader audiences. Universities recognize that a surge in government

funding in a specific area may drive private sector interest, and they may use this information to influence their own research priorities and to tailor their outreach to industry. Industry recognizes that a surge in government funding in a particular area may signal an agency priority that will drive demand from their industry customers down the road.

CLEMSON UNIVERSITY'S INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH (CU-ICAR) provides an example of the power of government, university, and industry partnerships. Located in Greenville, SC, the CU-ICAR began with financial resources provided by the university, state government, local government, and private funding partners BMW, Timken, and Michelin. Over time, new funding partners from the federal government and industry have joined, leading to construction of new buildings and labs, and to additional programs and initiatives. One such initiative is the Virtual Prototyping of Autonomy-Enabled Ground Systems, a partnership between CU-ICAR and the U.S. Army Ground Vehicle Systems Center. The focus of the program is the virtual prototyping of on- and off-road concepts and algorithms for military modernization. The Army requires industry participation in all phases of the research, including fabrication and validation of a physical vehicle.

While companies might seek out universities to partner on federal funding opportunities, they might also partner with federal funding agencies to offer university researchers insight into the market challenges driving their research interests. VMWare's partnership with National Science Foundation (NSF) on sustainable digital infrastructure is one example. They are interested in dramatically advancing the research, and to "support a research community committed to advancing research and education at the confluence of management technologies for software, hardware and power for Sustainable Digital Infrastructure, and to transition research findings into practice."[2] A similar partnership exists between NSF and Google in the area of Human-AI Interaction and Collaboration.[3]

Co-investment for basic and long-term research in strategic areas. Both university and industry representatives mentioned that they are interested in long-term relationships for research with long time horizons and a line of sight to applications.

For universities, long-term relationships allow them to plan for multi-year research efforts and to support graduate students throughout their programs. Some universities have observed that companies increasingly look for co-investment with universities. For example, they are looking for universities that have established labs, allocated space, and pursued faculty cluster hires in strategic areas shared by the company. The university investments manifest in research findings of interest to industry and in the kinds of unique assets, such as important equipment, mentioned above.

2 https://www.nsf.gov/pubs/2020/nsf20594/nsf20594.htm

3 https://blog.google/technology/ai/partnering-nsf-human-ai-collaboration/

Companies frequently fund pre-competitive research for exposure to the novel ideas and the basic research taking place by universities—but they are careful that the time and money they spend on pre-competitive research has a line of sight to a commercial application. This seems especially true in life sciences and quantum computing, where commercial applications may be a long way off. Industry interviewees mentioned that these relationships give them an earlier view and longer-term perspective on the potential pipeline of innovations. Even for technologies with shorter time-to-market, long-term agreements can be useful for overcoming administrative and legal barriers in contracting.

THE ENTIRE RESEARCH ENTERPRISE AT GEORGE MASON UNIVERSITY IS LARGELY ORGANIZED INTO THREE TRANSDISCIPLINARY RESEARCH INSTITUTES that help innovators find each other and prospective external partners navigate and engage with the often siloed and unfamiliar university innovation ecosystem. These institutes leverage resources and networks that span across the academic interests of teaching, research, and service while addressing the commercial interests of the university and its stakeholders. For example, the Institute for Biohealth Innovation (IBI) recently established a partnership with Sentara Healthcare for applied research exploring the potential of patented volatile organic compound (VOC) diagnostic technology developed through Mason research for COVID-19 detection. These kinds of partnerships unlock the commercial potential of university innovations by addressing translational gaps, connecting researchers, technologists, practitioners, and potential customers in areas of urgent societal need.

Access to startups and de-risking ideas. Particularly in the life sciences, but also in some other areas such as quantum computing, companies often watch university startups as they de-risk novel ideas. The companies are looking for technologies that have not yet been implemented, but where the startup has been able to reduce the technical risk of taking on the development of the idea.

THE UNIVERSITY OF MARYLAND LAUNCHED THE QUANTUM STARTUP FOUNDRY to deliver mutual value by connecting potential customers (industry and government) with startup companies, and to foster collaborative research and access to specialized facilities. This builds on a larger effort to connect entrepreneurs to the University of Maryland campus and to industry and government research partners.

Access to students and building the talent pipeline. All university interviewees stated that most industry relationships begin with industry interest in access to students. Industry representatives also mentioned talent development as a primary motivation for university engagement. R&D relationships typically take more time to develop than talent relationships, and even research partnerships might have talent development as

an important goal. R&D partnerships may start with a company funding graduate or undergraduate student research. Many companies are interested in observing student research skills and may participate in an internship program or offer to serve on a committee to judge a student competition. Building their talent pipeline in this way brings new ideas into the company, familiarizes the students with the company, and can also strengthen ties to the faculty member that trained that student.

Clinical data. In the life sciences, private industry is often interested in partnering with universities to collect clinical data through their hospitals. One industry interviewee confirmed that clinical data is essential to framing the benefits of their new products to patients. They also felt that in the future, university and industry will be forced to collaborate to meet the need to generate massive amounts of data to evolve artificial intelligence and machine learning applications to life sciences research and healthcare.

Factors mentioned by universities but not industry

Applied research. In some industries, such as automotive engineering, one university interviewee mentioned that companies are most interested in universities that can work at Technology Readiness Levels (TRL) 4 through 7—the technology levels at which some companies feel there is still too much risk in the technology, but where many universities don't normally operate.[4]

Many industry and university representatives recognized that university researchers frequently work in basic research and that the need for applied research is an inherent difference between the partners. However, this varies by industry and university. Many universities have invested in laboratories with equipment that simulates an operational environment and has applied research applications. Some of those investments, like the ICAR at Clemson, were made as a result of partnerships with industry and government.

Some industry representatives were doubtful that university researchers can work at that level of application and to do it quickly enough to capture an evolving market. It requires testing in an operational environment that certainly requires equipment that an industry partner is more likely to possess. However, this varies by industry; universities have invested in laboratories with equipment that simulates an operational environment, particularly in manufacturing and other applied engineering applications.

4 TRL 4 is "Component and/or breadboard validation in laboratory environment;" TRL 5 is "Component and/or breadboard validation in relevant environment;" TRL 6 is System/subsystem model or prototype demonstration in a relevant environment;" TRL 7 is "System prototype demonstration in an operational environment." GAO, "Technology Readiness Assessment Guide". Report 20-48G. January 2020. https://www.gao.gov/assets/gao-20-48g.pd

Factors mentioned by industry but not universities

Knowledge sharing with global experts. For some companies, working with the university is a chance to gain exposure to the ideas of leading thinkers in a field. For one industry interviewee, working with universities offers a more "open minded and curious" approach to thinking about development; industry researchers are inspired by university collaborations.

