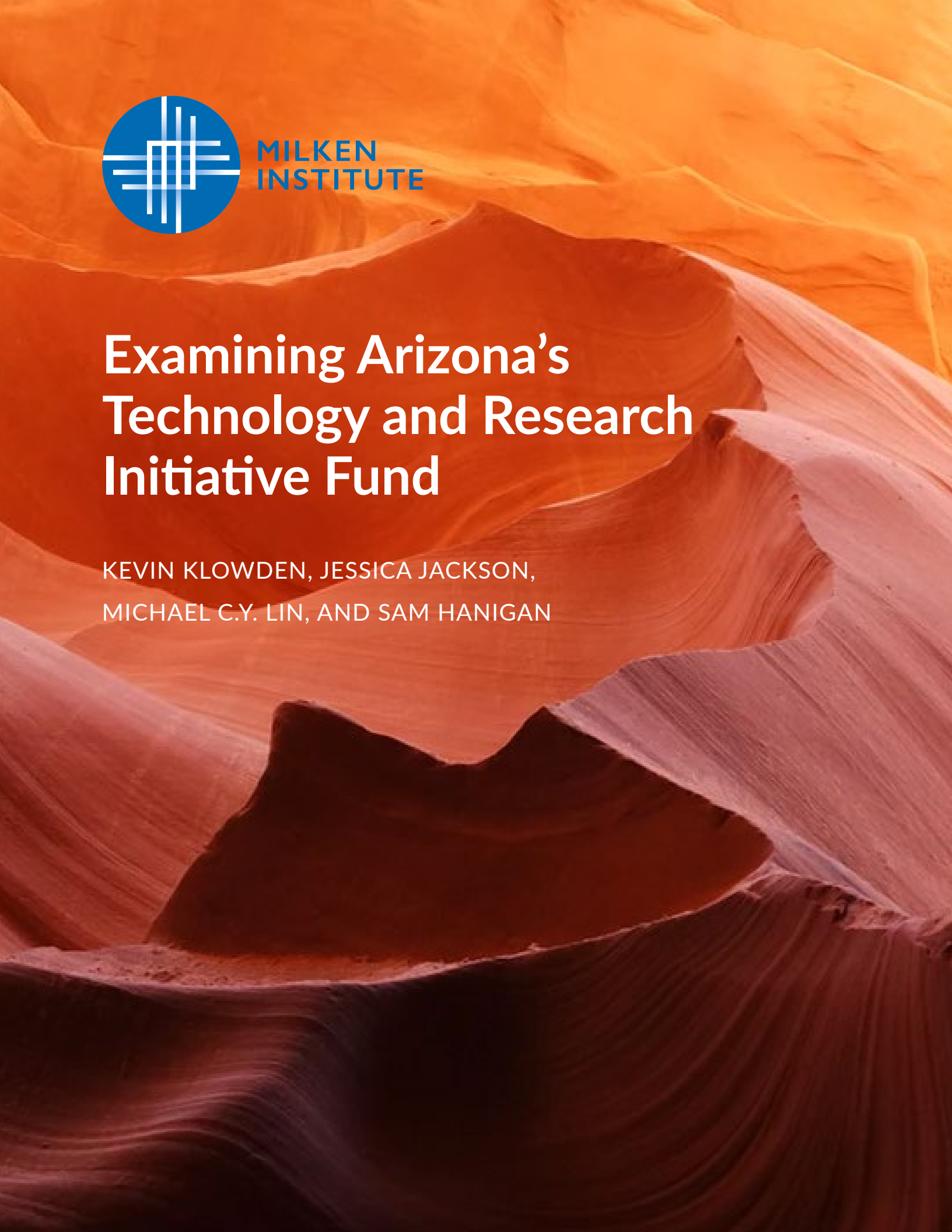

MILKEN INSTITUTE

Examining Arizona's Technology and Research Initiative Fund

KEVIN KLOWDEN, JESSICA JACKSON,
MICHAEL C.Y. LIN, AND SAM HANIGAN

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ACKNOWLEDGMENTS

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EXAMINING ARIZONA'S TECHNOLOGY AND RESEARCH INITIATIVE FUND

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EXECUTIVE SUMMARY

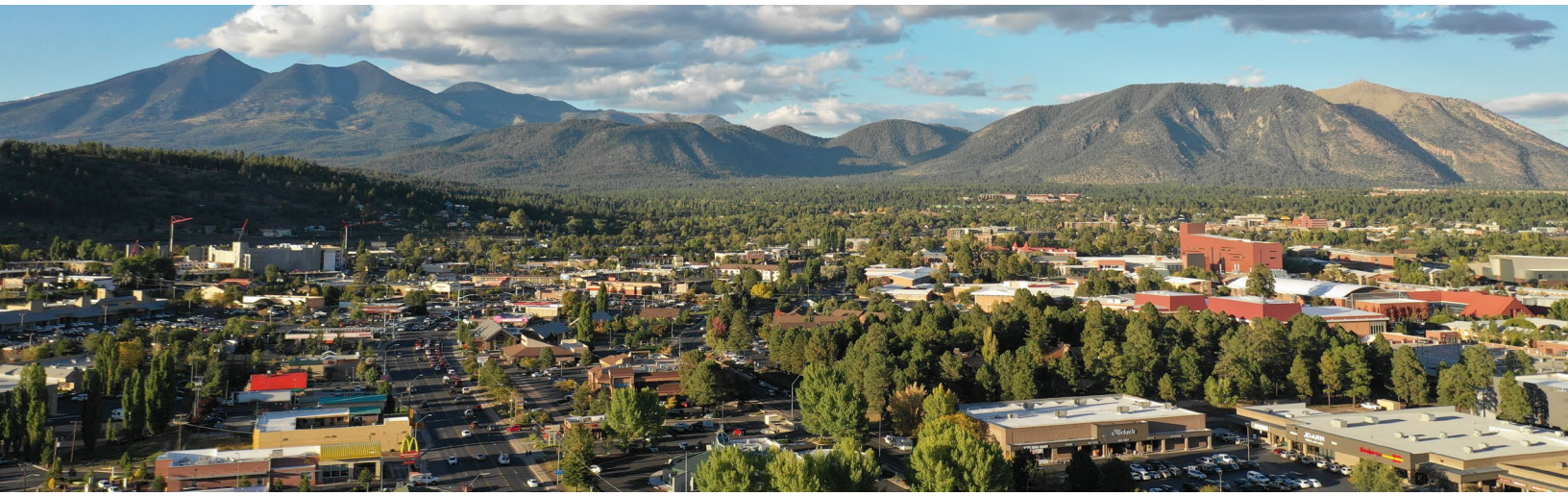
Over the past few decades, global competition has increasingly shifted growth to sectors driven by knowledge-based industries, technology, and innovation. States compete not only against each other for students, companies, and industries but also increasingly against foreign countries. Arizona's Technology and Research Initiative Fund (TRIF) has proven an essential tool for boosting both university and private-sector competitiveness. When Arizona voters passed Proposition 301 in the November 2000 election, they approved a 0.6 percent increase in the state's sales tax earmarked not only for key issues such as K-12 education and community college workforce programs but also for funding research and technology transfer at Arizona's three public universities (12 percent of the money raised). The establishment of the TRIF the following year established a foundation for developing a strong technology transfer and innovation infrastructure within Arizona. The continued existence of this fund, and the commitment to research and technology it represents, is an essential component of Arizona's innovation economy.

