THE INNOVATION IMPACT OF U.S. UNIVERSITIES

Rankings and Policy Conclusions

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Summary

America's long-term economic growth demands a stepped-up commitment to promoting the innovation impact of the nation's top-tier universities and other research institutions. For research institutions themselves, this commitment means prioritizing research, empowering great researchers, building efficient and outcomes-focused technology transfer operations, instilling cultures of innovation and entrepreneurship, and engaging with surrounding business and innovation communities. For America as a whole, it means funding more research resources and paying more attention to the worldwide competition for human talent, including high-skilled immigrants.

American universities play a pivotal role in fueling innovation, which in turn drives economic growth and raises living standards in the United States. U.S. universities spend approximately $75 billion per year on research, amounting to 13 percent of America's total spending on research and development (R&D). Most of this spending funds research activities in science, technology, engineering, and mathematics (STEM) fields.

Universities conduct a majority of the country's basic research, while the private sector largely focuses on product development, which is often reliant on discoveries from basic research. The overall volume and quality of R&D activity in turn drive the pace of technological progress in the economy as a whole.

The COVID-19 crisis has dramatically underscored the importance of great research institutions to America's well-being and economic future. Major research institutions are at the center of efforts to understand and combat the novel coronavirus, focusing new research programs on the emergency at a scale and pace reminiscent of their national defense mobilization during WWII. The economic aftershocks of the COVID-19 crisis threaten the financial models that underpin America's world-leading universities, raising urgent questions for policy makers. But institutions that build competitive research operations around life science, biotechnology, and other vital STEM fields are likely to be successful in overcoming growing challenges to traditional ways of doing business in higher education.

This report sets forth a new set of rankings of U.S. research universities and research institutions for innovation impact. We rank institutions for overall innovation output and separately for productivity in converting research inputs measured in terms of research spending to output. Our aim in publishing rankings is to highlight high-performing institutions — particularly stand-out performers in innovation impact productivity — so that other institutions, as well as policy makers and other leaders, can learn from their example. We also look closely at why some universities are exceptionally productive in generating innovation impact through their research activities.

In this report, innovation impact means the dissemination of research findings in STEM fields beyond the walls of academia in ways that directly drive technological progress in the wider economy and society.[1]

We have constructed our rankings based on data from the Association of University Technology Managers (AUTM) for the years 2013 to 2017, plus data on patent citations, academic paper citations, graduate numbers, and other university attributes from publicly available websites. We base our rankings on composite scores that combine nine variables measuring the success of universities in:

1. Technology commercialization
2. Entrepreneurship based on intellectual property and technologies licensed from the university
3. Research impact on other researchers and inventors
4. Production of STEM graduates, at the Ph.D., master's and bachelor's levels

1 To be clear, this report does not address the extent to which universities pursue innovative methods in their teaching activities or in non-STEM academic research, though we fully support the broader teaching and research missions of U.S. universities.

Our study of why some universities are so much more productive than others in creating innovation impact points to several findings:

- **Higher research spending predicts lower productivity in generating innovation impact.**
- **Universities in larger metro areas tend to produce more innovation impact than those in smaller metro areas.**
- **Universities in metros with larger immigrant population shares tend to achieve more innovation impact, independent of metro area population.**
- **The size, professional background, and policies of university technology transfer offices have surprisingly wide-ranging effects on innovation impact.**
- **The share of research spending funded by industry partners is negatively associated with innovation impact.**

Universities control their own fate in generating innovation impact to a significant degree through their allocation of resources to research, and also through policies and cultural factors related to innovation, commercialization, and entrepreneurship. **The universities that achieve the greatest innovation impact are the ones which choose to do so.**

This is a summary of a more detailed report detailing our methods, conclusions, and rankings.

Our study offers clear takeaways for university leaders as well as policy makers, business leaders, philanthropists, and communities, with the aim of improving the productivity of university research and promoting technological progress and growth in America's economy.

Summary Policy Conclusions:

For university leaders:

1. Prioritize research
2. Compete hard to attract and retain star faculty researchers
3. Run an efficient, outcomes-focused technology transfer operation
4. Instill a culture of innovation and entrepreneurship throughout the university
5. Engage closely with the surrounding business and innovation community
6. Avoid overreliance on sponsored research funding from industry
7. Monitor, quantify, and transparently disclose innovation impact results

For policy makers, business leaders, philanthropists, and communities:

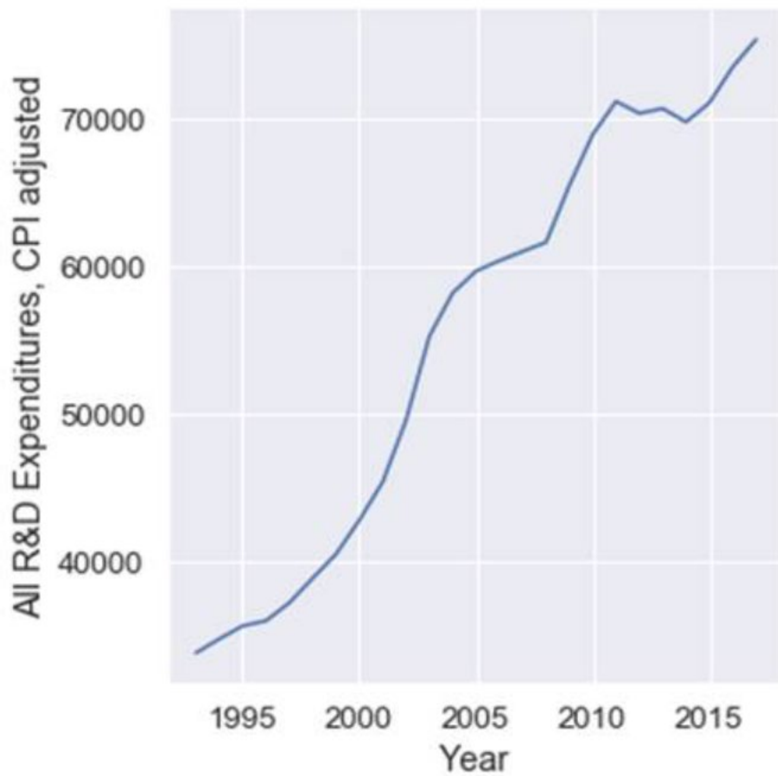
1. Increase public-sector support for university research
2. Understand how institutions vary in their innovation impact productivity
3. Compete hard for talent — including immigrant talent
4. Invest in integrated physical spaces that connect researchers with entrepreneurs, investors, and other potential nonacademic partners
5. Support technology transfer operations and other enablers of innovation impact