Interdisciplinary solutions. Some industry interviewees mentioned that it is sometimes difficult for university researchers to work in interdisciplinary areas – and this is needed to get to "interesting IP." Overcoming technical hurdles as the technology is implemented requires interdisciplinary thinking, which may explain why industry is skeptical of the university's ability to work at higher TRLs. One industry representative noted that interdisciplinary thinking is not only important for technology development, but also for risk management. In cyber security, for example, risk management solutions require technical interdisciplinarity in computer science, software development, and data analytics, but also legal and policy elements that will drive the preferred solution.

Differences in trends and needs in corporate-university collaboration by industry

As expected, some of the factors in university-industry collaboration noted by our interviewees demonstrated patterns specific to their industry or technology. For example, representatives of the biotechnology industry mentioned the importance of investing earlier in the R&D cycle, having access to patient data sets, developing AI research solutions, and having access to interdisciplinary teams. They also mentioned that the industry is reducing its own research staff, leading them to look to university research partnerships. Like the pharmaceutical industry, biotech companies are also interested in purchasing university startups.

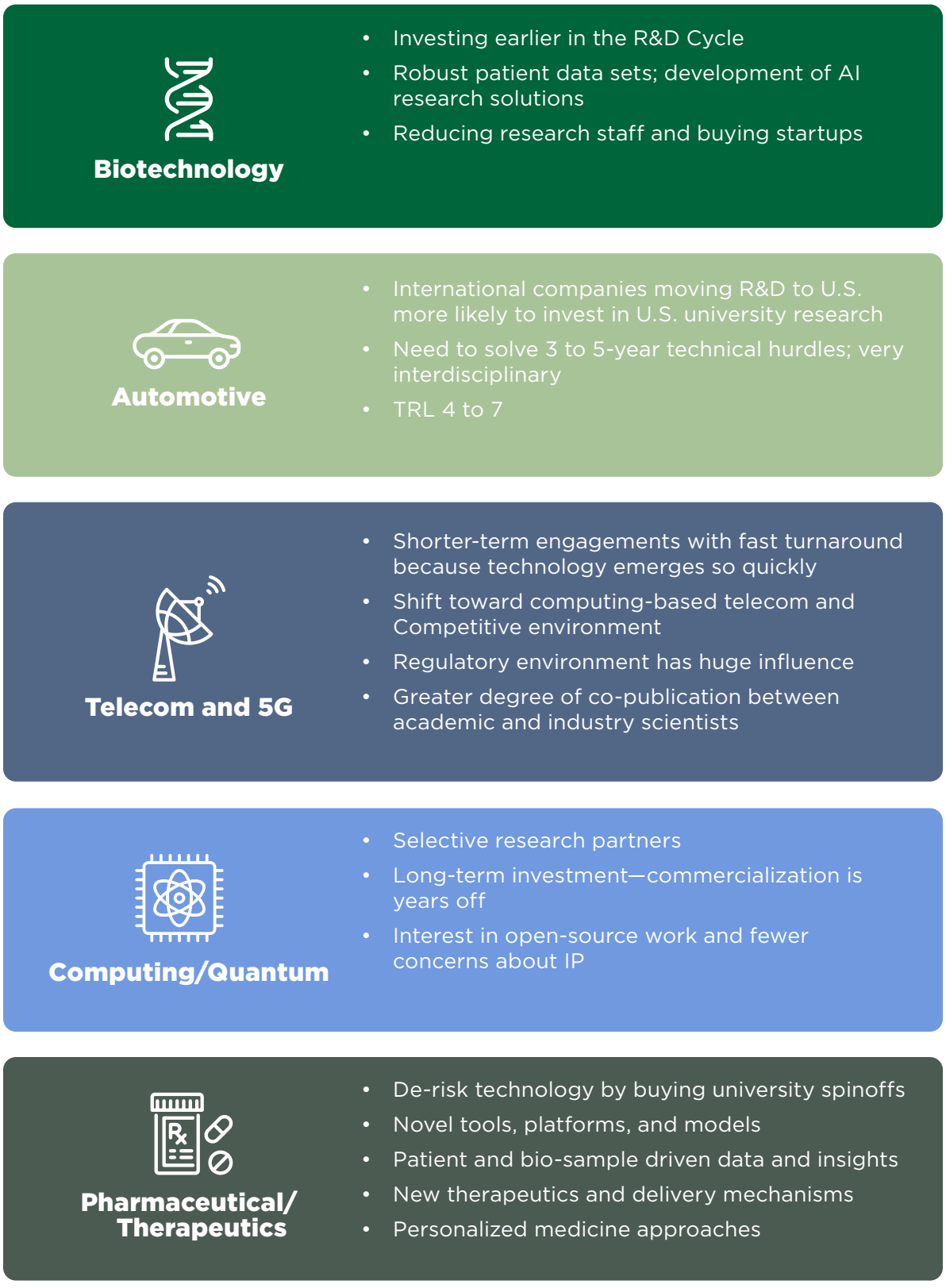
Universities working with automotive companies noted that internationally headquartered companies over time may move research facilities to work more directly with their U.S. production operations. When that occurs, they are more likely to fund U.S. universities to support innovation in those U.S. operations. Auto companies were also more likely to look to universities for technology development at higher TRL levels, solving three-to five-year technical problems, and, like biotechnology, using interdisciplinary methods.

Telecom companies and those developing applications for 5G are more likely to look for shorter-term engagement with a quick turnaround because of how quickly technology is emerging and the push to get it to the market. As 5G applications require advanced computing technology, the environment has become very competitive, and the regulatory environment will influence what technologies are developed. Because the technology goes

to market so quickly, telecom companies are able to co-publish with academic researchers without fearing that the publication will give away the technology.

In computing and quantum computing, companies seem to be more selective about their research partners, seeking out those universities that have arisen as top performers in this emerging field. Intellectual property issues, for the moment, cause less conflict in university-industry partnerships for quantum computing than in other fields. Furthermore, current collaborations are pre-competitive and are addressing industry-wide issues, with market applications years away. Open source work is more common.

Figure 5. Trends and needs in corporate-university collaboration by industry



What are the barriers, enablers, and incentives for partnering between academic institutions and industry?

▶ KEY BARRIERS

Barriers Mentioned Most Often by Both Universities and Industry

Misalignment between goals and incentives. The most frequently mentioned barrier to university-industry R&D partnerships was a misalignment of goals and incentives. While university faculty are rewarded for landing large federal grants, publishing in high-impact journals, and, often, pursuing more basic, ground-breaking research, industry researchers have specific technical objectives and the research must demonstrate a strong return on investment. Industry partners will often want to delay publication of results to protect their potential market, while university researchers want to publish their results to foster knowledge sharing, contribute to promotion and tenure, and, in the case of graduate students, provide the publication record they need for an attractive academic position.