Arizona faces a number of challenges to sustain an innovation economy. As a low-cost, low-regulation state, Arizona's overall level of funding for both K-12 and higher education lags behind many other US states. This low-cost structure has proven beneficial to the state's overall economic competitiveness, particularly around Phoenix, which has risen from 136th in 2011 to 12th in the 2020 Milken Institute Best Performing Cities Index.[1] However, the state has lagged in the Milken Institute's State Technology and Science Index, ranking 27th in 2018, partly due

1 Michael C.Y. Lin, Joe Lee, and Perry Wong, "Best-Performing Cities 2020: Where America's Jobs Are Created and Sustained" (Milken Institute, February 2020), https://milkeninstitute.org/reports/best-performing-cities-2020.

to the limited higher education funding in the state's budget. To overcome these limitations, developing effective partnerships with the private sector through technology transfer and spin-offs is essential, and TRIF is a central component of this strategy. As noted in this paper, before the passage of Proposition 301, Arizona had only one prominent research university: the University of Arizona (UArizona) in Tucson. Since the establishment of TRIF, not only has Arizona State University (ASU) in Tempe established itself as a nationally prominent research institution, but also Northern Arizona University (NAU) in Flagstaff has developed clear successes in technology transfer and research partnerships, spreading the benefits of the innovation economy throughout the state.

The growth in Arizona's research spending, along with the resulting patents and economic activity, has significantly benefited the state's economy. From 2013 to 2018, Arizona has seen high-tech employment rise by an impressive 15.48 percent, and high-tech gross domestic product (GDP) grow at an even more remarkable 27.16 percent.[2] From 2012 to 2019, the Arizona university system has seen its annual return on investment from TRIF funding nearly double, from $232,647,448 to $433,655,365.[3] This remarkable growth has been made possible by consistent and significant growth in patents issued, startups formed, and local success stories throughout the Arizona innovation economy. The continued TRIF funding to Arizona universities and the private sector continues to have a huge, sustained benefit to the Arizona economy.



2 "Principal Federal Economic Indicators," Bureau of Economic Analysis, accessed March 17, 2020, https://www.bea.gov/; Data from Moody's Analytics, accessed March 17, 2020, https://www.economy.com/; Milken Institute analysis.

3 "Fiscal Year 2019 Annual Report" (Arizona Board of Regents), accessed March 17, 2020, https://public.azregents.edu/News%20Clips%20Docs/AnnualReport2019.pdf.

BACKGROUND

UNIVERSITY RESEARCH

Innovative activities and their subsequent commercial applications are significant drivers of long-term economic growth in the United States. Although industry catalyzes innovation through research and development initiatives, the research university has always been the key facilitator of knowledge-based progress. As bidirectional exchanges of information between academic and industry researchers strengthen, so does the commercially attuned knowledge that leads to a rise in economic and entrepreneurial activity.[4]

In the 21st century, public research universities have increasingly become the cornerstone of knowledge-based economies. However, these universities require industry links to provide skilled workers and scientific research for private-sector usage. Research efficacy as measured by total output (patents, licenses, licensing, startups) relative to total input (research expenditures) illustrates how effectively universities deliver on their objectives.[5]

PUBLIC EDUCATION FUNDING IN ARIZONA

While all states rely on some form of federal support, some states are markedly more self-sufficient in funding public school systems than others. For example, southern states like Louisiana and Texas derive much of their funding from gas and oil production. In the Northeast, states like New York, Massachusetts, and Connecticut rely on their high property and income taxes to fund schools. In contrast, Arizona depends on various sales tax measures and other growth economy sources, such as property taxes, to fund its education system, leading to more variable funding levels. When the 2008 recession came into full force, Arizona's growth economy was shattered and, with it, its principal source of public education revenue. This crippling shortfall, combined with Arizona's pre-recession tax cuts, erased billions of dollars from state coffers.

To make up for the shortfalls elsewhere in the state, lawmakers cut funding for teacher salaries, support staff, and facility maintenance in school districts.[6] As of 2019, these funds still have not been restored to their pre-recession levels.

4 Ross DeVol, Joe Lee, and Minoli Ratnatunga, "Concept to Commercialization: The Best Universities for Technology Transfer" (Milken Institute, April 2017), https://milkeninstitute.org/reports/concept-commercialization-best-universities-technology-transfer.

5 Ibid.

6 Dale Russakoff, "The Teachers' Movement. Arizona Lawmakers Cut Education Budgets. Then Teachers Got Angry," *The New York Times Magazine*, September 5, 2018, https://www.nytimes.com/interactive/2018/09/05/magazine/arizona-teachers-facebook-group-doug-ducey.html.

According to the Arizona Joint Legislative Budget Committee 2018-2019 fiscal estimate, Arizona currently spends roughly $4,560 on per-pupil instruction, compared to roughly $5,220 in 2008.[7] Instruction spending covers things such as supplies, employee benefits, and teacher salaries.[8]

Over 10 years later, the state has not been able to fix these shortfalls. As it currently stands, according to the Education Week Research Center 2019 report, Arizona spends roughly $8,003 total per pupil, less than the national average at $12,756, faring second worst only to Utah.[9]

PROP 301 HISTORY

In November 2000, Arizona voters passed Proposition 301, a legislatively referred statute mandating an increase in the state sales tax from 5 percent to 5.6 percent. This 0.6 percentage point increase was specifically earmarked for K-12 education, university research funding, and community college workforce development programs. This "yes" vote to increase new investments in education funding and university research demonstrated a widely held belief that Arizona's future economic success rested on its ability to cultivate an innovation economy. The state's ability to commercialize cutting-edge research, while developing talented workers and providing good-paying jobs to local communities, was the key to unleashing Arizona's economic prowess.

Over the last few decades, the power of the knowledge economy has been substantiated not only in Arizona but around the country and world. Innovation has joined the development of a skilled workforce, natural resources, and investment as critical components of a flourishing economy. This focus has helped transition Arizona from a state formerly reliant on tourism and construction into a national competitor in research and commercialization. The funds supplied by Prop 301 have largely enabled this transformation to take effect.

Proposition 301 was the brainchild of former Governor Jane Hull and born from a case before the Arizona Supreme Court in the mid-1990s. In Roosevelt Elementary School District v. Bishop, the court struck down Arizona's facility and equipment funding mechanism under the state's constitutional "general and uniform" provision.

7 "Arizona Per Pupil State Funding 2007-2019," Joint Legislative Budget Committee, accessed March 17, 2020, https://infogram.com/state-funding-per-pupil-2007-2019-adjusted-for-inflation-1h7g6ko95k7j2oy.

8 Valorie H. Rice, "Arizona Ranks Last in Nation for Per Pupil Spending on Instruction," Arizona's Economic and Business Research Center, June 7 2019, https://www.azeconomy.org/2019/06/this-week/arizona-last-in-nation-for-per-pupil-spending-in-elementary-and-secondary-public-school/.

9 "Map: How Much Money Each State Spends Per Student," Education Week Research Center, June 4, 2019, https://www.edweek.org/ew/collections/quality-counts-2019-state-finance/map-per-pupil-spending-state-by-state.html.

The ruling maintained that Arizona's funding procedure had to provide equally to all students and refrain from causing sizable financing inequalities among the state's school districts.[10] To address this challenge, and with the support of the legislature, Gov. Hull signed into law the Fair and Immediate Resources for Students Today (Students FIRST) bill. This law established a capital deficiency financing program funded by the state's general fund and administered by the School Facilities Board. Students FIRST helped establish a baseline funding mechanism to help maintain the suitability of existing public school facilities.[11] While Students FIRST was a crucial first step in combatting this problem, the fund was roughly a billion dollars short of what was needed. To help fund the gap, Gov. Hull and her team began to formulate what would later become Proposition 301.

