



Ohio BOLD:

A Blueprint for Accelerating the Innovation Economy

Performed For: Ohio Chamber of Commerce Research Foundation
Performed By: TEconomy Partners, LLC

JULY 2018



**Research
Foundation**



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Ohio BOLD

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Foreword

Ohio's future in the innovation economy is at a pivotal point. Even with Ohio's economic development initiatives, cutting-edge innovation, and business-friendly tax incentives and regulation reforms, the speed of technological advancements requires Ohio to embrace a new paradigm. Disruptive technology is changing the face of every industry and will be the competitive strength needed to accelerate in this new economy. As innovation's role in driving economic growth continues to increase, Ohio's statewide macroeconomics fall further behind. Despite pockets of success, this slower pace manifests itself in the following categories:

- Slower population growth
- Slower growth in income and wages
- Increased poverty
- An aging and nondiverse population.

Ohio BOLD creates a blueprint for success in accelerating Ohio's economy. As a new governor assumes office in January, significant bold steps are required to leverage and build upon existing efforts to catalyze long-term economic growth. At the heart of this blueprint is the recommendation for a statewide organizational approach to pursuing strategic innovation opportunities around four opportunity platforms:

- NextGen Manufacturing
- Future Health
- Smart Infrastructure
- Data Analytics.

These four opportunities emerged through months of research, benchmarking Ohio against eight peer and aspirational states, leveraging its core competencies, and assessing areas of potential exponential growth.

Each of these platforms would be represented by newly created statewide Innovation Hubs through which Ohio would foster the infusion of advanced innovation processes, products, and techniques. Ohio already is home to several successful initiatives that would benefit the entire state if scaled up. Examples include the following:

- The America Makes facility in Youngstown provides a significant stake in the ground in terms of signature research in NextGen Manufacturing and Materials.
- The Research, Entrepreneurship, Discovery, and Innovation Zone (REDIzone®) located on the campus of Northeast Ohio Medical University in Rootstown enables innovators of biotechnology to take their research from concept to capital.

FORWARD

- Smart Columbus, DriveOhio, and the Transportation Research Center are paving the way for the entire state to succeed and lead with smart infrastructure design and models.
- The University of Cincinnati's 21st Century co-op experience breaks down the walls between being a college student and being an employee by exploring creative opportunities for workforce development.

While statewide strategies are being proposed, it must be noted that one-size-fits-all models do not generally work. The recommendation for Innovation Hubs relies on local relevancy, existing strengths, and a strong connected ecosystem. Statewide Innovation Hubs will support current innovation while bringing together industrial partners, research institutions, and the public sector in a new unique partnership to accelerate Ohio's economy. The Innovation Hubs will advance technological convergence and capacity; attract and generate a skilled technical workforce; and foster the growth, attraction, and creation of businesses. The Innovation Hubs will focus on industry-facing activities and specialized shared-use facilities to advance new product development, process improvements, and commercialization of new technologies.

In addition, Ohio needs to further elevate an entrepreneurial and risk capital ecosystem to drive future economic growth by doing the following:

1. Expanding the role of regional Entrepreneurial Signature Programs to ensure that the opportunities generated by the future Innovation Hubs are scaled statewide.
2. Focusing additional efforts to create early-stage risk capital on funding the creation of emerging firms from the four opportunity platforms.
3. Stimulating the creation and attraction of later-stage risk capital financing to ensure that emerging opportunities can grow and scale in Ohio.

While past and current initiatives to catalyze entrepreneurial development have obtained significant returns on investment, the overall macro entrepreneurship needle isn't moving fast enough. Ohio must nurture a risk capital community that is both oriented toward early-stage financing and committed to indigenous investment. Such indigenous funds would help to identify promising discoveries, support new ventures, and facilitate their connection to outside capital.

Ohio must also achieve improved talent. Human capital is one of the few market factors that are locally based and have the potential to create significant advantages and disadvantages. Ohio needs to develop, retain, and attract the talent that its industries demand by pouring significant talent development into both the Data Analytics and the NextGen Manufacturing Innovation Hubs, offering financial incentives for Ohio graduates pursuing careers in any of the opportunity platforms, and creating an Ohio Alumni Outreach Program.

The cost to implement this blueprint is quite significant; however, funding streams already exist that could provide resources for these efforts. The price of not investing is even higher. Failure to advance the four innovation platforms identified will have significant long-term ramifications. First movers in creating the next-generation environments based around these Innovation Hubs will enjoy disproportionate advantages and economic growth. Now is the time for Ohio to be **BOLD**.