This misalignment may lead to disincentives for faculty to engage in industry research. They may feel that industry research will not be as prestigious as a federal research grant. One university interviewee mentioned that they wanted to avoid being seen as a vendor to industry but rather as a research partner; federal research grants provide more freedom to experiment and to pursue the science where it leads. Faculty who are working toward tenure or students trying to achieve an academic position may fear that this industry involvement will harm their chances by distracting them from what is more valued by hiring and tenure review committees and department chairs.[5] They may also believe that federal research grants offer the longer timelines and higher funding levels that they need to support their research and students over a longer period.

Some of this misalignment may be due more to perception than reality. Some university engagement officers mentioned that once faculty are more aware of the potential opportunities offered by corporate engagement, they may become more interested in understanding how to shape a research relationship in which the needs of both industry and university researchers are met. Industry representatives also mentioned that they look for opportunities for mutual benefit to the university and to the industry partner. So while it may be difficult to find the right industry-faculty match, it is possible to align incentives when the partners clearly understand each partner's technical, business, and other goals. Corporate engagement specialists can serve as translators to ensure that communication is clear at the outset, and so that potential partners don't waste time building relationships in which this alignment is not possible.

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5 The PTIE project generated broad agreement about how promotion and tenure processes and incentives might shift to make it easier for faculty to engage in industry partnerships without fearing that it will harm their promotion and tenure process. A set of principles have been developed that can be adopted by universities.

Friction in the contracting system was often perceived as a barrier, but one that many university and industry partners have learned to overcome. Tools such as master research agreements and standardized licensing terms that have been approved by university counsel can shorten the length of time to negotiate an agreement, as can skilled and experienced negotiators. UIDP points out that not all master agreements will save time for all projects and offers a set of guidelines for determining when Master Research Agreements are best used.[6]

THE UNIVERSITY OF MINNESOTA HAS BEEN AT THE FOREFRONT OF DEVELOPING INDUSTRY-FRIENDLY SPONSORED RESEARCH AGREEMENTS and master agreements since 2011 with the MN-IP (Minnesota Innovation Partnerships) model –specifically the MN-IP Create program. The Create program offers a menu of choices to corporate research sponsor. One example of how this has been implemented and the benefits for both parties is the partnership between the University of Minnesota and Cisco Research. The University of Minnesota and Cisco Research negotiated the research agreement in only three months, modeling it on the MN-IP program. The agreement funded six projects in edge computing, ethics in AI, and tech for health care.

Lack of capacity. A related issue both industry and universities mentioned is a shortage of personnel with experience developing and negotiating university-industry relationships. Some universities noted that faculty need a lot of support when first working with industry, and corporate engagement offices often don't have the capacity to assist in every project. This leads to the need for better training for faculty for managing their own industry relationships, discussed later. Additionally, there is a shortage of experienced corporate-university contract negotiators—both in universities and in industry.

Barriers Mentioned by Universities but Not Industry

Misunderstanding of F&A policy. A research agreement might run into problems if industry partners misunderstand Facilities and Administrative (F&A) policies practiced by universities.

Faculty lack familiarity with industry research needs and contracting. Faculty may become frustrated with the process of developing a relationship or a contract with an industry partner if they are more familiar with federal grant processes. This points again to the need for training for faculty that may be interested in working with industry. Also, faculty do not have time for the business development stage of the relationship-building process. Therefore, universities have to invest in engagement specialists to help them.

6 UIDP. 2021. *15 Effective Practices for Strong U-I Partnerships.* UIDP also has a library of Master Research Agreements accessible by its members.

Misunderstanding a university's research mission might be perceived as a lack of respect and an unwillingness to treat a university as a research partner. One university mentioned that some of their industry interactions have demonstrated a misunderstanding of the role of universities in the innovation process and a desire to contract the university as they would a vendor, rather than in the spirit of discovery. A vendor kind of relationship cannot lead to a mutual understanding of the science. It dissuades faculty from engaging with industry for fear that they will be unable to follow the interesting questions that arise as the research progresses. A faculty member may prefer to pursue a government research grant with fewer expectations for specific findings.

Barriers Industry Mentioned that Universities Did Not

Faculty and university attitudes toward IP. Industry representatives mentioned a variety of barriers related to IP negotiations and usage. In some cases, faculty have plans to create startups from their IP, which would limit the opportunity for industry to partner on sponsored research agreements. Others mentioned that university IP licensing terms may pose significant barriers. However, many universities and industries are learning to overcome these barriers. One barrier that remains a challenge for a few of the interviewees is when industry requests background IP.

Compliance topics. Industry has specific needs for compliance, such as data protection, safety, and animal welfare. At times they may opt to use a private company for their research that has a better grasp of these needs.

Data reproducibility. Some industry representatives mentioned that university researchers don't pay enough attention to the need to be able to reproduce their data.

▶ INCENTIVES AND MOTIVATIONS

Incentives for Universities and their Faculty

Universities and their faculty look to corporate partnerships for a variety of reasons. Those mentioned most often during the interviews are described below.

Offer student internships and employment opportunities. Consistent with the desire to meet industry needs for talent, universities mentioned that relationships with companies, including research relationships, provide opportunities for hands-on learning for students and the chance for exposure to industry officials and researchers who may later offer them employment.

Diversification of funding portfolio. University leaders are aware of the growth in industry R&D spending as well as the relatively flat growth of federal R&D. Many see the flat federal R&D growth as a risk to their plans to continue growing research. Industry research growth is an opportunity to mitigate that risk by diversifying their funding portfolio, especially at universities that are highly dependent on federal funding.

Realize mission of public impact research. Almost all university interviewees mentioned that their public service missions drove them to solving problems facing society and that industry funding helps them do that by commercializing the results of their research. This mission-driven motivation includes aiding the growth of the regional economy. Several universities mentioned the importance of coordination with their state's economic development strategy, and their desire to be an important economic asset. Working with industry to help them invest, grow, and thrive in their region helps universities meet that mission of public service.

Support interested faculty. University administrators want to support their faculty's research interest and help industry partners find alignment with faculty expertise to create research partnerships supports that mission.

Drive the development of IP. This was not a unanimous opinion, and in fact, some universities felt that in dealing with industry, it is more useful to stop thinking of IP as a revenue generator and to be more flexible with IP terms. If the university's goal is to commercialize research and promote application of their research findings, protecting IP can be an insurmountable barrier working against those goals. However, in the right application, co-developing or licensing of IP between universities and industry can protect investments and further advance the partnership as well as generate revenue for both parties.