During these initial stakeholder discussions, Gov. Hull concluded that Arizona had many other educational needs beyond covering a funding gap for Students FIRST. She believed that additional funding for teacher salaries, public university research, and community college workforce development were all critical to Arizona's education infrastructure. Given that this funding was to be collected through a tax increase, Gov. Hull knew she had to tread carefully with garnering support from not only the legislature but also the general public. Using public polling, the governor's team came up with an 85-12-3 funding split: 85 percent of the money would be used for K-12 funding, 12 percent would be used for university research and tech transfer operations, and the remaining 3 percent would be used for community college workforce development programs.

Despite the breakthrough in the proposed funding structure, the governor still had to garner three-fourths of the legislature's approval. This consensus was difficult to achieve even with bipartisan support. The solution? Propose the tax increase through a legislatively referred state statute to allow the people of Arizona to decide its fate outside the politically contentious legislature. In November 2000, 53.5 percent of Arizona voters said "yes" to Proposition 301, ushering in what would later be recognized as the most significant investment in public education in Arizona's history.[12]

TRIF OVERVIEW

Within the funding received through Proposition 301, the Technology and Research Initiative Fund (TRIF), a program similar to those in only a few states, distributes the 12 percent of Prop 301 revenues designated for Arizona's three public research universities. Arizona state law mandates that these monies are continuously

10 "Arizona State Constitution and Major Cases," Education Law Center, accessed March 6, 2020, https://edlawcenter.org/states/arizona.html.

11 "Agency Overview," Arizona School Facilities Board, accessed March 16, 2020, https://sfb.az.gov/about.

12 "Arizona Sales Tax for Education, Proposition 301 (2000)," Ballotpedia, accessed March 6, 2020, https://ballotpedia.org/Arizona_Sales_Tax_for_Education,_Proposition_301_(2000).

appropriated by the Arizona Board of Regents (ABOR), providing policy and project supervision to Arizona State University, Northern Arizona University, and University of Arizona.

As it stands, ABOR approves TRIF budgets and project plans in five-year cycles. The most current five-year cycle goes from July 1, 2016, to June 30, 2021. ABOR uses data from the Joint Legislative Budget Committee to help inform the decision-making process. Under state law, the board must provide both the legislature and governor a detailed account of the previous year's TRIF expenditures by September 1 of each year.[13]

In the most recent fiscal year, TRIF provided the three universities with roughly $83.6 million. Since its official launch in 2001, the TRIF has provided over $1.12 billion to develop projects in certain ABOR-approved policy areas. For research investment, the universities must develop initiatives that support the following:

1. Improving health
2. Water, environmental, and energy solutions
3. National security systems
4. Space exploration and optical solutions

For workforce development investment, the universities must focus on higher education access and must meet one or more of the following criteria:

1. Promote university research, development, and technology transfer related to the knowledge-based global economy.
2. Expand access to baccalaureate or post-baccalaureate education for time-bound and place-bound students.
3. Implement recommendations from the Governor's Task Force on Higher Education and/or the Arizona Partnership for the New Economy.
4. Develop programs that will prepare students to contribute in high technology industries located in Arizona.[14]

13 "2019 TRIF" (Arizona Board of Regents, 2019), https://www.azregents.edu/sites/default/files/public/ABOR_TRIF_2019.pdf.

14 Ibid.

THE GOAL OF THE STUDY

Although each part of the public education system draws from a separate allocation of Prop 301 funding, all pieces are integrated. The K-12, community college, and university systems rely on each other, making it vital to secure Prop 301 funding for the entire public education ecosystem.

One of the advantages Arizona has is its deserved reputation as a low-cost state that attracts talented people. However, it also presents challenges for generating sufficient resources for education funding and facilitating tech transfer from major universities. Arizona depends on various sales tax measures and other "growth economy" sources, like property taxes, for education funding, but these revenue streams depend highly on a strong economy. Arizona has been hard-hit by previous economic downturns. Not only does Arizona continually rank among the lowest in the nation for K-12 funding, but also it ranks middle-of-the-road in human capital investment (HCI).[15] Although Arizona ranked higher than Texas, Florida, and Nevada for HCI, it ranked 27th nationally in the Milken Institute's 2018 State Technology and Science Index.[16] Arizona does not have any major private research universities, unlike competing states such as Utah, Colorado, and Texas, further highlighting the importance of Prop 301 funding for both K-12 and higher education.

15 Human capital is the most important intangible asset of a regional or state economy. We look at indicators that suggest the skill levels of the current and future workforce. Examples include the number of bachelor's, master's, and doctorate degrees relative to a state's population and measures specific to science, engineering, and technology degrees. For more, see Kevin Klowden, Joe Lee, and Minoli Ratnatunga, "State Technology and Science Index 2018" (Milken Institute, December 2018), https://assets1b.milkeninstitute.org/assets/Publication/ResearchReport/PDF/State-Tech-2018-FINAL.pdf for more information.

16 Kevin Klowden, Joe Lee, and Minoli Ratnatunga, "State Technology and Science Index 2018" (Milken Institute, December 2018), https://assets1b.milkeninstitute.org/assets/Publication/ResearchReport/PDF/State-Tech-2018-FINAL.pdf.

By sustaining TRIF as a dedicated source of funding for university research in technology and life sciences, Arizona's economy benefits by attracting additional researchers and innovators, thus creating a bigger pie from which Prop 301 can draw.

"The underpinning theme here is that we're producing more and more of a knowledge economy for the region as opposed to an economy that's built around other less fungible and more fragile types of income streams. Knowledge economies are known to be much more resilient."

ELIZABETH CANTWELL
Senior Vice President for Research and Innovation, University of Arizona

Arizona's technology ecosystem does not simply reflect the work done at the universities but also includes technology spin-offs, the workforce employed at newly created companies, and all secondary companies contributing to the success of the new firms. We aim to demonstrate TRIF's impact on local companies and wider benefits to the state's business environment and economy.

ARIZONA'S COMPETITIVENESS

The Arizona tech ecosystem does not exist in a vacuum. To attract talent and capital to build future-focused businesses, Arizona has to compete with peer states and foreign countries to attract and keep ideas, talent, and companies. TRIF plays a key role in this process as a dedicated source of funding for Arizona's tech ecosystem.

In the last several years, Arizona's economic performance has shown some of the fruits of TRIF's initial and ongoing investment in higher education technology and research initiatives. Phoenix, in particular, has risen dramatically over the last several years in the Best Performing Cities Index, led by rapid job and wage growth. Tucson has also improved significantly in the index, a result of its high-tech industries, and Flagstaff ranks in the top half of our small city index. All three metros have done well in attracting investment in these sectors.

Table 1. Metro Rankings on Best-Performing Cities US Over Time

	2018	2017	2016	2015	2014	2013	2012	2011
Phoenix-Mesa-Scottsdale	20	40	46	62	65	66	122	136
Tucson	102	154	155	175	161	115	150	112
Flagstaff*	84	71	81	42	98	50	123	57

Note: * indicates that Flagstaff is in our small city ranking while the others are in our large city ranking.

Source: Milken Institute Best-Performing Cities (2020)

While Phoenix ranked higher in the Best-Performing Cities Index during the housing boom, since 2013, the metro has greatly benefitted from a broader base of knowledge-based industries. In 2018 it cracked the top 20 partly because of TRIF's benefits.

Arizona has been building a competitive advantage in high-tech and life science industries since the implementation of TRIF. Arizona's employment in high-tech and life science industries grew 15.58 percent from 2013 to 2018 and 3.05 percent from 2017 to 2018, higher than Colorado, Florida, or North Carolina.[17] Arizona also made improvements in high-tech and life-science wage growth in 2018, pulling ahead of Texas and Florida over the past year.[18] Jobs in high tech and life sciences consistently pay well above median incomes, and employees benefit, especially from the state's low tax rate.