The role of Universities in American Innovation and Growth

The last four decades have seen a tremendous increase in the university sector's investment in patenting and commercializing intellectual property generated by university researchers. The Bayh-Dole Act of 1980 permitted U.S. universities to assert ownership of intellectual property financed partly by government funds for the first time. Between 1980 and 2017, the number of universities with dedicated technology transfer offices (TTOs) focused on patenting and commercialization activities rose from 25 institutions to more than 225.

Figure 1 shows the inflation-adjusted growth of total U.S. university investment in research since 1993:

Figure 1. Total Research Spending by U.S. Universities (USD millions in 2017 constant dollars)



Data is in 2017 constant dollars in millions. Department of Education, National Center for Education Statistics data, adjusted for changes in the U.S. Consumer Price Index, Bureau of Labor Statistics.

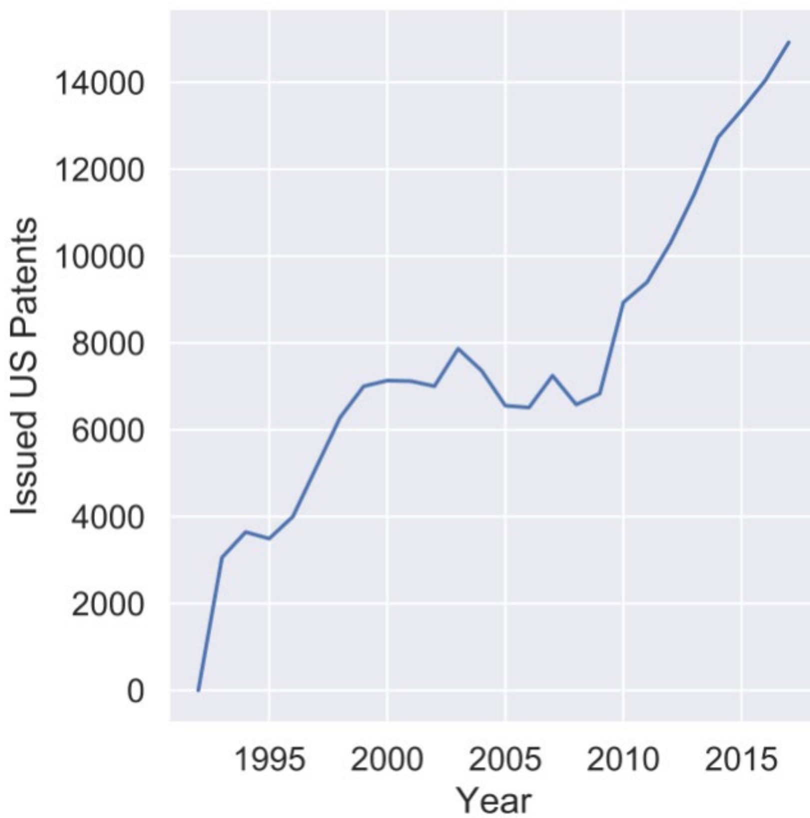
In a survey Opus Faveo Innovation Development conducted in 2014 with 92 large universities, 51 percent rated the importance of intellectual property commercialization to their university's mission as "high," while 38 percent rated its importance as "medium." Based on the survey, the top priorities of these universities related to intellectual property include commercializing patents, increasing the number of license agreements with outside businesses, launching more spinout companies, and raising more funds from industry-sponsored research.

Increased research and commercialization activities have led to large increases in innovation outputs, based upon a variety of measures.

- Patents issued each year to U.S. universities and their faculty rose more than fourfold from 1980 to 2017, growing as a share of all U.S. patents issued to American inventors.
- The number of new spinout companies launched by university TTOs increased from virtually zero in the 1970s to approximately 1,000 per annum from 2013 to 2017.
- Aggregate income to universities from licensed intellectual property rose from approximately $200 million in 1990 to almost $3 billion by 2015, a sixfold increase, after adjusting for inflation.