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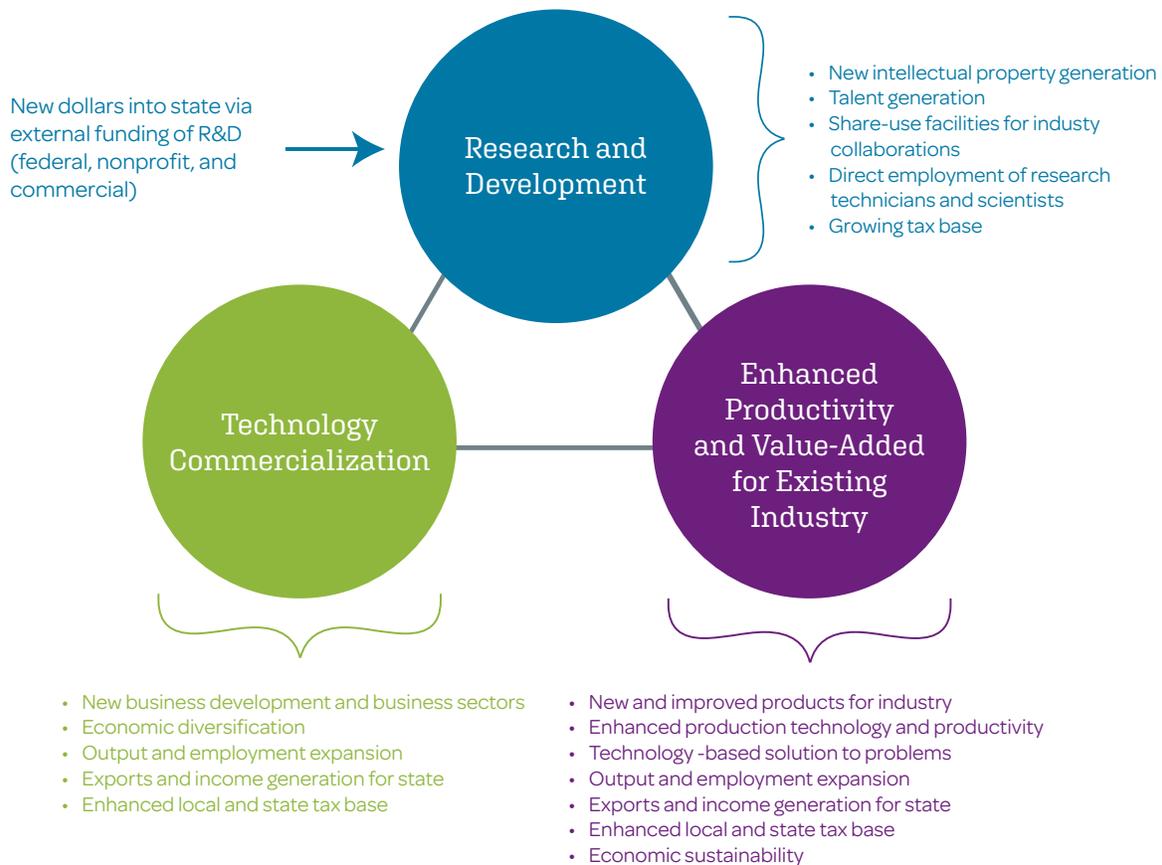
Executive Summary

A Call to Action

Innovation is the key driver of economic growth (Figure ES-1)—leading to high-quality jobs and rising standards of living. As the World Economic Forum in its highly touted Global Competitiveness Report explains:

In the long run, standards of living can be expanded only by technological innovation ... This requires an environment that is conducive to innovative activity, supported by both the public and the private sectors.¹

Figure ES-1. Innovation-Led Development is a Key Driver of Economic Growth



Source: TEconomy Partners, LLC

¹ World Economic Forum, *The Global Competitiveness Report 2010–2011*, page 8.

EXECUTIVE SUMMARY

Understanding the importance of advancing innovation to help ensure economic prosperity, the State of Ohio has a long history of investing significant resources in innovation-based investments that have helped strengthen the state's key economic industrial drivers. Beginning in the 1980s with investments in the Thomas Edison Program and continuing through today with investments in both the Ohio Third Frontier and JobsOhio, the state has been heralded by many as a pioneer in innovation-based economic development.