Table 2. Growth in High-Tech and Life Sciences across Peer States

	Employment		Wages			GDP	
	2013-2018	2017-2018	2012-2017	2016-2017	2016-2017	2013-2018	2017-2018
Arizona	15.48%	3.05%	21.30%	5.19%	5.19%	27.16%	6.83%
California	17.63%	2.85%	41.17%	8.78%	8.78%	43.31%	7.65%
Colorado	17.49%	2.87%	27.93%	5.93%	5.93%	23.04%	6.56%
Florida	15.45%	2.42%	26.57%	4.94%	4.94%	26.56%	5.10%
Nevada	25.62%	5.17%	31.11%	6.27%	6.27%	41.82%	7.32%
New Mexico	8.50%	0.87%	12.45%	1.36%	1.36%	12.40%	2.50%
North Carolina	11.08%	2.38%	26.21%	6.02%	6.02%	20.12%	3.41%
Texas	12.05%	2.30%	25.60%	4.88%	4.88%	25.00%	6.57%
Utah	19.62%	3.22%	37.36%	6.38%	6.38%	37.43%	7.33%

Sources: US Bureau of Labor Statistics: Current Employment Statistics, Quarterly Census of Employment and Wages; Bureau of Economic Analysis; Moody's Analytics; Milken Institute (2020)

17 "Current Employment Statistics, Quarterly Census of Employment and Wages," US Bureau of Labor Statistics, accessed March 17, 2020, https://www.bls.gov/cew/; Data from Moody's Analytics, accessed March 17, 2020, https://www.economy.com/; Milken Institute analysis.

18 Ibid.

Productivity in these industries has also increased significantly. Arizona's high-tech and life science GDP grew by 27.16 percent in the five years ending in 2018 and grew 6.83 percent in 2018 alone.[19] Arizona remains highly competitive with peer states, trailing only some of the country's fastest-growing tech and bioscience states: California, Nevada, and Utah. Any potential cuts to TRIF would threaten not only the state's overall momentum but also the predictability of the investment environment.

19 Ibid.

TRIF OUTCOMES

ACCESS AND WORKFORCE DEVELOPMENT

Access and workforce development are also important outputs of TRIF. ASU spent over $4 million of its TRIF allocation on programs focused on entrepreneurship and innovation in advanced manufacturing.[20] NAU used TRIF dollars for its $5.2 million expenditure on its Access and Workforce Development (AWD) program, representing 40 percent of NAU's total TRIF expenditure in 2018.[21] NAU's tech transfer office is still in its nascent stage.

TECHNOLOGY TRANSFER AND SPENDING

"I employ almost 150 people between TGen and NAU. TGen North is definitely a shining star for economic development in Flagstaff—TGen North employs about 50 people and runs on a budget of nearly $4 million a year. This all started in my NAU lab, and if I had left for California, we wouldn't have TGen North. That's a clear example of economic development, which was highly dependent upon TRIF money."

PAUL KEIM
Executive Director of Pathogen and Microbiome Institute, Northern Arizona University

Technology transfer is, perhaps, the most tracked output from technology research. Tech transfer from Arizona's public universities has grown significantly since the implementation of TRIF, and there are no other state government sources of seed funding for such activity outside TRIF. Key measures of tech transfer include startup creation and issuing of patents for technology developed at university labs, and TRIF has helped Arizona's public universities register significant improvements on both fronts. In 2017, ASU and UArizona spun off 15 startups each (Figure 1). Though 15 may not sound like a large number, if each startup hired a few people, they would create hundreds of high-paying jobs. ASU went from 11 US-issued patents in the year 2000 to 85 US-issued patents in 2017 (Figure 2) and reported $546.5 million in total research expenditure in 2017, up from $67.1 million in the year 2000 (Figure 3). UArizona went from 21 issued licenses in 2005 to 80 issued licenses in 2017 (Figure 4).

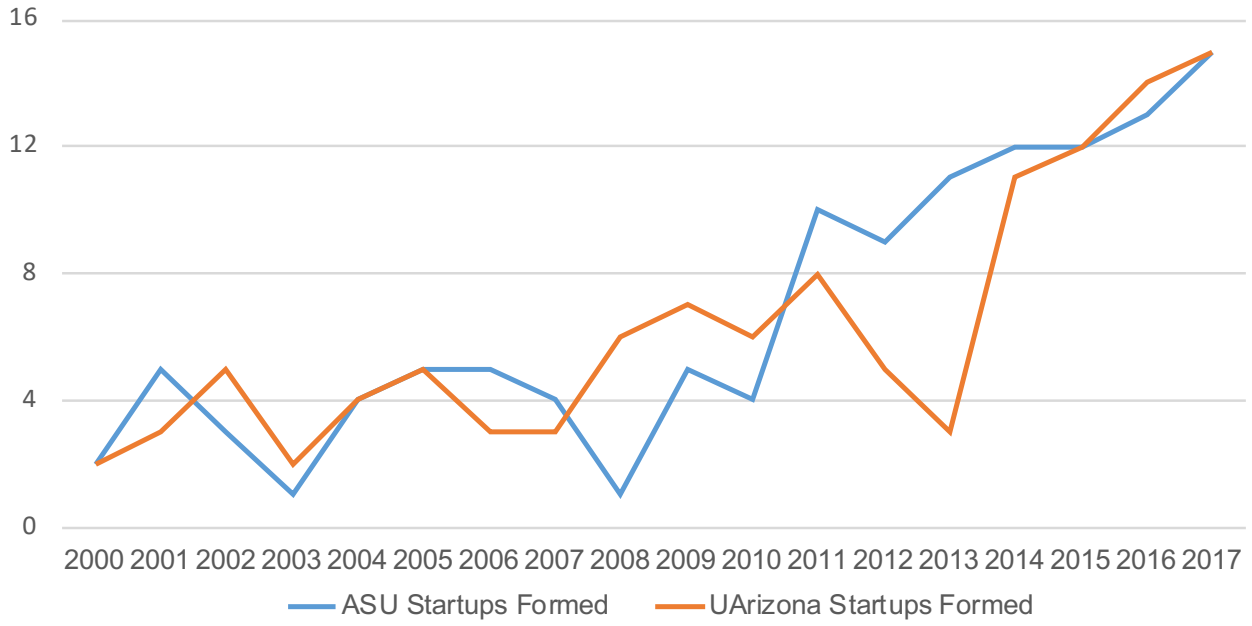
"Tech-transfer success at NAU would not be anything like it is without TRIF."

DAVID SCHULTZ
Vice President for Research, Northern Arizona University

20 "Technology and Research Initiative Fund FY 2018," Arizona Board of Regents, accessed March 10, 2020, http://www.azregents.edu/sites/default/files/public/ABOR_TRIF_2018.pdf.