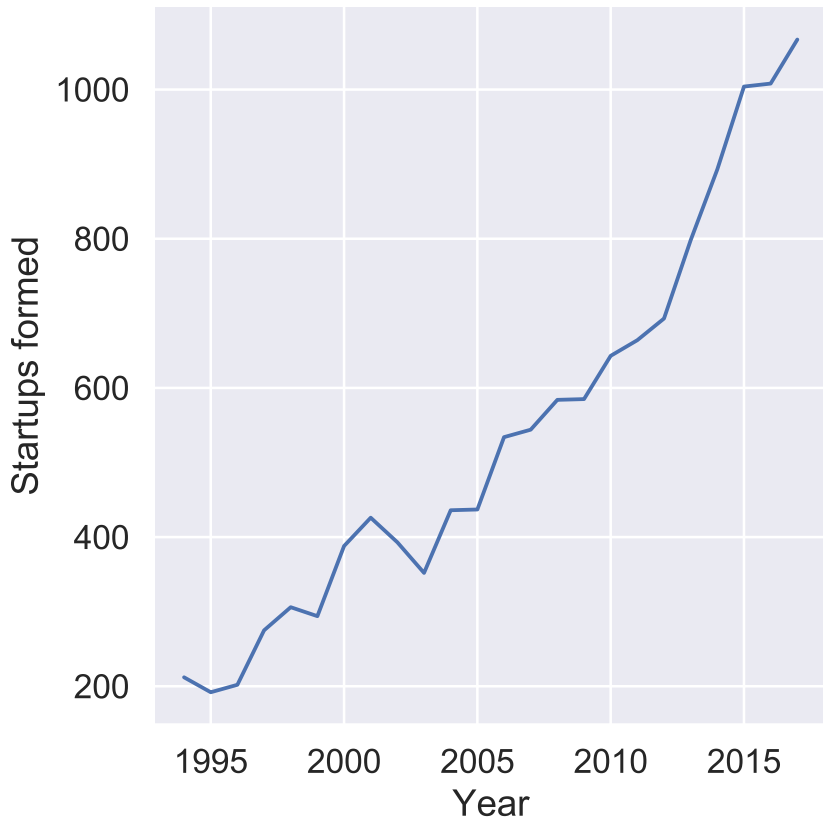
Figures 2 and 3 show the aggregate growth in issued patents and spinout companies, respectively. Each reflects aggregate data for institutions that report to AUTM.

Figure 2. Total Patents Issued to U.S. Universities



Association of University Technology Managers dataset.

Figure 3. Total Spinout Companies Launched by U.S. Universities



Association of University Technology Managers dataset.

Benefits from Innovation Activities

Increased innovation activity has brought significant benefits to U.S. universities, the localities in which they reside, the national economy, and society as a whole.

Universities:
Commercializing intellectual property has paid dividends in numerous forms. The 225 universities for which we have data earned aggregate license income of $2.98 billion per year on average between 2013 and 2017, amounting to a 4 percent return per annum on total research spending during the period. A number of America's largest universities spending between $500 million and $1.6 billion per year on research have created license income streams of $50 million to $250 million a year, generating annual returns in excess of 10 percent.

Innovative research activities also play an increasingly important role in attracting high-quality faculty and students. In the 2014 Opus Faveo survey, 75 percent of universities said that technology commercialization success is "very important," "important," or "somewhat important" in recruiting faculty members. And 53 percent said it's at least "somewhat important" in attracting students.

Contrary to early fears that a rising emphasis on commercialization would detract from the quality of basic research, numerous studies have found evidence for positive relationships at the level of overall universities between patent applications on the one hand and research publication quantity and quality on the other (see here, here, and here).

Localities:
Studies in Europe and the United States have found that a disproportionate share of the technology spillovers from university research to the private sector occur locally. Other studies have found that localities with a relatively rich portfolio of research-intensive universities have experienced greater R&D activity, innovation, and growth among local firms than have other places (see here and here). And a university's research and teaching work also spills over to its local economy by producing STEM graduates who frequently opt to stay in the area for the long term.

The National Economy:
Between 2011 and 2015, the 225 research institutions in our dataset produced an average of 62,542 doctoral graduates and 399,129 bachelor's or master's degree graduates per year in STEM fields, amounting to more than 10 percent of the individuals entering (or re-entering) the U.S. labor force each year. Growing numbers of STEM graduates, together with high-skilled immigrants, have contributed to a doubling in the share of the U.S. workforce engaged in R&D activities since the 1980s.

While we cannot be confident about how much the innovation impact of U.S. universities has added to America's economic growth, economists generally agree that technological progress and a rising stock of human capital — both of which owe a great deal to America's universities — have accounted for at least 70 percent of the nation's long-term average growth of 2.0 percent in Gross Domestic Product (GDP) per capita over the last century.

Social Benefit:
University research has spawned a wide variety of products with significant societal benefits, including the automobile seatbelt from Cornell University, Global Positioning System technology from Massachusetts Institute of Technology (MIT), beta carotene-rich "golden rice" from Louisiana State, fluoride toothpaste from Indiana University, the cancer drug Cisplatin from Michigan State, the glaucoma drug Trusopt from The University of Florida, antiretroviral drugs from Yale University, the calcium supplement Citracal from The University of Texas Southwestern Medical Center, genome-sequencing techniques from Tufts University, web browsers from The University of Illinois at Urbana-Champaign, and the Google search engine from Stanford University.

Cold Spring Harbor Laboratory, a premier private, nonprofit research institution, illustrates the social benefits derived from cutting-edge research well. The Laboratory played a key role in the discovery of DNA and has long been among the premier research centers engaged in elucidating the genetics and molecular biology of cancer. In 2016, the FDA-approved SPINRAZA®, a drug for the deadly childhood disease Spinal Muscular Atrophy that researchers at Cold Spring Harbor Laboratory discovered using the lab's novel RNA-splicing technology. SPINRAZA® was the first approved drug that alters the underlying biology of a neurodegenerative disease.

For all these reasons, America has a vital interest in supporting the innovation impact productivity of its research universities and institutions.

Our Approach

Our rankings include 195 institutions, based on the availability of data from the Association of University Technology Managers dataset for the years 2013 to 2017.[2]

2 A small number of prominent institutions — notably Yale University and most prominent liberal arts colleges — do not report data to AUTM, so we cannot include them in our rankings.