Incentives for Industry

Cultivating talent and access to students. As mentioned earlier, industry motivations begin with student engagement and the development of their talent pipeline. This sometimes leads to longer-term research relationships, but not always. One industry representative noted the importance of generating local talent, rather than only working with a select group of the highest tier of universities. They understand that the talent needs are too large to work with only a few universities.

Gain understanding of new discoveries and emergence of new technologies. Companies that have the capacity to engage with universities often do so to gain a sense of the future direction of their industries and the technologies that will drive its evolution. One company mentioned "playground basic research," meaning research they think will be fruitful but is pre-competitive and not yet tied to a particular product line.

Access to specialized equipment. As mentioned earlier, some companies build research relationships with universities to gain access to specialized equipment and other research assets.

Opportunity to reduce costs. Some companies view partnership with the university as a lower-cost way to conduct some kinds of research, and this may also drive their incentive to use university equipment.

Acceptance of open innovation. In some industries, including quantum computing, companies are embracing open innovation as a method for accelerating the scientific discovery required before market applications are possible.

▶ ENABLERS OF STRONG PARTNERSHIPS

Enablers Mentioned by Both Industry and Universities

Aligned goals and potential for mutual value. As the discussion above indicates, the most important enabler of a strong university-industry partnership is an alignment of goals and incentives and the ability to articulate mutual value for the partnership. Both university and industry interviewees mentioned that they look for partnerships that generate value for both sides. Most universities are not interested in simply doing contract research; they look for partners that are driven by a shared interest in discovery that advances the science and provides value for industry. At the same time, industry interviewees said that while they also want to advance the science and are motivated to solve social problems and improve the human condition, they assess investments in university research based on their return on investment. While it is not possible to know how research will progress, they choose researchers and partners they know will deliver value.

Mutual trust and professional respect at the faculty level. Building trust in a university-industry partnership occurs over time. Some university-industry partnerships start when industry and university scientists meet at conferences and develop mutual professional respect. The scientist-to-scientist match in interest is key to growing these grass roots partnerships. They might be jumpstarted by a previous professional relationship or an alumni relationship. In most cases, trust must be built over a series of growing interactions so that the relationship is tested in lower risk situations, working through any issues that cause problems, and then, if successful, moving to longer-term, higher-risk engagements.

Long-term perspective. University and industry interviewees said that a long-term perspective on a relationship is important to its success. While the partnership will usually begin with a series of engagements to test how well the partners work together, they are looking for longer-term partnerships and are willing to invest in ensuring that partnership is on solid footing.

Faculty with industry experience. Both university and industry interviewees mentioned that the partnership can benefit from a faculty member with experience in industry because it helps them to understand the research culture, motivations, and business environment of industry. If they can see the potential commercial applications of their

inventions and the fit between the company's goals and their research, they may be more successful in directing their research toward applications that will have market value, therefore attracting funding from companies. For some companies, summer sabbaticals for faculty help build this expertise in universities they value as partners.

Mutually agreed upon expectations. Both industry and universities believe that agreement on expectations will reduce misunderstandings. This might include mutual agreement on methods for measuring and reporting success.[7]

Effective relationship management. Both universities and industry mentioned that it is very beneficial to charge specific people with the responsibility of managing the university-industry relationship. For universities, this usually takes the form of a corporate relations office with personnel charged with ensuring clear, up-front communication about motivations and expectations. It may also mean training faculty in techniques of relationship management, since it is neither possible nor desirable for university corporate relations offices to manage all the individual interactions occurring between faculty and industry. Some universities have distributed systems, where the central corporate relations offices manage the largest and broadest relationships that span different departments or institutes, while each college or research unit may also have a corporate relations officer that can handle the relationships that are important to that individual unit. Corporations can have similar university engagement functions. The industry models vary from charging alumni from the partner university to serve as a campus champion to having centralized university relations units. University corporate relations staff provide a valuable service to their faculty by understanding and navigating the varied corporate-university relations structures found in industry.

THE UNIVERSITY OF MINNESOTA IS FOCUSING ON HOLISTIC CORPORATE ENGAGEMENT AND HAS LAUNCHED A CORPORATE ENGAGEMENT CENTER to offer relationship management and match-making to fulfill corporate needs.

Standard or simple agreements or templates. Industry and universities both discussed the benefits of a template agreement or set of standard agreements that are acceptable to the university. Clarifying the terms up front allows universities and industries to quickly decide if there is a possibility of an agreement, saving time for both universities and industries.

7 UIDP has published relationship metrics that may be helpful. *Collaboration Metrics 2021*. UIDP.

Enablers Mentioned by University Interviewees

Multifaceted relationships. One university interviewee mentioned that strong industry partnerships have many touchpoints, so that if a single contact leaves, or if a project needs attention from others, there is a network within the partnership to capture value and build upon success. Furthermore, relationships that involve not only research but also student internships, membership on advisory committees, participation in events, etc. will bring multiple sources of benefit to each partner. This can encourage the partners to maintain the relationship if one aspect of the relationship, such as a disagreement over a research project, runs into problems.

Committed partnership strategy. Some university leaders said that a clearly articulated industry partnership strategy fully supported by university leadership is critical to strong partnerships.

Internal champion with influence. Universities prefer that companies identify champions for the university partnership. The champion, who might be an alumnus or have some other previous connection to the university, provides a point of contact to ensure clear communication, advance the partnership with the company's leadership, and provide partnership management.

Mentioned by Industry Interviewees

Geographic proximity. Many companies find geographic proximity to a university an enabler because there is a possibility multiple types of interactions: co-location of research staff, opportunities to engage and participate in programming and events, etc. This gives company researchers and recruiters the opportunity to get to know university faculty and students. This is especially true where there is strong alignment between the company's talent needs and the university's degree programs.

What are the most effective mechanisms for securing, establishing, and expanding research collaborations between industry and academic institutions?

There was quite a bit of agreement between university and industry representatives about what mechanisms are effective in gaining industry interest in university research, establishing a partnership, and expanding research collaborations.

Centers and institutes provide a focal point for communicating technology strengths that may be of interest to industry, and offer strategic areas of focus for specialized research, investment, and support. They signal the co-investment that industry looks for in a university partner. They also provide a way to convey multidisciplinary and transdisciplinary capabilities that industry values.

Master agreements with general terms agreed upon ahead of time may be reserved for partnerships that have matured to the point where multiple projects are expected. This agreement saves time and legal fees. A master agreement enables a project to move forward much more quickly.

Joint steering committees were mentioned as a great tool for keeping larger partnerships on track, staying in communication, evaluating the success of the partnership, and co-determining research direction. Joint steering committees should have equal representation from leadership of the company and university.