21 Ibid.

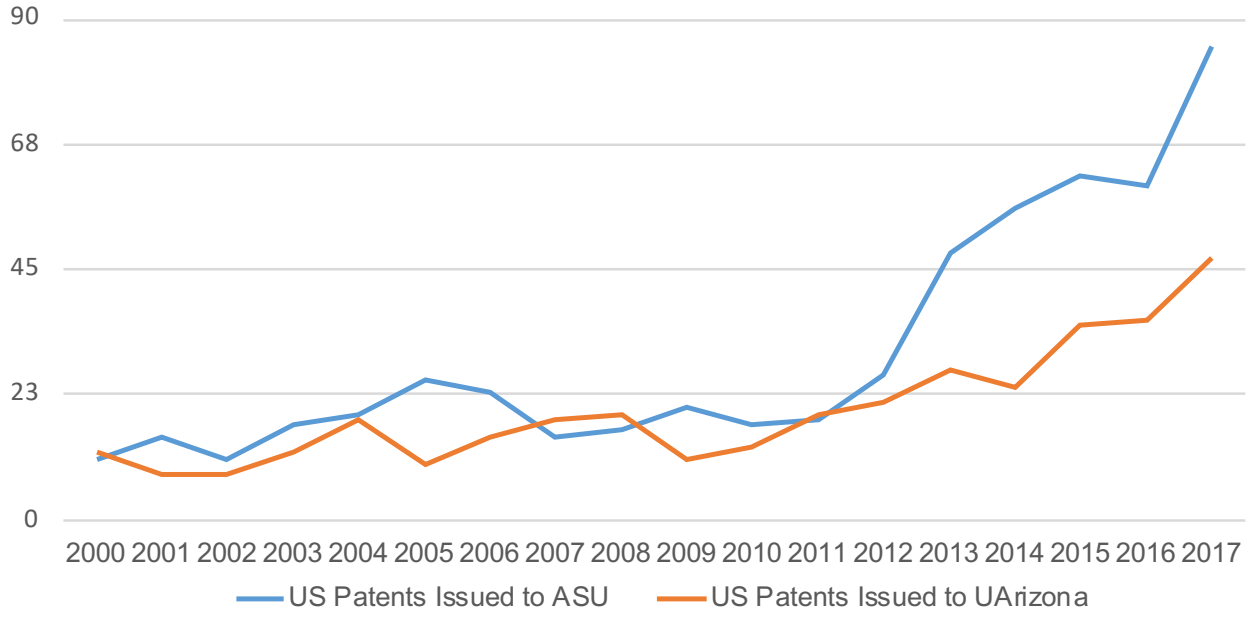
Figure 1. Growth of Startups Formed



Source: Milken Institute analysis of data from Association of University Technology Managers (2020)

Note: Equivalent for NAU is not currently publicly available.

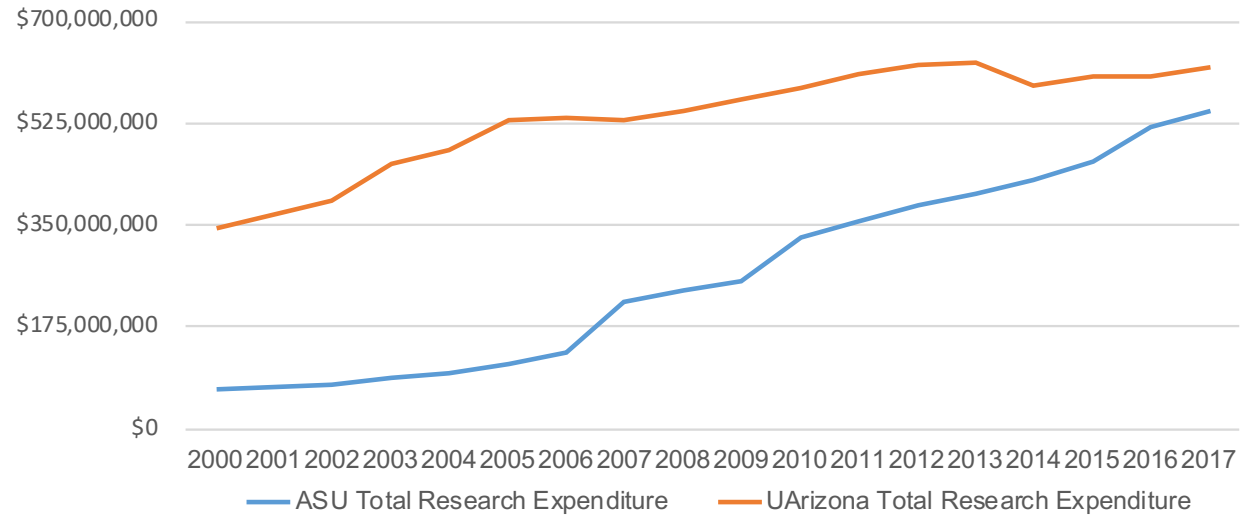
Figure 2. Growth of US Patents



Source: Milken Institute analysis of data from Association of University Technology Managers (2020)

Note: Equivalent for NAU is not currently publicly available.

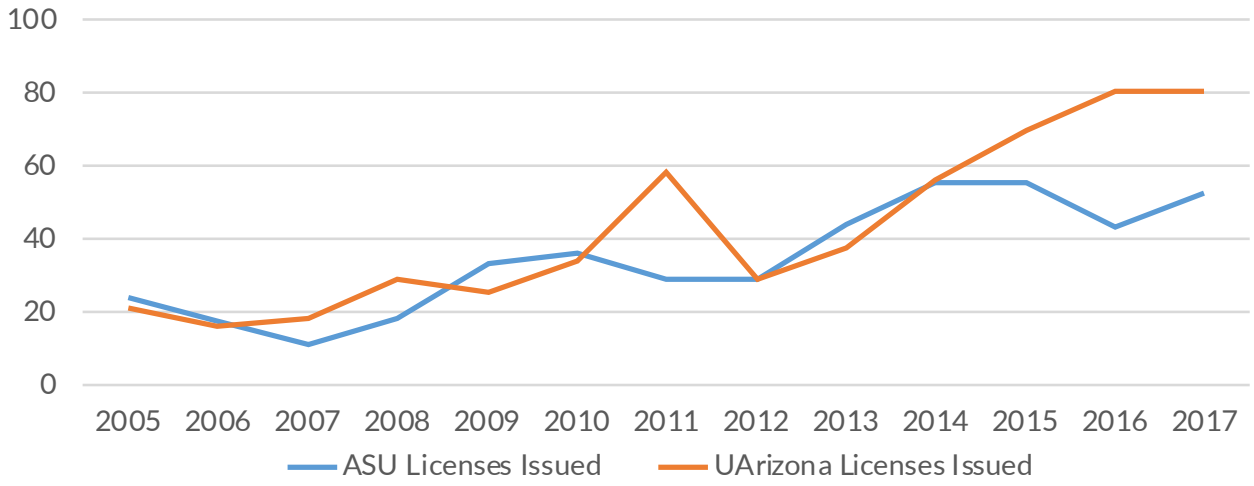
Figure 3. Growth of Total Research Expenditure



Source: Milken Institute analysis of data from Association of University Technology Managers (2020)

Note: Equivalent for NAU is not currently publicly available.

Figure 4. Growth of Licenses Issued



Source: Milken Institute analysis of data from Association of University Technology Managers (2020)

Note: Equivalent for NAU is not currently publicly available.

"We were never in the game, and we are very much in the game now and looked upon as a model and an example of how universities can not only grow their research but actually influence and impact economic development in the great state of Arizona."