We calculate a composite innovation impact score for each university, comprising nine variables grouped into four categories:

1. Commercialization impact:
    - New patents issued
    - New licenses
    - License income
2. Entrepreneurship impact:
    - Spinout companies
    - Licenses to spinout companies
3. Research impact:
    - Paper citations
    - Patent citations
4. Teaching impact:
    - New STEM doctoral graduates
    - New STEM bachelor's and master's graduates

In contrast to existing ranking systems[3], we separately rank universities according to their overall innovation impact and according to productivity in generating innovation outputs from research inputs, measured by research spending. Our approach reflects the observation that some universities might have large output but only moderate productivity, while some smaller institutions might be especially productive but generate only medium-sized overall innovation impact because their research resources are more modest.

Table 1 summarizes our data for university research spending, as well as for our nine output variables. All figures represent annual averages over the years between 2013 and 2017.

Table 1. Summary of Data on Research Spending & Innovation Impact

	Highest Value	10th-2nd Highest Values	Media Value	No. of Institutions	Top Institution
Research spending ($m)	$4,999	$1,018 - $2,676	$160	217	Univ. of California system
Licenses signed	315	138 - 275	13	209	Univ. of Washington
License income ($m)	$327	$86 - 235	$2	211	City of Hope Med. Ctr.
Patents issued	457	114 - 297	14	214	Univ. of California system
Spinout companies	81	16 - 29	3	216	Univ. of California system
Licenses to spinouts	72	24 - 45	3	208	Univ. of California system
Paper citations (000s)	1,100	253 - 654	18	225	Univ. of California system
Patent citations	43,608	3,065 - 13,812	145	225	Cold Spring Harbor Lab
STEM doctoral graduates	3,883	907 - 2,456	160	225	Univ. of California system
STEM bachelor's/master's grads	22,953	5,378 - 17,494	1,184	225	Univ. of California system

3 We describe the differences between our ranking system and two prominent existing systems in the longer version of this report (here).

We construct our scores for innovation impact for each university by calculating 2013 to 2017 annual averages for each of the nine output measures to smooth out fluctuations in the data, standardizing the annual average for each measure to make the distributions for the nine output variables comparable, and aggregating the nine standardized variables into a composite score using principal component analysis (PCA), a standard statistical technique. The chief benefit of using PCA is that it essentially allows the data to tell us what the implicit weighing factor on each of the nine standardized variables should be.

As a double-check, we also calculate composite scores taking a simple weighted average of the nine standardized variables, as other ranking approaches in the literature generally do.

We evaluate the productivity of institutions in converting inputs to outputs by dividing each university's composite PCA score by its total research spending.[4] We view this ratio as a reasonable measure of productivity, based on two considerations. One is that the numerator effectively preserves scale relationships across universities. If one university has twice as much output as another university on all nine output measures, then it will have twice as high a PCA score. The other consideration is that the denominator, research spending, is in our view a reasonable proxy for total research inputs. The longer version of this report explains our data and methods in detail.

Rankings

Innovation Impact Rankings

Table 2 sets forth our ranking of the top 25 U.S. universities for overall innovation impact.[5] Table 2 also shows the innovation impact rank of each institution based on our alternative method, using simple weighted averages across our output variables. Our two methods generate very similar rankings. Finally, we include the rankings of each institution for commercialization impact, entrepreneurship impact, research impact, and teaching impact, all based on our alternative weighted average method.[6]

As Table 2 shows, the leading universities for innovation impact create far greater innovation impact as we measure it in this report than most other institutions. The University of California and University of Texas systems, which like numerous state systems report data to AUTM at the system level, achieve innovation impact significantly above even the next several institutions, reflecting their vast scale. The 10th-ranked University of Pennsylvania scores more than five times higher than the median institution in our ranking, even though most of the 195 institutions in our dataset are relatively large in terms of research spending.

In a handful of cases, the choices institutions have made about how to report data to AUTM modestly influence the rankings. For instance, the Johns Hopkins University Applied Physics Laboratory reports separately from the rest of Johns Hopkins University. If the two reported their data as one institution, Johns Hopkins University would report research spending roughly equivalent to that of the University of Texas system and would rank approximately 8th in innovation impact, instead of 11th and 125th. If Harvard University included the data from its associated hospitals which report separately, its research spending would approach $1 billion and its innovation impact ranking would rise several spots.

4 To calculate the scores we report for innovation impact productivity, we multiply each institution's ratio by 108 to arrive at more readable figures.
5 The table provides each university's PCA score, recalibrating scores such that the top-ranked University of California system earns an adjusted score of 100. The long version of this report (here) sets forth our comprehensive ranking of all 195 institutions for innovation impact.
6 Note that our principal component analysis (PCA) necessarily uses all nine output variables, so we cannot generate scores for commercialization impact, entrepreneurship impact, research impact, and teaching impact using PCA.

Table 2. Ranking of Top 25 Universities for Innovation Impact

		Innovation Impact Score (PCA)	Total Research Spending ($m)	Innovation Impact Productivity Score	Innovative Impact Rankings (simple weighted average method)				
					Overall Rank	Comm Rank	Entrep Rank	Res Rank	Teaching Rank
1	University of California System	100.00	$4,998.8	2.00	1	1	1	1	1
2	University of Texas System	55.03	2,675.9	2.06	2	2	2	4	2
3	MIT	31.25	1,639.4	1.91	3	4	3	9	56
4	University of Washington	29.56	1,197.9	2.47	6	3	6	18	10
5	University of Michigan	28.70	1,362.5	2.11	5	10	7	10	7
6	University of Florida	28.11	565.1	4.97	7	7	9	28	4
7	Columbia University	27.24	753.8	3.61	4	8	5	5	27
8	University of Minnesota	24.92	916.2	2.72	8	15	15	15	6
9	Stanford University	24.53	946.1	2.59	9	11	8	12	39
10	University of Pennsylvania	23.25	908.1	2.56	11	13	10	14	35
11	Johns Hopkins University	22.86	1,632.0	1.40	12	16	16	6	29
12	University of Illinois U-C	21.02	1,014.9	2.07	13	20	17	11	22
13	University System of Maryland	20.30	1,018.2	1.99	15	35	14	26	3
14	University of Wisconsin-Mad.	19.32	1,120.6	1.72	18	14	35	24	16
15	Purdue Research Foundation	19.15	611.4	3.13	17	28	18	27	11
16	Northwestern University	18.56	554.1	3.35	14	6	22	19	59
17	New York University	18.09	546.5	3.31	16	9	31	22	32
18	University of Pittsburgh	17.83	732.4	2.43	21	21	20	30	23
19	Cornell University	17.29	801.6	2.16	20	22	27	16	50
20	North Carolina State University	17.12	464.4	3.69	23	29	12	36	28
21	Harvard University	17.08	827.9	2.06	19	32	29	7	53
22	Ohio State University	16.81	924.7	1.82	22	46	36	20	8
23	Duke University	16.77	897.7	1.87	24	19	34	13	64
24	University of Utah	16.45	386.8	4.25	26	23	11	48	48
25	State University of New York	16.36	949.3	1.72	25	34	26	33	13
	Median institution:	**4.17**	**160.0**	**2.68**					