However, there is great concern that the past decades' economic success may have been part of a nonsustainable bubble, hiding the fact that Ohio's economic competitive strength was being eroded by changing economic drivers, including outsourcing, declining real-dollar investment in domestic research and development (R&D), and the rise of a new breed of technology-savvy global competitors. ***In this fast-paced, global economic paradigm, innovation initiatives are no longer just an important endeavor, but an absolute necessity for the state's economic competitiveness moving forward.*** In an interesting paradox, the more global and integrated the economy becomes, the more local R&D know-how, entrepreneurial culture, workforce skills, and manufacturing competencies matter for economic success. Even with Ohio's proactive stance in cutting-edge innovation and economic development initiatives, global competition and continued technological advancements requires Ohio to embrace new paradigms to ensure its investments are impactful and far reaching.

Today, Ohio's citizens are concerned that the state's economy is not as strong as it needs to be and, as a result, is falling behind the nation and competitor states. Since 1968, often thought to be the height of the industrial economy, Ohio's gross domestic product (GDP) per capita (a leading indicator of a region's standard of living) has remained stagnant while the nation's continues to increase, indicating that Ohio is losing ground.

As innovation's role in driving economic growth continues to increase, Ohio's economy falls further behind. Ohio's private sector average annual GDP growth rate from 1991–2016 was 6.7 percent compared with the U.S. average annual GDP growth rate of 8.8 percent—behind by more than 2 percent per year over the 26-year period. This slower economic pace, directly or indirectly, manifests itself in the following:

- **Slower population growth**—Ohio's total population during the 1991–2016 period grew by 6.1 percent, compared with 27.7 percent for the United States overall.
- **Slower growth in per capita income**—Ohio's per capita income, in real terms (USD 2016), grew by 1.38 percent from 1991–2016, to \$44,593, compared with the U.S. growth rate of 1.63 percent reaching \$49,246.
- **Slower growth in real wages**—Ohio's average wage, in real terms (USD 2016) grew by 17 percent from 1991–2016, compared to U.S. average wages that grew by 26 percent over the same period.
- **Lower median household income**—Ohio's median household income grew by 3.2 percent during the 1991–2016 period, compared with the United States growing at 3.8 percent during the period.
- **Increase in levels of poverty**—Ohio's share of people in poverty increased by 0.3 percentage points from 1991–2016, reaching 13.7 percent, while the U.S. levels saw a decline of 1.5 percentage points to 12.7 percent.

These key economic indicators are of grave concern to key thought leaders across the State of Ohio. Recognizing the opportunity to rethink strategic public policy initiatives in light of a new administration coming into office, the Ohio Chamber of Commerce Research Foundation, in partnership with regional Chambers of Commerce, commissioned this study to develop a blueprint for public policies that will help secure Ohio's position as a leader in the tech-based/innovation economy.

Shifting Ohio's Innovation Paradigm to Catalyze Economic Growth

While manufacturing has been, is, and will continue to be, a significant driver of Ohio's economy, the state continues to diversify, adding additional industrial drivers within various services sectors, including healthcare, insurance, and financial services. However, each of Ohio's industry clusters has had varied growth rates, impacted by specific circumstances related to broad market factors, as well as the following:

- Lagging investment in R&D,
- Trailing levels of innovation as measured by patenting activities, and
- Lower productivity levels.