An effective alliance/relationship management function can assist both universities and companies to maximize the benefits of their strategic partnerships. This is usually structured through a corporate/university engagement office. Ideally, university corporate engagement offices have alignment from development and alumni offices.

Industry-university consortia. Some industry and university interviewees mentioned consortia as an important university engagement mechanism, but this assessment was not shared by all interviewees. It likely depends on the strength of the consortia and its effectiveness in identifying opportunities for joint investment that will move the science forward and provide a return on investment.

What might be the first steps to creating a more user-friendly, scalable partnering infrastructure?

There was broad agreement between industry and universities on principles for improving research relationships:

- Understand and articulate each partner's strengths, interests, and intended role in the innovation process.
- Demonstrate a mutual commitment to advancing the science in an area of shared strategic interest.
- Develop a long-term vision for the partnership and its ability to generate mutual value and value for the economy and for society.
- Invest in a centralized relationship management function and in personnel with experience nurturing industry-university partnerships.

Universities currently employ a variety of strategies to improve their research relationships with industry:

- Cultivate talent relationships with industry; they can lead to research relationships.

- Leverage faculty connections that naturally arise from mutual research interests with industry scientists; coach faculty on how to build on that interest toward a partnership.
- Use multiple touch points with companies to maintain momentum and interest.
- Understand the company's growth strategy and the technologies that will play an important role in that strategy. Clearly communicate university strengths in the areas that align with the company's technical and market goals. When possible, commit to mutual investment in shared resources that align with industry as well as the university's research strategy.
- Search for and implement solutions that address common pain points in the contracting and relationship management systems. Test the proposed solutions with valued partners to be sure they don't create new problems.
- For some industries, scout for smaller companies with high-growth potential in emerging areas of strength; they provide an opportunity to grow university strengths to meet companies' needs as they grow.
- In some industries, look for trends toward decentralizing R&D that may create opportunities to foster research collaborations.
- Identify opportunities to partner on government funding proposals that encourage or require industry participation and ensure there is mutual value in the partnership.
- Spend time nurturing relationships; use a relationship management approach to maintain regular communication and share information internally to ensure alignment.
- Leverage the university's brand; it offers value for many companies.

Based on these findings, what are some potential policy levers for advancing this agenda?

Most interviewees from both universities and industry felt that many of the steps needed to improve university-industry research relationships require internal investment and strategy. However, there were some public policy steps that might be taken by federal and state government entities as well.

▶ FEDERAL POLICY OPTIONS

Options Mentioned by Universities

Create additional funding programs for translational research, gap research, and collaborative research. Most universities believe that translational research is underfunded, and that additional funding for translational research, gap research, and

funding that explicitly supports industry-university collaborative research could help to close the gap between the two independent R&D systems for industry and universities. Developing these programs requires open communication between industry and funding agencies to ensure that technologies advanced by these programs are most likely to improve the future competitiveness of the nation.

Offer additional funding for student and post-doc experiences in industry. There was broad agreement among university and industry interviewees that funding in this area could go a long way toward building the relationships, trust, and shared interest that are essential to successful collaborative R&D.

Examine geographic patterns of research funding. There are already programs such as EPSCoR that work toward enhancing research competitiveness in areas that are important to improving national science capacity. However, some feel that these programs have not done enough to provide opportunities for more equitable distribution of funding across states.

Reduce the delay in federal funding decisions. Some university interviewees felt that a quicker timeline for federal grant decisions would help university researchers address urgent research questions that are important to industry through their federally funded grants.

Options Mentioned by Industry

Maintain or enhance federal funding for basic research. Federal funding for basic research in universities must be maintained or universities will not generate the ideas that lead to innovation by industry.

Offer additional funding for student and post-doc experiences in industry. This was important to both industry and university interviewees.

Continue to enhance the Manufacturing USA model. The model's enhancements in workforce development are important to the competitiveness of the manufacturing industry.

Offer more dual employment opportunities. Work through policy issues related to conflict-of-interest issues to enable dual employment between the company and university that enhances partnerships and shared understanding of strategic goals.

Provide the opportunity for additional funding without diluting IP to further commercialize technologies developed at universities. The de-risking would make the technologies and research a more interesting investment.

▶ STATE AND LOCAL POLICY OPTIONS

Options Mentioned by Universities

Incentivize stronger regional collaboration. State and local governments can use funding to incentivize stronger regional collaboration among universities and with industry to address research compositeness for important regional industries.

Assist in convening and incentivizing partners. Local economic development agencies can be very helpful when they bring industry partners to the table for big collaborative research proposals to the federal government. They can be useful conveners and can offer incentives, such as matching funds, that improve the competitiveness of proposals.

Next Steps

ISSUES REQUIRING FURTHER EXPLORATION

Many opportunities for improving university-industry collaborations have been highlighted in this report. Existing structures exist for working through some of these issues, making recommendations, and developing and executing strategy.

APLU's Council on Research and its Future of Research Working Group are working together to prioritize them in collaboration with the Commission on Economic and Community Engagement (CECE).

The University Industry Demonstration Partnership (UIDP) and the Government-University-Industry Research Roundtable (GUIRR) are both existing structures for collaboration on these issues. They can take the highest priority issues and work on them collectively.

GUIRR serves as a catalyst and forum for cross-talk and interdisciplinary thinking. The Roundtable convenes meetings on pressing national/global challenges that require greater involvement, collaboration, and/or communication between government, academia, and industry sectors. The topics considered generally fall into three buckets: New/Emerging Technologies (i.e., blockchain, quantum information systems; machine learning); Societal Focus (i.e., health equity, sustainability, misinformation); and Policy (i.e., workforce, research infrastructure). The goal is to tease out and identify roadblocks to progress (over- or under-regulation, misalignment of priorities, varying timelines, lack of incentives, etc.) as well as opportunities for collaboration and partnership across sectors and disciplines to affect change. The UIDP was created initially as a project under GUIRR specifically to address issues impacting university-industry relations.

Appendix A

ADDITIONAL DATA

Figure A-1. Number and percentage of publications in Automotive Engineering with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.