The complete ranking of 195 institutions is available in the longer version of this report (here).

Our rankings on the right side for commercialization, entrepreneurship, research, and teaching demonstrate that, with few exceptions, the universities that rank high overall for innovation impact rank high in each of these four categories as well.

Several private universities — MIT, Columbia University, Stanford University, the University of Pennsylvania, Johns Hopkins University, Northwestern University, Harvard University, and Duke University — rank somewhat lower in the teaching impact category than they do in the other three categories, as they are considerably smaller than the largest state universities in student numbers. A handful of institutions, meanwhile, rank significantly higher in one category than in the others, such as Northwestern and NYU in commercialization impact, the University of Utah and North Carolina State in entrepreneurship impact, Harvard in research impact, and the University of Maryland system and Ohio State in teaching impact.

Innovation Impact Productivity Rankings

Table 3 presents our rankings for the top 10 institutions for innovation impact productivity in each of five categories. Our categorization breaks down the 162 comprehensive research universities into three equal-sized groups of 54 each based on total research spending. Institutions in the group of largest universities had 2013-17 average annual research spending between $333 million and $5 billion, while the mid-sized institutions spent between $100 million and $333 million per year, and the smaller institutions spent less than $100 million. We treat pure medical institutions and research/health care institutions as two additional, separate groups. We separate institutions in this way because we believe that when comparing institutions on productivity, it makes more sense to compare institutions to peers of roughly similar size and mission than to institutions that differ widely in both respects.

Table 3 includes the innovation impact productivity score for each institution, calculated as our PCA innovation impact score divided by total research spending. We also include each institution's rank within its group based on our alternative weighted average method, and again, the rankings don't change much under the alternative method.

As Table 3 illustrates, the five groups differ significantly from one another in innovation impact productivity, in the scores of both their top performers and their median institutions. Within the group of smaller comprehensive research universities, first-ranked Brigham Young University has a productivity score of 30.21, far above any other institution in our study. And Drexel University, the productivity leader in the mid-sized group, scores far ahead of any member of the largest research university group.

Table 3. University Rankings for Innovation Impact Productivity

	Largest Research Universities:	**Innovation Impact Productivity Score**	**Rank Based on Weighted Average**
1	University of Florida	4.97	1
2	University of Utah	4.25	2
3	California Institute of Technology	3.93	17
4	University of Chicago	3.80	3
5	North Carolina State University	3.69	6
6	Columbia University	3.61	4
7	Northwestern University	3.35	5
8	NYU	3.31	8
9	Purdue University	3.13	11
10	University of Georgia	3.01	12
	Median of group:	**2.09**	

	Mid-Sized Research Universities:	Innovation Impact Productivity Score	Rank Based on Weighted Average
1	Drexel University	7.85	1
2	University of New Mexico	6.77	2
3	Princeton University	5.68	3
4	Carnegie Mellon University	5.42	4
5	University of Central Florida	4.78	5
6	University of New Hampshire	4.57	8
7	University of Houston	4.34	6
8	Washington State University	4.27	7
9	Rice University	4.12	9
10	Temple University	3.70	10
	Median of group:	**2.81**	

	Smaller Research Universities:	Innovation Impact Productivity Score	Rank Based on Weighted Average
1	Brigham Young University	30.21	1
2	University of Wisconsin - WiSys	20.30	2
3	Northern Illinois University	15.83	3
4	Duquesne University	15.43	4
5	Creighton University	14.39	5
6	Ball State University	12.56	12
7	Stevens Institute of Technology	12.49	6
8	University of North Carolina at Charlotte	10.09	8
9	University of North Florida	9.91	7
10	East Carolina University	9.45	9
	Median of group:	**5.13**	

Table 3. University Rankings for Innovation Impact Productivity (cont.)

	Pure Medical Schools:	Innovation Impact Productivity Score	Rank Based on Weighted Average
1	University of North Texas Health Science Center	6.15	1
2	Georgia Health Sciences University	3.33	2
3	Medical University of South Carolina	2.21	3
4	Mayo Foundation for Medical Education and Research	1.55	4
5	Baylor College of Medicine	1.49	5
6	Mount Sinai School of Medicine of NYU Medical Center	1.46	6
7	Medical College of Wisconsin Research Foundation	1.06	7
	Median of group:	**1.55**	

	Pure Research/Health care Institutions:	Innovation Impact Productivity Score	Rank Based on Weighted Average
1	Cold Spring Harbor Laboratory	10.87	1
2	Whitehead Institute for Biomedical Research	6.08	2
3	Jackson Laboratory	4.41	3
4	Hospital for Special Surgery	3.27	4
5	The Wistar Institution	3.02	5
6	City of Hope National Medical Center	2.58	6
7	Moffitt Cancer Center	2.36	7
8	Salk Institute for Biological Studies	2.30	8
9	National Jewish Health	2.28	9
10	Cedars-Sinai Medical Center	1.91	10
	Median of group:	**1.40**	

Table 3 separates research universities into the three categories of largest, mid-sized, and smaller based on each university's average total research spending between 2013 and 2017. The cutoff points separating the three groups are $333 million and $100 million. The complete productivity rankings of all 195 institutions are available in the longer version of this report (here).