SETHURAMAN PANCHANATHAN
Chief Research and Innovation Officer, Arizona State University

Table 3. Percentage of Tech Transfer Activity from Biosciences in 2018

	ASU	NAU	UArizona
University R&D Funding	24.48%*	44.76%	58.19%
Invention Disclosures Received	45.96%	32.00%	45.09%
Total US Patent Applications Filed (including provisional)	52.13%	51.85%	58.45%
US Patents Issued	37.40%	40.00%	50.00%
Licenses & Options Executed	32.05%	50.00%	31.25%
License Income Received	72.04%	0.00%	66.79%
Startups from University IP	41.18%	NA	68.75%

Source: Data received directly from each university as facilitated by the Flinn Foundation; Milken Institute (2020)

Before TRIF, UArizona was the state's sole research university of national prominence. TRIF has lifted the performance of all Arizona's public universities in tech transfer, with ASU emerging as a particular success story. TRIF funding for ASU research increased from $23.7 million in 2009 to $32.5 million in 2018.[22] The funds from TRIF and ambitious leadership under President Michael Crow allowed ASU to become a nationally ranked research institution. The emergence of ASU's research capabilities on its Tempe campus has also helped the economy of the neighboring Phoenix metro area thrive with a strong tech concentration.

22 "Comprehensive Annual Financial Report 2018" (Arizona State University, 2018) https://www.asu.edu/fs/documents/annual_reports/ASU-2018-CAFR.pdf.

Much of Arizona's tech transfer activity comes from biosciences, as shown in Table 3. An impressive 72.04 percent of ASU's license income was from bioscience licenses.[23] Also, UArizona received $2.8 million in bioscience license income in 2018, which was 66.79 percent of the university's total license income received.[24] Though NAU's licensing department is in nascent stages, bioscience is lucrative for ASU and UArizona.

ASU has also boosted its technology commercialization capabilities. In 2003, ASU formed AzTE, now known as Skysong Innovations, to manage its Exclusive Intellectual Property Management Company. Its goal is "…the rapid and wide dissemination of ASU discoveries and inventions to the marketplace." ASU monitors commercialization performance (outputs) relative to the size of its research operations (inputs).[25] Both the TRIF funding increase and ASU's own efforts have generated positive outcomes. In the Milken Institute's Technology Transfer and Commercialization Index, ASU jumped from 43rd in 2006 to 21st in 2017 (out of 225 universities in the US).[26] While only Arizona State submitted data on technology transfer at the time of the 2006 report, by the 2017 report, the University of Arizona also ranked an impressive 58th place out of all universities, with Northern Arizona University coming in at 180th—a strong placement for a regional university.

Compared with the states that have similar populations and resources, Arizona has also demonstrated positive trends in the expansion of its knowledge-based industry workforce. In the Milken Institute's 2018 Technology and Science Workforce rankings, Arizona stood 14th, not far behind peers with similar resources such as Colorado (No. 4) and Utah (No. 9).[27] In addition, Arizona's high-tech scene has recently been booming. For instance, the location quotient[28] for three tech industries in Arizona—satellite telecommunications, semiconductor and other electronic component manufacturing, and aerospace product and parts manufacturing—outperformed Utah and New Mexico, which also have similar resources.

23 Data received directly from each university as facilitated by the Flinn Foundation; Milken Institute analysis.

24 Ibid.

25 Ross DeVol, Joe Lee, and Minoli Ratnatunga, "Concept to Commercialization: The Best Universities for Technology Transfer" (Milken Institute, April 2017), https://milkeninstitute.org/sites/default/files/reports-pdf/Concept2Commercialization-MR19-WEB.pdf.

26 Ibid.

27 Ibid.

28 Location quotient is the ratio of industry employment in the state compared to the national average, providing a key indicator for measurement of a state's relative performance.

Table 4. Technology and Science Workforce Rankings (2018)

State	Ranking
Arizona	14
Colorado	4
Indiana	41
Missouri	27
New Mexico	22
Tennessee	42
Utah	9

Source: Milken Institute State Technology and Science Index (2018)

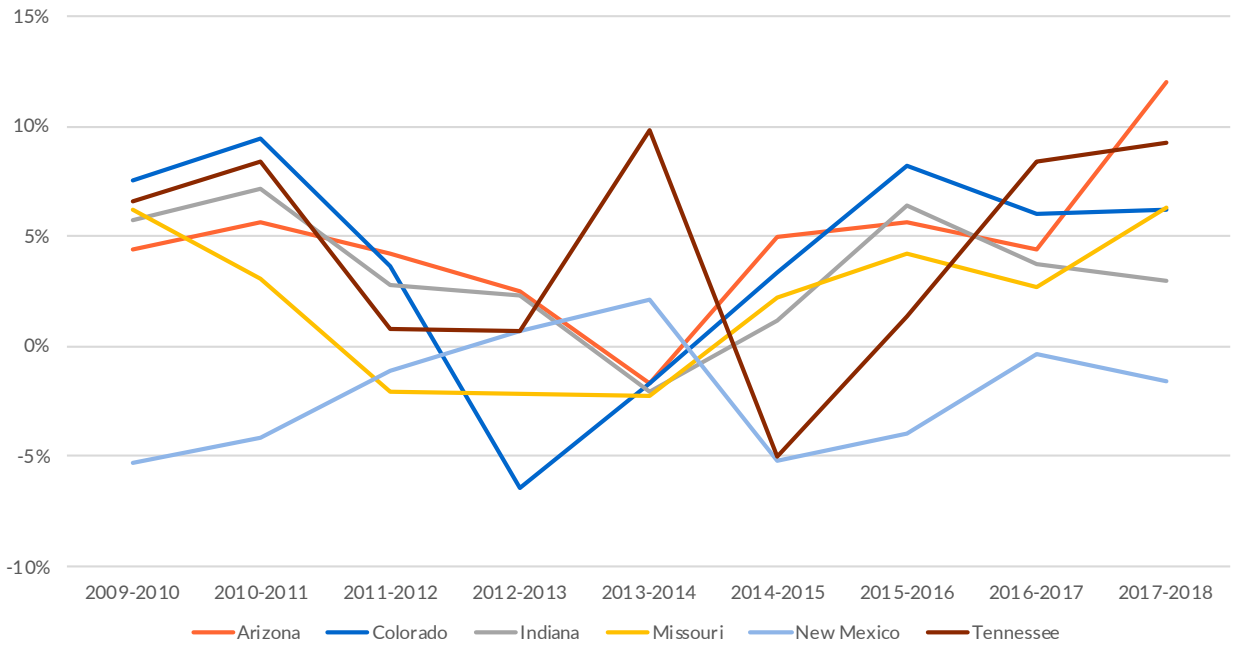
Table 5. Location Quotient for Three Tech Industries (2019)

	Satellite Telecommunications	Semiconductor and Other Electronic Component Manufacturing	Aerospace Product and Parts Manufacturing
Arizona	11.66	2.98	2.91
New Mexico	0.01	1.30	0.26
Utah	3.23	0.95	1.42

Source: Arizona Technology Council (2019)

Figure 5 compares growth in higher education R&D expenditure during the 2009 and 2018 fiscal years for states that have similar resources to Arizona. Despite some fluctuation, R&D spending in Arizona has steadily increased since 2014. Arizona's 12 percent growth rate from 2017 to 2018 led among all its counterparts. These indicators demonstrate Arizona's success in boosting its capacity in technology and research.

Figure 5. Higher Education R&D Expenditure Growth (2009–2018 Fiscal Years)



Source: National Science Foundation (2019)

ADDITIONAL INVESTMENT ATTRACTED (MULTIPLIER EFFECT)

Public universities in Arizona have built a tech transfer ecosystem by leveraging funds from TRIF without wholly relying on the fund. Universities have been able to match the money with additional resources to both retain and recruit faculty from a variety of other sources, including the federal government, the private sector, and other universities. In this respect, TRIF has helped to attract outside funding. Table 6 shows how total return on investment (ROI) grew from 2012 to 2019. In 2019 a TRIF expenditure of $83.6 million brought in $433.65 million in additional investment to ASU, NAU, and UArizona.