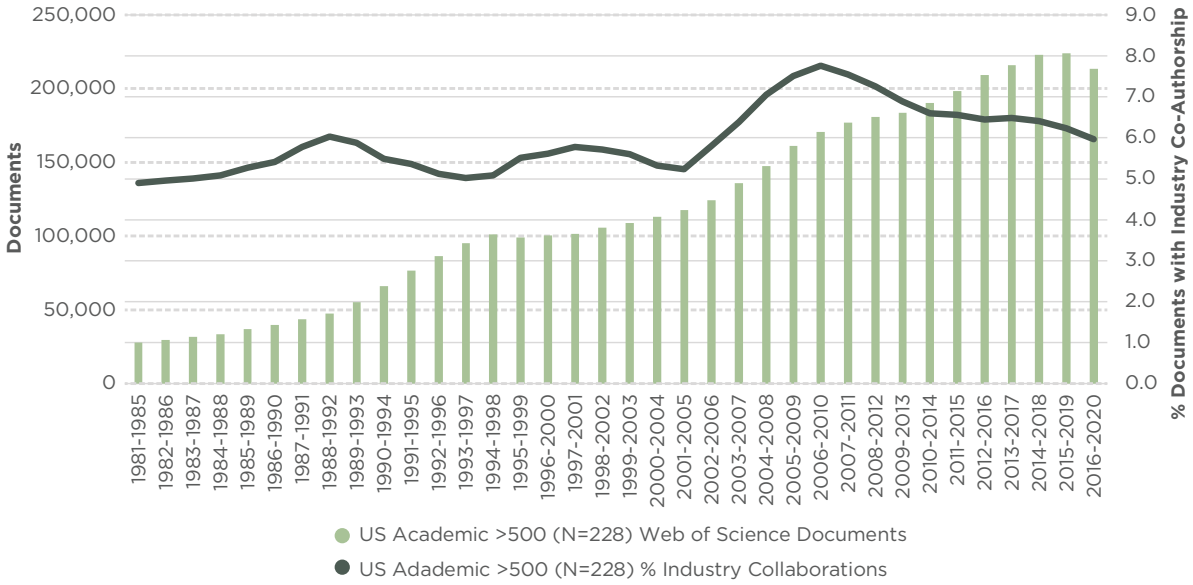

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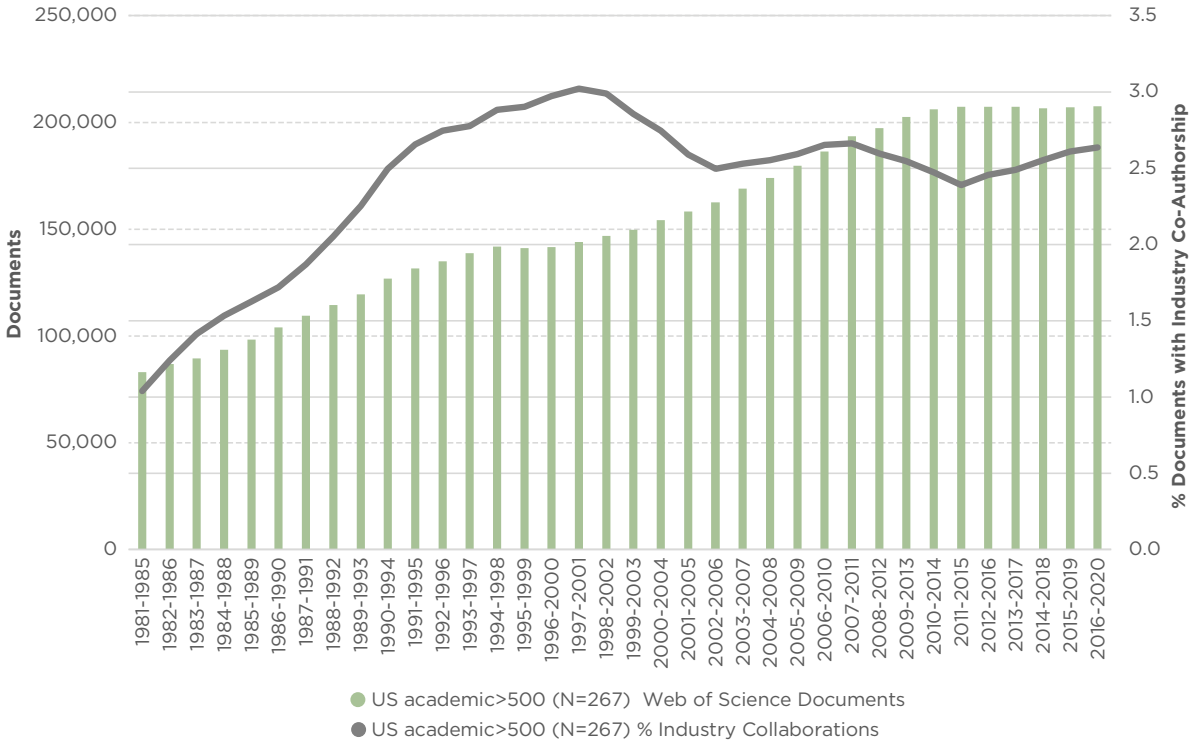
Figure A-2. Number and percentage of publications in Biotechnology with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.



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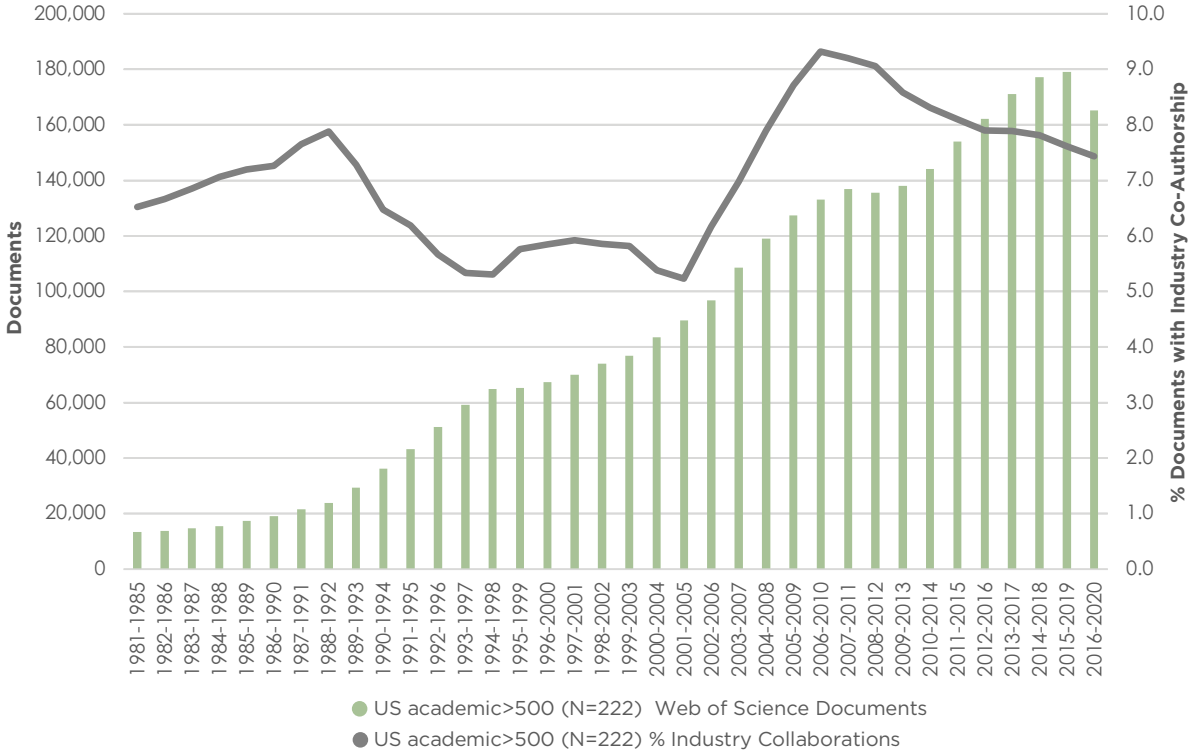
US Academic: Institutions with >500 documents between 1981-2020; Exported date Jun 21, 2021. InCites dataset updated 2021-05-28. Includes Web of Science content indexed through 2021-04-30.