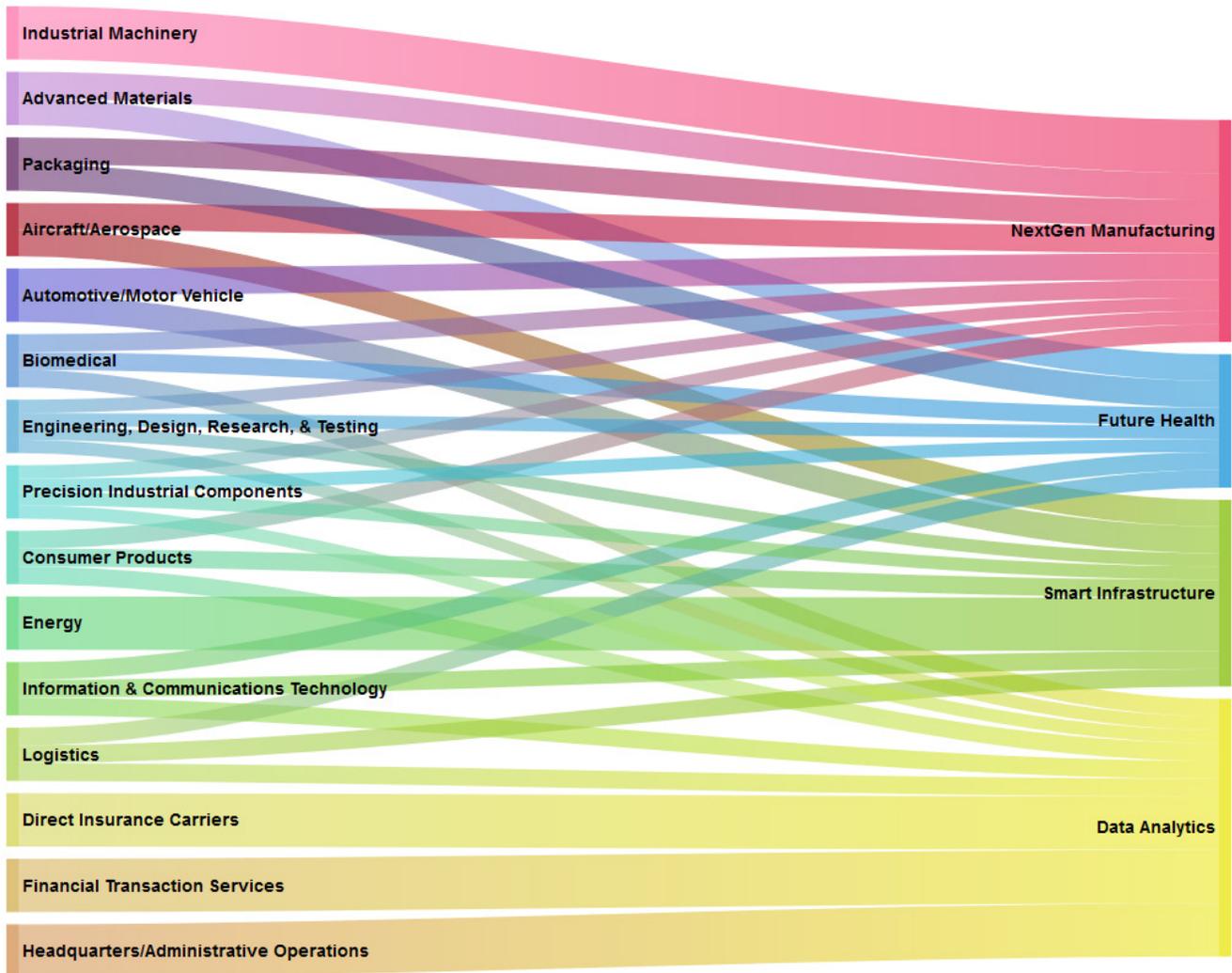
Together, these factors—the diversification of Ohio's economic drivers, uneven growth rates across many clusters, significant concerns over levels of research, innovation, and productivity growth—warrant a new approach to fostering innovation. It is paramount that Ohio embrace the increasing role that both innovation and technological convergence will play across all sectors of the economy and treat it as an opportunity—or risk Ohio's industrial and economic future.

To elevate and accelerate Ohio's economy, this new paradigm seeks to strategically realign Ohio's innovation investments to focus not on industry clusters, but instead on transformational innovation platforms—areas of convergence, where innovation and disruptive technologies can and will impact many of Ohio's traditional industry clusters. After a thorough analysis of the state's competitive position, including an examination of Ohio's performance against eight benchmark states as well as assessing where it has the opportunity for significant future growth, four key innovation platforms emerged. As Figure ES-2 visually illustrates, these four innovation platforms are impacting Ohio's key industry drivers and will accelerate their future growth and ensure their economic viability:

- **Next-Generation Manufacturing and Materials**
- **Future Health**
- **Smart Infrastructure**
- **Data Analytics.**

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Figure ES-2. Mapping Key Industry Clusters to Ohio's Innovation Opportunity Platforms