Table 6. Return on Investment from TRIF Expenditures from ASU, NAU, and UArizona

Year	Total TRIF Expenditure	ROI
2019	$83,610,510	$433,655,365
2018	$77,211,246	$457,350,814
2017	$72,797,471	$363,239,721
2016	$69,703,829	$363,240,790
2015	$68,438,317	$309,803,154
2014	$65,475,490	$282,143,620
2013	$60,241,824	$237,847,734
2012	$57,190,239	$232,647,448

Source: Data provided by Arizona Board of Regents (2019)

"We have attracted over $1.725 billion in external funding, all of it because of the fact that TRIF investments have helped shape our key research priorities, attract outstanding faculties, and be able to win unbelievable external funding to validate the ideas that it puts forth by our faculty and faculty groups."

SETHURAMAN PANCHANATHAN
Chief Research and Innovation Officer, Arizona State University

There is great strength in Arizona's collaborations between universities and medical groups (e.g., ASU and the Mayo Clinic in Scottsdale/Phoenix). ASU's Improving Health initiative alone turned a $14.96 million TRIF investment into over $104 million in additional investment in 2019.[29] Among US institutions without a medical school, ASU's health and human services (including National Institutes of Health) funding stood in seventh place in fiscal year 2018.[30] UArizona also attracted

29 Data provided to the Milken Institute by the Arizona Board of Regents (2019).

30 "Facts and figures," Arizona State University, accessed March 17, 2020, https://research.asu.edu/about-us/facts-figures.

significant outside funding for improving health and used a $7.6 million TRIF investment in space exploration to draw an $86.8 million return.[31] These TRIF investments have been extremely successful in seeding projects that draw large amounts of outside funding. Given that TRIF funding has helped attract such sizable sources of outside investment in priority areas, losing access to TRIF would be severely detrimental to Arizona's public universities.

IMMEASURABLE BENEFITS

In addition to measurable ROI, TRIF offers a multitude of practical benefits to Arizona that are not as closely tied to financial indicators. For example, TRIF enables significant water conservation efforts to continue.

"TRIF dollars at U of A support activities that enable people in Arizona to become more resilient with respect to our water realities, our heat realities, and the health realities associated with the constant heat and water challenges."

ELIZABETH CANTWELL
Senior Vice President of Research and Innovation, University of Arizona

Perhaps the most important outcome that cannot be directly measured by ROI is the attraction and retention of university talent; the state's universities would not have the research funding to keep talent if TRIF were cut.

"When I left Arizona to go to Berkeley as an undergraduate, I did not think I was ever coming back. From there, I went to UC San Francisco, where I did an MD-PhD. My PhD was in biochemistry and biophysics. After medical school, I went to Boston, where I worked at Harvard in one position or another for the next 20 years, including internship and residency, clinical and research fellowships, and finally a faculty position. I was more than happy in Boston and had a very successful lab there. It was the establishment of this Biodesign Institute, which was established in large part because of TRIF funding, that created an interest in coming to Arizona."

JOSH LABAER
Executive Director and Professor, Biodesign Institute, Arizona State University

In addition to drawing experienced researchers to the state, keeping top talent is extremely important.

31 Data provided to the Milken Institute by the Arizona Board of Regents (2019).

"In 2003, I was ready to move to Livermore, California, and lead a prestigious genomics program at the University of California. While it was a very lucrative offer, living in Flagstaff has some definite benefits, and I'm super glad I stayed. My retention was highly dependent upon the TRIF funding that flowed into my laboratory."

PAUL KEIM
Executive Director, Pathogen and Microbiome Institute, Northern Arizona University

TRIF's benefits extend beyond the ones that can be easily quantified in terms of direct and indirect jobs. The benefits created by the program extend well beyond the major metropolitan areas through involving subcontractors and key supply chains throughout the state. One of the consistent sources of feedback from stakeholders interviewed on the impact of TRIF noted that the impact of the program extended statewide. Numerous tertiary jobs created by the program came through interactions outside of the core metro areas. In addition, the opportunities created for public-private sector collaborative research have also allowed for broader opportunities for firms located throughout the state to partner with research both at the state universities and with the firms created as a result of the research.

CASE STUDIES

The following three case studies illustrate the non-monetary, practical benefits TRIF has brought to Arizona.

Case Study 1: Pain Therapeutics Project at the BIO5 Institute of the University of Arizona[32]

While opioid misuse transformed from a quiet backstory to a national epidemic, researchers at the University of Arizona's BIO5 Institute leveraged TRIF funding to invent an alternative therapy to treat pain, ultimately resulting in a Tucson-based commercial spin-off.

BIO5's pain therapeutics project began as a collaborative effort between Vijay Gokhale, associate research professor at the BIO5 Institute, and Rajesh Khanna, professor of pharmacology at the University of Arizona and a member of BIO5, to tackle the ever-growing epidemic of opioid misuse.

With the initial support of TRIF funding, Gokhale's medicinal chemistry research group was able to identify and make potential chemical compounds for testing as pain therapeutics. Khanna identified a mechanism and protein target that could be used to develop non-addictive, non-opioid pain therapy. Together with their interdisciplinary research teams, they invented a new class of non-opioid compounds to treat pain.

They worked with the UA's Tech Launch Arizona to license the invention and formed a local startup, Regulonix, LLC, in 2015. The startup's co-founders include Khanna, Gokhale, and May Khanna, assistant professor of pharmacology.

Regulonix received a $300,000 STTR grant in 2017 and $2 million in venture funding in 2018 from UAVenture Capital Fund, an early-stage capital fund focused on commercializing UA technologies.[33] The company has licensed the newly invented class of non-opioid painkillers that are non-addictive, non-toxic at high doses, and more effective than morphine.[34] While chronic pain and opioid misuse and overdose are widely prevalent, the discovery could provide viable options to combat these major public health crises.

32 Vijay Gokhale, associate research professor at BIO5 Institute, University of Arizona, contributed this case study.

33 Paul Tumarkin,"Startup Regulonix Licenses UA Non-Opioid Pain Drug Candidates," UA News, November 1, 2017, https://uanews.arizona.edu/story/startup-regulonix-licenses-ua-nonopioid-pain-drug-candidates; Regulonix, "Non-opioid Pain Therapeutics Company Regulonix Raises $2 Million in Seed Funding Led by UAVenture Capital Fund," Regulonix, accessed April 9, 2020, https://regulonix.com/non-opioid-pain-therapeutics-company-regulonix-raises-2-million-in-seed-funding-led-by-uaventure-capital-fund/.

34 Paul Tumarkin, "Startup Regulonix Licenses University of Arizona Non-opioid Pain Drug Candidates," University of Arizona, October 30, 2017, https://techlaunch.arizona.edu/news/startup-regulonix-licenses-university-arizona-non-opioid-pain-drug-candidates.

The goals of the University of Arizona's BIO5 Institute, launched in 2001, include:[35]

- Fostering collaborative projects that address major challenges in the biosciences, biomedicine, and biotechnology and that forge significant progress on novel treatments for asthma, cancer, valley fever, diabetes, sudden cardiac death, malnutrition, infectious disease, and Alzheimer's and other age-related brain diseases.
- Strengthening and expanding translational research by recruiting the best and brightest faculty to Arizona and supporting projects that will advance the development of new medicines, devices, diagnostics, and nutritional and therapeutic strategies.
- Engaging and training future generations of scientists by maintaining successful outreach and internship programs to promote experiential learning and STEM proficiency in the state.
- Expanding shared resources in computational biology, imaging, high throughput screening, genomics, proteomics, and cell analysis across all life science disciplines to expedite large-scale, team science grants. These grants will boost federal research funding, serve as a resource for local industries, and create new services and companies in Arizona.
- Promoting an entrepreneurial culture in which scientists work across disciplines to accelerate the commercial translation of research breakthroughs.