Figure A-3. Number and percentage of publications in Telecommunications with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.



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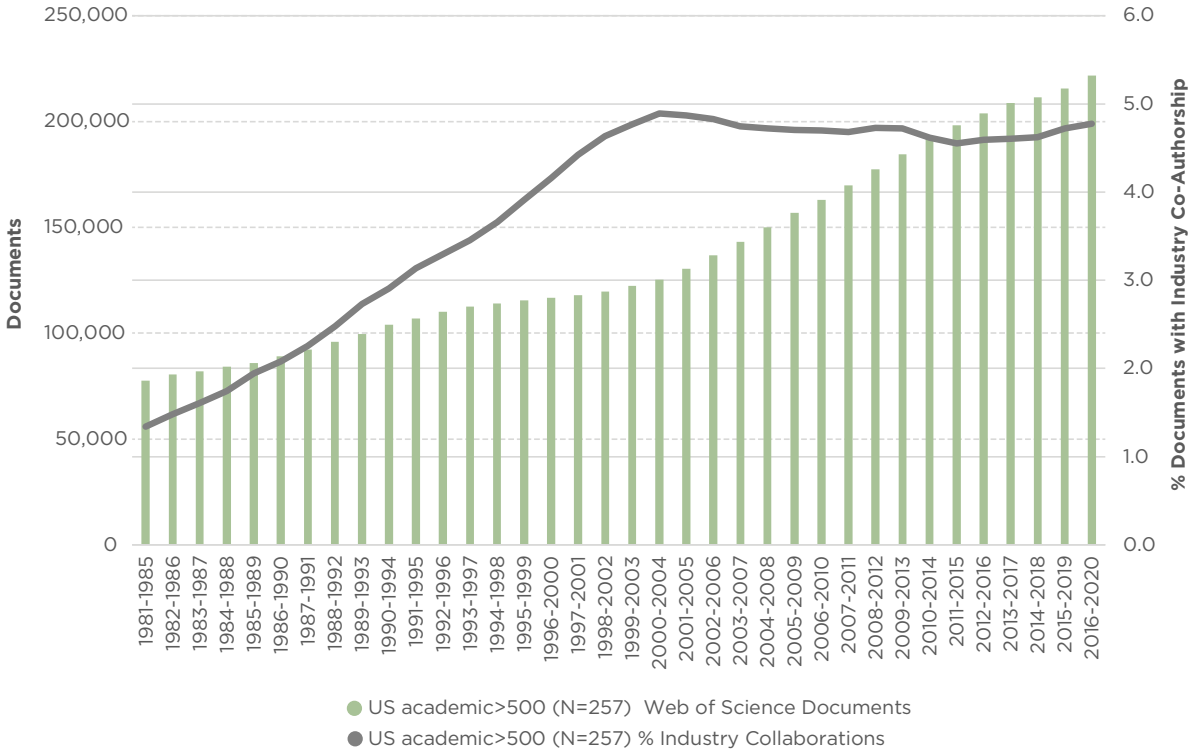
InCites dataset updated 2021-05-28. Includes Web of Science content indexed through 2021-04-30.

Figure A-4. Number and percentage of publications in Pharmaceuticals with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.



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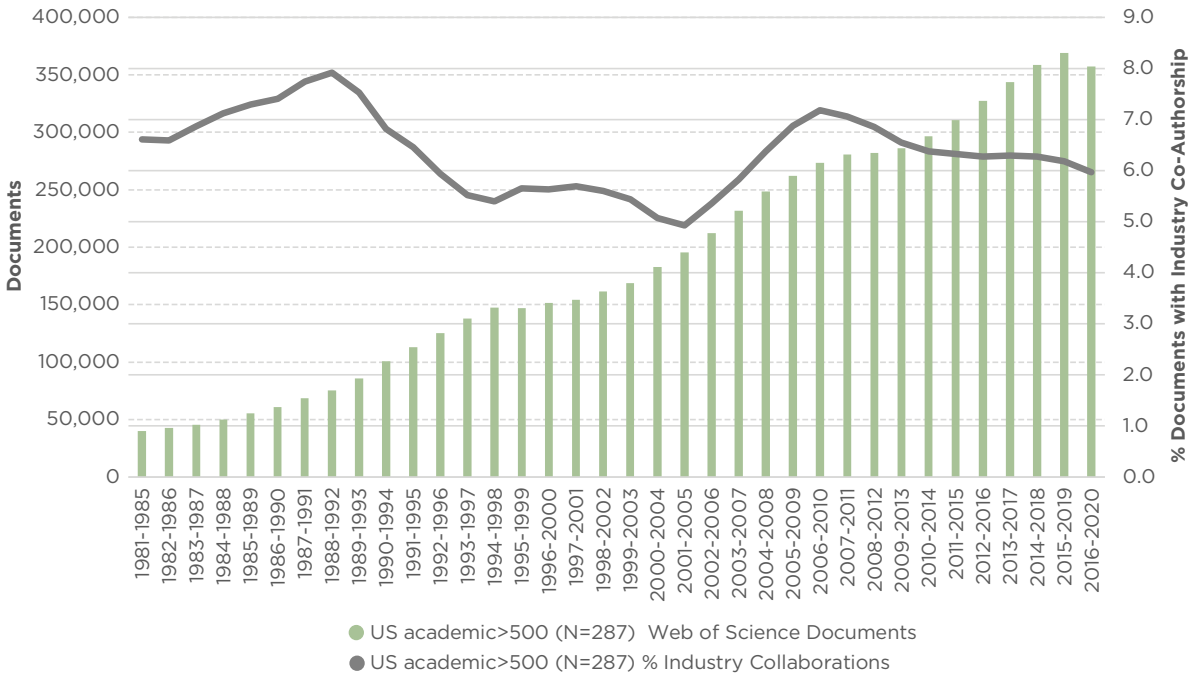
Document Type: [Proceedings Paper, Note, Article, Review]
Research Area: [VETERINARY SCIENCES, RHEUMATOLOGY, PHARMACOLOGY & PHARMACY, ONCOLOGY, INFECTIOUS DISEASES, CRYSTALLOGRAPHY, CHEMISTRY, ORGANIC, CARDIAC & CARDIOVASCULAR SYSTEMS, VIROLOGY]
US Academic: Institutions with >500 documents between 1981-2020; Exported date Jun 21, 2021. InCites dataset updated 2021-05-28. Includes Web of Science content indexed through 2021-04-30.