Explaining Success in Generating Innovation Impact Productivity

Through a variety of statistical methods, we analyze the influence of numerous factors, which we group into four categories: (1) scale of the university and its research effort; (2) attributes of the metro area where the university is located; (3) other non-scale attributes of the university such as widely cited measures of faculty quality and whether a university has a medical, business, or engineering school; and (4) policy variables, meaning resource allocation decisions that universities could reasonably change.

Scale:

A variety of evidence in this study suggests diseconomies of scale in converting research inputs to innovation impact output, where we define scale according to total research spending. The correlation between total research spending and our main measure of innovation impact productivity is -0.25.

Looking at each of our nine output variables one by one, our study shows that larger research spending predicts lower productivity in turning research dollars into outputs in eight of nine cases. The one innovation impact measure which shows consistent evidence of increasing returns to scale is patent citations.

Why university innovation activities suffer declining economies of scale is a question that deserves further study. We suggest two possibilities, each admittedly speculative. First, very large institutions may have the resources to pursue marginal projects that smaller institutions cannot, which may yield societal benefits but pull down their innovation impact productivity as we measure it. Second, research activities at the largest institutions may be more subject to waste and bureaucratic inefficiencies than those at smaller universities.

Metro Areas:

Based on our analysis, metro-area population is positively associated with innovation impact productivity, as is the foreign-born share of metro-area population. A university in a metro area with a foreign-born population share of, say, 20 percent will have an innovation impact score roughly 0.7 points higher than an otherwise similar institution in a metro area with a 10 percent foreign-born share, equivalent to about 20 spots in our ranking. Looking at our nine innovation impact variables separately, the foreign-born share has especially large effects on issued patents and spinout companies.

Similar analysis on metro-area educational-attainment levels, median household income, median age, and housing prices shows very little relationship with innovation impact productivity.

The evidence we present on the positive effects of being in a large metro area is consistent with a vast literature on the economic benefits of large, diverse cities. Big cities give rise to broad diversity of firms, vibrant labor markets, and intermingling of ideas. Abundant evidence indicates that large cities enjoy higher rates of innovation and productivity than smaller places, and that this advantage is growing as the world economy becomes more knowledge centric (see here and here).

Our new findings on the benefits to a university of being in a metro area with a relatively large foreign-born population, moreover, are consistent with numerous studies on the economic vibrancy immigrant populations bring to American cities. Immigrants are roughly twice as likely as native-born U.S. citizens to file a patent application, commercialize an invention, or start a successful technology company, as research by the George W. Bush Institute has documented (see also here, here, and here). At the same time, causality likely points in both directions, as great research institutions — and the innovative ecosystems that surround them — are likely to attract high-skilled immigrants to their hometowns.

University Attributes:

The most notable result relating to non-size university attributes is that faculty quality as proxied by the number of members in the prestigious National Academies of Sciences, Engineering, and Medicine has a significant positive effect on innovation impact and particularly on issued patents and paper citations. This finding points to the importance of star researchers to innovation impact.

Our data show a slight edge for public universities over private ones, all else equal, mostly reflecting greater production of STEM graduates per dollar of research spending.

Our study reports some evidence that having a medical school improves an institution's innovation impact productivity, but no evidence that having a business school or an engineering school has any effect.

University Policy:
Seemingly small differences in the technology transfer office's size, professional makeup, and policies make a surprisingly large difference to a university's innovation impact. The most productive institutions seem to have larger TTO resources per dollar of research spending, a greater tendency to employ trained engineers as TTO heads, bigger patenting budgets per dollar of research spending, and a greater tendency to have seed funds. Based on our results, a university with a TTO staff of, say, 20 will achieve an innovation impact score approximately 1.1 points higher than an otherwise similar peer with a staff of 10, equivalent to about 10 spots in our ranking. Perhaps surprisingly, these technology transfer policies influence not only an institution's success in generating patents, technology licenses, and spinout companies but also its research impact and teaching impact.

In our analysis, the share of a university's research spending funded by industry sponsors is negatively associated with innovation impact. It is also negatively associated with success on all nine of our innovation impact measures when we analyze them separately. This finding runs counter to a widely held view in universities that industry-funded research is more economically productive than research funded by other sources.

There are numerous reasons why the size, sophistication, and commercial orientation of a university's technology transfer operation might exert a significant influence on the institution's innovation impact. One simple reason: the evidence suggests that intellectual property management and technology transfer present difficult challenges. Past studies have shown that inadequate staffing often leads to poor marketing of university inventions, that most innovative work by faculty researchers never makes it to the TTO, and that interactions between university administrations and individual researchers — including the incentives universities make available to innovative faculty members — vary widely across institutions (see here and here).

Our results raise fresh questions about how the size and professional makeup of a university's technology transfer office might influence variables the TTO does not directly touch, such as patent citations and STEM graduates. One possibility is that an effective technology transfer operation attracts unusually innovative researchers, who not only publish widely cited papers but in turn attract talented students and raise the intellectual level of the whole university.

Another hypothesis is that it is not just an effective TTO in itself but also the overall university culture in which an effective TTO comes into being that drive a university's innovation impact. Our study suggests that some institutions simply prioritize innovation activities more than others do. The University of Utah, California Institute of Technology, Columbia University, and Stanford University — all in the top third of large universities for innovation impact productivity — operate unusually large TTOs, and all besides Stanford run seed funds and "accelerators."[7] Each is known for being especially well connected to innovative businesses and venture capital firms in their localities.