Vijay Gokhale

Rajesh Khanna

Source: Photos provided by Vijay Gokhale and Rajesh Khanna (2020)

35 Bio5 Institute, accessed March 17, 2020, www.bio5.org.

Case Study 2: Cancer Treatment Project at Arizona State University's Biodesign Institute

Upon receiving initial TRIF funding, ASU decided to allocate the money to advance bioscience and scientific research and development activities, including by establishing the Biodesign Institute in 2002.[36] Over nearly two decades, the Biodesign Institute has used TRIF funding to hire local workers and attract talented people from other places. Joshua LaBaer, executive director of Biodesign, was familiar with Arizona as he grew up in the state before leaving for college. He returned to join Biodesign in 2009 after leading the Institute of Proteomics at Harvard University. As he puts it:

"It would never have occurred to me to come to Arizona because I never thought of it as a state that was doing cutting-edge biotechnology research. TRIF funding established a top-tier research institute like Biodesign, creating an opportunity to come to Arizona to do that kind of work.... In the end, it was the voters of this state who decided to invest significant funding into growing this type of high-technology research that attracted me, and ultimately this decision will grow the base of the economy."

With the talented professionals it has recruited, Biodesign has also been able to conduct state-of-the-art research, license technologies, and spawn new firms. In addition, TRIF dollars have enabled Biodesign to generate more funding for itself. As LaBaer states:

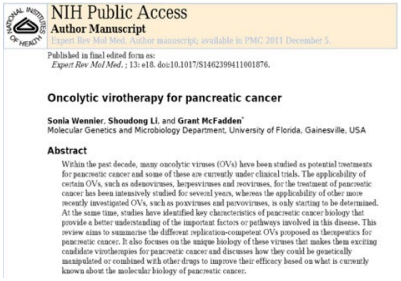
"[The] initial $5 million in funding that TRIF provided towards the startup costs for my lab has blossomed into over $84 million in funding that I've brought into the university from external sources, not to mention more than $20 million in funding from the other labs in my center. The combined total of more than $100 million represents a significant multiplier of the initial investment."

36 "Timeline," Arizona State University, accessed March 9, 2020, https://biodesign.asu.edu/about/impact/timeline.

One of the key activities at the Biodesign Institute supported by TRIF is cancer research. Grant McFadden, director of the institute's Biodesign Center for Immunotherapy, Vaccines, and Virotherapy, currently focuses on oncolytic virotherapy and immunotherapy. The former uses a virus to kill cancer cells; the latter uses the immune system to keep attacking the remaining cancer after virotherapy.[37]

Like LaBaer, McFadden's research team has used TRIF funding to seed projects that have gone on to draw much larger research grants from other sources, including the National Institutes of Health. Additionally, his research has created significant opportunities for commercialization. One spin-off firm, OncoMyx Therapeutics, raised $25 million in series A venture-capital funding in 2019 on the promise of uniting oncolytic viruses and immunotherapeutics to attack cancer cells.

Joshua LaBaer[38]



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Oncolytic virotherapy for pancreatic cancer

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Abstract

Within the past decade, many oncolytic viruses (OVs) have been studied as potential treatments for pancreatic cancer and some of these are currently under clinical trials. The applicability of certain OVs, such as adenoviruses, herpesviruses and reoviruses, for the treatment of pancreatic cancer has been intensively studied for several years, whereas the applicability of other more recently investigated OVs, such as poxviruses and parvoviruses, is only starting to be determined. At the same time, studies have identified key characteristics of pancreatic cancer biology that provide a better understanding of the important factors or pathways involved in this disease. This review aims to summarise the different replication-competent OVs proposed as therapeutics for pancreatic cancer. It also focuses on the unique biology of these viruses that makes them exciting candidate virotherapies for pancreatic cancer and discusses how they could be genetically manipulated or combined with other drugs to improve their efficacy based on what is currently known about the molecular biology of pancreatic cancer.

Publication: Oncolytic virotherapy

37 "Grant McFadden," Arizona State University Biodesign Institute, accessed March 9, 2020, https://biodesign.asu.edu/grant-mcfadden.

38 Photo from "Joshua LaBaer," Arizona State University, Biodesign Institute, accessed March 13, 2020, https://biodesign.asu.edu/joshua-labaer.

Case Study 3: Local Talent Retention

Beyond funding research and development activities in Arizona, TRIF has also helped attract and retain talented people. The case of Kristen Swingle, chief operating officer at Critical Path Institute (C-Path), illustrates how the TRIF program allows professionals to advance their careers in Arizona.

Swingle was born and raised in Tucson. She holds a bachelor's degree in biology from Northern Arizona University and a master's degree in medical sciences from Texas A&M University. After earning her master's degree, she and her husband returned to Arizona, where she conducted R&D at an environmental testing laboratory in north Phoenix. After three years, she joined Cord Blood Registry in Tucson, where she later served as vice president of laboratory operations for 10 years. In July 2019, she joined C-Path as chief operating officer. In addition, Swingle has been on the board of the Arizona Bioindustry Association since 2015, serving as chair for the last two years.

For Swingle, TRIF funding plays a critical role in fueling innovation and recruiting talent to companies looking to expand in Arizona. When asked about the potential economic impact of cutting the TRIF program, Swingle replied:

"If TRIF is not sustained, the impact on research and innovation in Arizona will be substantial. The lure for students and companies to commit to Arizona will be drastically reduced because they will recognize that their futures will be limited, whether it be due to lack of research opportunities or a struggle to find talent to support their anticipated growth projections… The last 20 years of TRIF have primarily supported the research infrastructure that is needed to draw talent to our state, and we are just beginning to reap its benefits, economically."

The life science industry in Arizona has boomed over the last 20 years. Swingle believes that TRIF will continue to be an essential supporting pillar to local life science and medical research activities. The research outcome will benefit people in both Arizona and other parts of the world. As she puts it:

"Over the next 5-10 years, I believe it will be critical that we continue to support the diversification of research and innovation within our state. In particular, the drugs of 30 years ago are not the therapies of the future. With the age demographic and diversity of Arizona's constituents, Arizona is poised to be a hotbed for the creation of new, innovative treatments that impact our local and global communities."

Kristen Swingle

Source: Photos provided by Kristen Swingle (2020)

CONCLUSION

Arizona has seen its number of patents, new startups, and related activities soar since 2002, particularly accelerating since the end of the Great Recession in 2010. Arizona's universities have been increasing their contributions to Arizona's economy. In particular, since the passage of Proposition 301 and the establishment of TRIF, Arizona's public universities have been able to greatly expand their role in technology transfer and life sciences research and to generate more high-paying jobs in the state.

In this report, we have presented both quantitative and qualitative evidence showing the impact of Proposition 301 and TRIF on the economy. We have presented a number of success stories in different parts of the state that have benefited from the TRIF program and its emphasis on technology transfer. Proposition 301 remains an essential source of funding for education in Arizona, and TRIF demonstrates a strong commitment by the state to tech transfer at the universities. Arizona's universities have benefited from increased state funding. In turn, the state's private sector has also benefited massively from the strong partnerships and robust economic activity that have resulted from TRIF-supported research at these universities. Furthermore, these benefits have extended not only to the core innovation hubs in and near the major research universities but to all corners of the state. As the competition for jobs in knowledge-based industries, high technology, and especially the life sciences remains fierce nationally and globally, Arizona must consider how to make TRIF more sustainable to deepen Arizona's research capacity and further boost its economic development.

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