Figure A-5. Number and percentage of publications in Computing and Quantum Computing with university-industry co-authorship, 1981 to 2020, five year overlapping intervals.



Filter Summary:
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Document Type: [Proceedings Paper, Note, Article, Review]
Research Area: [PHYSICS, APPLIED, PHYSICS, CONDENSED MATTER, NANOSCIENCE & NANOTECHNOLOGY, MATERIALS SCIENCE, MULTIDISCIPLINARY, ENGINEERING, ELECTRICAL & ELECTRONIC, COMPUTER SCIENCE, SOFTWARE ENGINEERING, COMPUTER SCIENCE, INFORMATION SYSTEMS, COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE, COMPUTER SCIENCE, HARDWARE & ARCHITECTURE, COMPUTER SCIENCE, THEORY & METHODS, COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS, QUANTUM SCIENCE & TECHNOLOGY]
US Academic: Institutions with >500 documents between 1981-2020. Exported date Jun 21, 2021. InCites dataset updated 2021-05-28. Includes Web of Science content indexed through 2021-04-30.

Appendix B

INTERVIEW PROTOCOLS

EXPLORING SUCCESS FACTORS TO DRIVE U.S. R&D COMPETITIVENESS QUESTIONS TO REVIEW WITH ACADEMIC INTERVIEWEES

QUESTIONS RELATED TO CURRENT R&D APPROACH

- Tell me about your organization's R&D goals and primary focus areas.
- How would you characterize your mix of R&D activities in support of those focus areas?
- How do you identify the research areas that merit investment?

QUESTIONS RELATED TO PARTNERING ACTIVITY

PARTNERING APPROACH

- For instances where you choose to partner, does your institution have an overall R&D partnering strategy?
  - If so, do you feel it is meeting your R&D needs?
  - How do U.S. companies fit into that strategy?
  - Does your organization have a dedicated office, function, or team for managing individual R&D collaborations and/or your company's R&D collaboration portfolio?
- What do you look for in potential partners?
- How are decisions about potential partnerships made (e.g., who is consulted, by what process, using what criteria)?
- Is your academic institution limited or constrained regarding the types of industries or companies with which it can partner?

Partnerships

- What does your portfolio of R&D partnerships look like today?
  - What needs are primarily addressed through these partnerships (e.g., new technology, additional expertise)? Do you feel like they are being well met?

- Are there specific companies with which you do a lot of work? Are there companies with which you're interested in working?
- How are your R&D partnerships typically structured?
- Are there specific incentives or externalities that have shaped your portfolio (e.g., government funding, university-wide initiative)?
- Are there any market trends or university plans that could affect your research portfolio in 5-10 years? How do you see U.S. companies fitting in?

- How are your R&D partnerships typically structured? Are there special considerations depending on the type of partner?
- Focusing in on just collaborations with U.S. companies, what have you found to be true in your most successful relationships?
  - Alternatively, what have been sources of disagreement or failure? What are the key challenges to overcome?
  - Are there specific partnership mechanisms that you've found most valuable?

CLOSING QUESTIONS

- What are some of the barriers you see to innovation, R&D, and academic/industry collaboration?
- re there enablers or changes you would need to see at the regional or national level to encourage movement in the right direction?
- Are there others at the university that we should talk with that would have insights into these questions?

APLU
EXPLORING SUCCESS FACTORS TO DRIVE U.S. R&D COMPETITIVENESS
QUESTIONS TO REVIEW WITH INDUSTRY INTERVIEWEES

QUESTIONS RELATED TO CURRENT R&D APPROACH

- Tell me about your organization's R&D goals and primary focus areas.
- How would you characterize your mix of R&D activities in support of those focus areas?
- How do you go about sourcing the research you need to move things forward, deciding between doing it yourself, partnering externally, or looking to buy/license?

QUESTIONS RELATED TO PARTNERING ACTIVITY

Partnering approach

- For instances where you choose to partner, does your company have an overall R&D partnering strategy?
  - If so, do you feel it is meeting your R&D needs?
  - How do academic institutions fit into that strategy?
  - Does your company have a dedicated office, function, or team for managing individual R&D collaborations and/or your company's R&D collaboration portfolio?
  - What are the benefits you derive from your partnerships?
- What criteria do you use to source and evaluate potential partners?
  - Are these criteria consistent across all potential partners or do they vary by type of partner or planned relationship?
  - Do you feel like the criteria are adequate (or do they over/under constrain)?
- How are decisions about potential partnerships made (e.g., who is consulted, by what process)?
- Is your company subject to formal or informal policies related to academic partnerships?

Partnerships

- What does your portfolio of R&D partnerships look like today?
  - What needs are primarily addressed through these partnerships (e.g., new technology, additional expertise, scientific employee retention)? Do you feel like they are being well met?
  - Are there specific academic institutions with which you do a lot of work? Are there universities with which you're interested in working?
  - Are there special considerations for international university partnerships?
  - Are there specific incentives or externalities that have shaped your portfolio (e.g., government funding, tax incentives, company-wide initiative)?
  - What do you think that portfolio will look like in 5-10 years? How do you see academic institutions fitting in?
- How are your R&D partnerships typically structured?
  - What types of agreements are typical (MTA, Sponsored research, testing and analysis, clinical trials, etc.)?
  - What kinds of deliverables do you typically expect?
- Are there special considerations depending on the type of partner?
- Focusing in on just collaborations with academic institutions, what have you found to be true in your most successful relationships?
  - Alternatively, what have been sources of disagreement or failure? What are the key challenges to overcome?
  - Are there specific partnership mechanisms that you've found most valuable?

CLOSING QUESTIONS

- What are some of the barriers you see to innovation, R&D, and academic/industry collaboration?
- Are there enablers or changes you would need to see at the regional or national level to encourage movement in the right direction

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