As for the negative effect of having relatively large industry funding as a share of research spending, it may be that industry funding tends to push researchers towards highly applied projects that lead to fewer widely cited papers, patents, licenses, and spinout companies than projects more focused on transformational basic research. Our findings raise fundamental questions about university strategy, as our 2014 survey indicated that many institutions place a high priority on increasing their industry-sponsored research.

7 An accelerator is a program supporting early-stage, innovation-driven, growth-focused companies, typically for a short duration such as 12 weeks, through education, mentorship, financing, and sometimes office space. Prominent examples include YCombinator in the San Francisco Bay area and TechStars in Boulder, Colorado.

Case studies

The University of Florida:
The University of Florida ranks first among the group of largest universities in our study for productivity in turning research inputs to outputs. It ranks sixth in our ranking for overall innovation impact, even though it ranks only 36th in total research spending. It generated an average of 123 issued patents and 15 spinouts per year, placing it among the top-performing U.S. universities on these measures. It was also a strong performer in license income, earning an average of $36 million per annum, equal to 6.4 percent of research dollars. Additionally, the University of Florida ranks 4th overall in teaching impact. It produced one third as many STEM doctorates each year as the entire University of California system between 2013 and 2017, despite having a research budget only about one-tenth as large.

The University of Florida has famously earned more than $280 million in royalties since 1967 from its invention of Gatorade. But the university is very far from being a one-hit innovator. Its biotechnology effort has produced more than 60 companies, including more than a dozen that have been acquired by major pharmaceutical, food, agricultural biotechnology, and energy enterprises.

The University of Florida operates one of the largest and most respected technology transfer offices (TTOs) in the United States. Indeed, the university has claimed to have "the best tech transfer team in the world." The TTO has a staff of 42 and a leader with an engineering background.

Based on our interview with the TTO's chief, the TTO operates as a "high-volume shop" and takes a highly "business-like" approach to its activities. The TTO relies heavily on management tools borrowed from the business world to achieve consistency in its licensing activities.

Drexel University:
Drexel ranks first among the group of mid-sized research universities for innovation impact productivity. Between 2013 and 2017, Philadelphia-based Drexel averaged 41 issued patents and five spinout companies per year. It produced an average of 447 STEM Ph.D.s per annum, more than numerous much-larger institutions. The more than 30 spinout companies launched since 2014 cover a wide range of technologies, including wireless infrastructure, energy storage, AI-enabled software development, smart fabrics, health care management software, diagnostics, and medications for rare diseases. One Drexel University spinout has developed the Dragon Gel sports nutrition snack, which Drexel believes could be "the next Gatorade."

Drexel's TTO employs seven professionals, in line with the median institution in our dataset. But this figure understates the university's commitment to innovation impact. The university operates the Drexel Ventures University Accelerator, the Drexel Ventures Ben Franklin Seed Fund, and the Proof-of-Concept Academy. According to an interview we conducted with a longtime Drexel researcher, the university generously supports innovative researchers with funding and lab space and offers unusually favorable financial terms to inventors.

Drexel's emphasis on innovation in part reflects its heritage, as it was established as an engineering school. But the university's technology transfer policies and innovation ecosystem are also part of a much more recent, broad-based commitment to innovation and entrepreneurship. As the university's president from 1995 to 2009, Dr. Constantine "Taki" Papadakis led a comprehensive effort to promote innovation in the university's academic programs and raise the caliber of its faculty and students. He created a leading medical school and school of public health, partly through the acquisition and turnaround of a bankrupt medical institution nearby.

Drexel's efforts to promote innovation have included increasing its integration with the wider innovation community in Philadelphia. It set up lab space in the University City research and business facility operated by the larger University of Pennsylvania a few blocks away, alongside researchers from Penn, four other universities, startup businesses, and venture capital firms. Later, Drexel created the Excite Center to catalyze transdisciplinary interactions among its faculty, its students, and outside innovators in the community. It now operates the IC@3401 incubator space, which houses several dozen startup companies.

Drexel shows what a university can achieve in innovation impact when it prioritizes innovation throughout the institution and engages broadly in its home city — particularly when it's located in a large, culturally diverse metro area with other innovative institutions and deep business talent.

Brigham Young University:
BYU ranks first in our smaller research university group for innovation impact productivity. Its composite score for innovation impact between 2013 and 2017 is roughly even with those of several respected institutions spending some 10 to 20 times more per year on research. During the five years starting in 2013, BYU averaged 32 issued patents, 12 spinout companies, and $2.7 million in license income per year — a remarkable return on its modest annual research spending of about $30 million. Recent licenses cover technologies for improved contact lens coatings, a handheld liquid chromatography device for scientific research, and a camera designed to enable the Internet of Things. The numerous spinout companies developed by BYU faculty and students prominently include Qualtrics, a leader in customer experience-management solutions that has raised significant capital from venture capital firms.

BYU operates a small TTO with just three licensing professionals, but it enjoys a vast campus-wide innovation ecosystem. According to BYU, the University Growth Fund is the largest venture/private equity fund based at a higher-education institution. The business school's Rollins Center for Entrepreneurship & Technology provides space for inventors and startup entrepreneurs, mentoring, startup competitions, and frequent lectures on technology-focused entrepreneurship. BYU operates at least nine Innovation Lab spaces, covering not only life sciences and computer science but also animation, the arts, and social innovation. The campus features thriving student clubs focusing on entrepreneurship, venture investing, and design thinking. The university also is known for offering particularly generous financial terms to both faculty and student inventors.

Finally, BYU has exceptionally tight interconnections with the wider technology and business community, across the whole Silicon Slopes region stretching from Provo through Salt Lake City to Park City. BYU's engineering school is a leader in working closely with local firms to create hands-on learning opportunities for students. The university hosts regular coffee meetings to promote networking among local startup founders and BYU faculty and students.

Conclusions

Conclusions for Universities

Generating high innovation impact is, in significant measure, a choice that some universities have made. Among large public research universities, the Universities of Florida, Washington, Michigan, Minnesota, and Utah, as well as North Carolina State University run very large research budgets, operate effective TTOs, promote innovation-minded campus cultures, and achieve relatively high innovation productivity. The same is true, in some cases on a smaller scale, of the most productive private institutions — for instance, MIT, Columbia University, Stanford University, the University of Pennsylvania, Northwestern University, Rice University, NYU, and the University of Chicago.

A number of considerably smaller institutions besides BYU, such as Northern Illinois University and Creighton University, achieve significant innovation impact with much smaller resources. The Cold Spring Harbor Laboratory is the leading example of a pure research/health care institution that has achieved remarkable innovation productivity.

This report shows that university leaders should not fear that prioritizing technology innovation, commercialization, and entrepreneurship will detract from their traditional missions in teaching and basic research. On the contrary, success in generating innovation impact reinforces the research and teaching activities of universities, at least in STEM fields.

Our analysis also shows that most institutions could achieve very significant increases in innovation impact by moving towards the productivity levels of high-performing peers. Among the institutions in our large research university group, for instance, the median university in terms of productivity would increase its innovation output by 34 percent, if it reached the productivity level of the bottom institution in the first quartile. Improving from the third quartile cutoff level to the first would mean increasing innovation impact by 59 percent.

Our report suggests seven takeaways for university leaders who aim to maximize the innovation impact of their institutions:

1. Prioritize research: More research spending likely means greater innovation impact.
2. Compete hard to attract and retain star faculty researchers: Institutions with relatively large numbers of members of the National Academies of Sciences, Engineering, and Medicine generate high innovation impact, even controlling for total research spending.
3. Run an efficient, outcomes-focused technology transfer operation: First of all, this means paying close attention to the size, professional makeup, and policies of the technology transfer office. It also means operating a well-funded seed fund, interacting well with faculty and staff, forging deep connections with the business and finance community, and offering competitive financial terms to faculty inventors.
4. Instill a culture of innovation and entrepreneurship throughout the university: MIT, Stanford University, Drexel University, and BYU demonstrate the benefits of a culture that prizes technological innovation, commercialization, and startup entrepreneurship.
5. Engage closely with the surrounding business and innovation community: While it helps to be in a big, diverse city with many entrepreneurs and a substantial immigrant population, universities can amplify these benefits through purposeful engagement.
6. Avoid overreliance on sponsored research funding from industry: The most successful institutions in terms of innovation impact generally fund no more than five to seven percent of their research spending from industry sources.
7. Monitor, quantify, and transparently disclose innovation impact results: BYU publishes brief but transparent annual reports on how they are doing, including much of the data they report to the Association of University Technology Managers (AUTM). All universities focused on maximizing their innovation impact should do the same.

Conclusions for Policy Makers, Business Leaders, Philanthropists, and Communities

For America's economy as a whole, higher innovation impact from universities would likely bring a greater pace of technological progress and faster economic growth.

Over the last four decades, applied research by the private sector has risen as a percentage of America's GDP, while basic university research funded by the federal government has declined in relation to the economy. The United States now ranks 28th of 30 Organization for Economic Co-operation and Development (OECD) nations in government funding of university research as a share of GDP, far behind Germany, Switzerland, Denmark, Sweden, and numerous other countries. China's public sector investment in university research, meanwhile, is rapidly growing.

This report also suggests that local government, business, and philanthropic leaders can strengthen their hometown economies by promoting the innovation impact of local universities.

Our report suggests five takeaways for policy makers, business leaders, philanthropists, and communities:

1. Increase public-sector support for university research: This report suggests that most research institutions could increase innovation impact, if they had more resources to invest in research.
2. Understand how institutions vary in their innovation impact productivity: Smaller universities can achieve remarkable productivity in converting research inputs to outputs. Funders should consider the extent to which institutions not only do great research but are also effective in achieving innovation impact beyond the university's walls.
3. Compete hard for talent — including immigrant talent: Metro areas with a relatively large foreign-born population share tend to host universities with high innovation impact. Localities can promote the innovation impact of local institutions by pursuing a welcoming approach to diverse populations, especially immigrants. While the competition for talent among localities for talent may seem like a zero-sum game, the federal government can create positive-sum conditions by welcoming more skilled immigrants from abroad.
4. Invest in integrated physical spaces connecting researchers with entrepreneurs, investors, and other potential nonacademic partners: We show clear benefits from bringing faculty researchers into close proximity with nonacademic entrepreneurs, venture capital firms, and other investors.
5. Support technology transfer operations and other enablers of innovation impact: Funders should consider supporting expansion of TTOs and other innovation-promoting activities. The federal government should expand successful programs to support academic technology transfer such as the National Science Foundation Innovation Corps (I-CorpsTM), National Institutes of Health REACH, the Small Business Innovation Research (SBIR), and the Small Business Technology Transfer (STTR). State governments should replicate programs like the Massachusetts Technology Transfer Center.

More generally, we hope this report encourages additional research on how America and its research institutions can generate greater innovation impact. Our analysis raises questions about why very large universities experience declining returns to scale in converting research inputs to innovation impact outputs, why metro areas with high foreign-born population shares host universities with relatively high innovation impact, and why the share of research spending funded by industry is negatively associated with innovation impact. We also hope this report encourages more detailed case studies into the innovation programs of high-performing institutions.

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