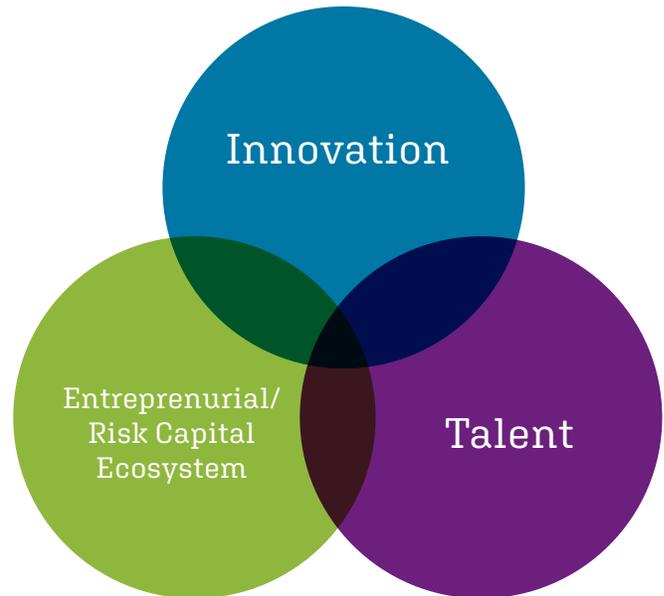


Source: TEconomy Partners, LLC

Strategic Recommendations to Accelerate Ohio’s Economy

The State of Ohio has a critical role to play in ensuring its innovation ecosystem is structured to leverage disruptive change and adapt to it. To accelerate Ohio’s economy, it is proposed that the state focus its innovation investments on three strategic priorities. The emphasis should be on leveraging and complementing existing efforts while catalyzing long-term economic growth across the state. Specifically, the three strategies should focus on the following:

- **Infusing cutting-edge innovation into Ohio’s industrial economic drivers through focus on the four identified platforms to ensure existing industries remain globally competitive and new industries emerge;**
- **Further elevating the entrepreneurial/risk capital ecosystem to drive future economic growth; and,**
- **Developing, retaining, and attracting talent that Ohio’s industry demands.**



The primary recommendation is that Ohio should create four statewide Innovation Hubs that address the full innovation ecosystem of needs by advancing and deploying cutting-edge innovation within the opportunity platforms.

This statewide organizational approach to pursuing strategic innovation opportunities offers the advantage of supporting strategic areas of innovation, while bringing together numerous industrial partners, public and private research institutions, and the public sector in a unique partnership to advance Ohio’s economy.

While Ohio has already made significant investments in a number of these innovation platforms, the activities are often not connected nor of a scale to have statewide impact. The proposed Innovation Hubs will work statewide to leverage these disparate efforts to develop critical mass and statewide relevance. The statewide Innovation Hubs will focus on “industry-facing” activities and specialized shared-use facilities to advance new product development, process improvements, and commercialization of new technologies through active connections to serial entrepreneurs, angel investors, and seed-stage venture capital funds. By focusing on specific areas of innovation that are relevant to large sectors of Ohio’s industrial economy and encompasses numerous projects and organizations, these targeted development initiatives will accomplish the following:

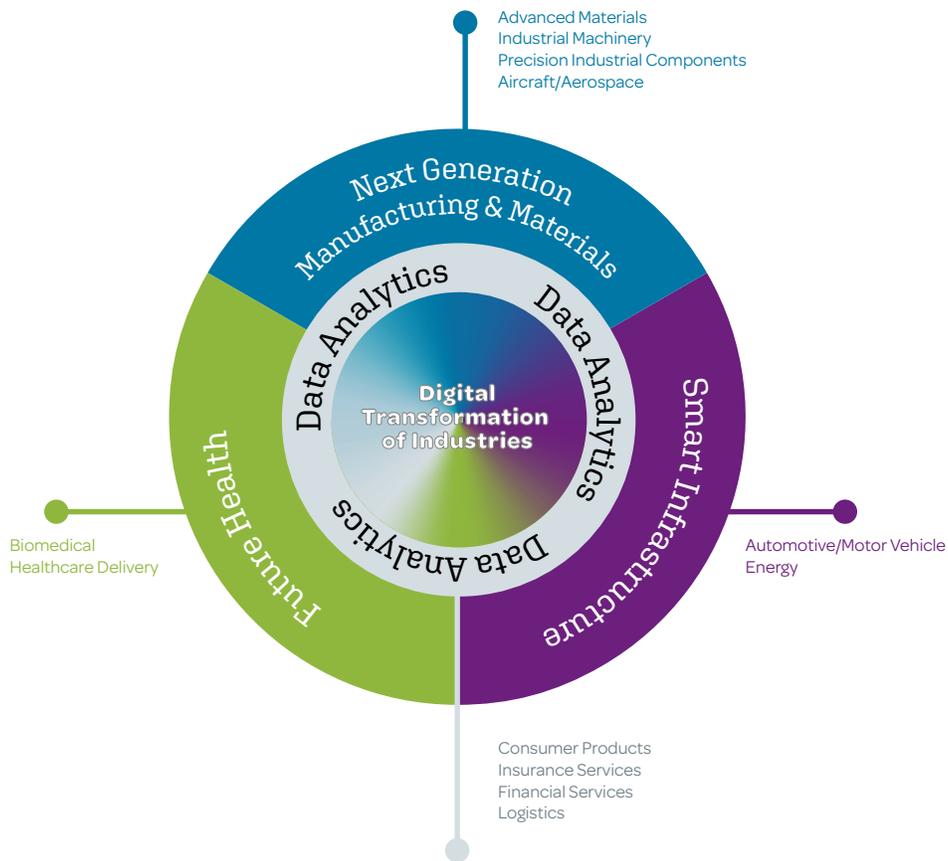
- **Advancing technological convergence and innovation capacity**, with a strong focus on building innovation capacity across Ohio’s economic industrial drivers;
- **Attracting top talent** that industry needs; and
- **Fostering the growth of existing firms, creation of new firms, and attraction of firms.**
- Additional benefits of these dedicated Innovation Hubs are their ability to support the following:

EXECUTIVE SUMMARY

- **Branding and proactive outreach** that creates and sustains a market leadership position for Ohio and helps generate business attraction leads for Ohio.
- **Addressing workforce and new talent generation** from development of new curriculum and degree programs at the postsecondary level to experiential learning and internships that connect students with industry to creating career academies, summer programs, and career awareness at the K-12 education level.

These four innovation opportunity platforms (Figure ES-3) incorporate multiple state industry clusters into a new innovation investment strategy that seeks to accelerate the transformation of Ohio's industries and position the state for future economic growth.

Figure ES-3. Ohio's Four Innovation Opportunity Platforms



Source: TEconomy Partners, LLC

The four innovation platforms demonstrate opportunities for convergence in the ways they interact with one another to create combination technology solutions, driven by the underlying digitization of industries. Each platform can have profound impacts on the future of the state's economy and quality of life:

- **Investing in next-generation manufacturing and materials can allow the state to create a world-class “smart” manufacturing environment that serves a variety of industry verticals and maintains Ohio’s specialized workforce advantages.** Industry will be able to produce highly customized products with minimal waste using on-demand, cloud-based design templates and design consultants. Workers will experience large increases in the level of technical skills and be able to utilize more flexible training and continuing education models.
- **Organizing the medical and healthcare industries around an integrated future health vision will allow the state to spur development of integrated care environments and see the widespread adoption of digital health platforms.** Increases in connected health will allow high-quality treatment to be delivered remotely within patients’ homes and cut down on medical product abuse while improving early diagnoses of problems. The state can eventually implement a true population health system of networked industries and healthcare data that demonstrates long-term reductions in levels of serious disease and attracts skilled workforces eager to take advantage of the availability of high-quality healthcare options.
- **Successfully branding Ohio as a world-class smart city and smart infrastructure test-bed environment and widespread investment in connected infrastructure will make the state a regional hub for new innovation opportunities.** The state will build a reputation as a signature destination for testing unmanned and automated systems, as well as pioneering approaches to revitalize aging infrastructure and energy grids while incorporating advanced data collection systems that allow advancements in civil engineering and utilities management. The overall perception of the state’s focus on smart infrastructure will attract skilled talent bases that want to take advantage of highly connected and sustainable live-work-play environments and further reinforce the brand of the state as an innovation hub.
- **Creating a high-quality data analytics innovation ecosystem will result in improved business intelligence and insights for the companies of the state, in turn leading to improvements in customer products and services that generate industry growth.** The presence of visionary thought leaders in specialized areas of data science will create a more vibrant entrepreneurial ecosystem around next-generation finance, insurance, digital marketing, consumer experience, logistics, and health IT companies that sustains a broad base of tech start-ups.

Achieving this aspirational vision of the future where digital transformation has spread across Ohio’s industries is within reach if the state adopts a forward-thinking focus on innovation platforms.

While the creation of four statewide Innovation Hubs is the anchor recommendation, it is not alone sufficient to accelerate Ohio’s economy. Other important strategies and critical actions must be pursued to ensure long-term economic growth and vitality. Table ES-1 provides a summary of the recommended action plan to accelerate Ohio’s innovation economy.

Table ES-1. Recommended Action Plan: Accelerating Ohio's Economy

Strategy One: Foster the Infusion of Advanced Innovation Processes, Products, and Techniques throughout Ohio's Industrial Base

Action 1: Create four statewide Innovation Hubs that focus on the innovation opportunity platforms and represent public-private partnerships.

See above narrative that summarizes the proposed action.

Action 2: Review and update Ohio tax code to create additional ways to incent Ohio companies to invest in new products and process improvements.

- Increase level of R&D credit for companies within the four innovation platforms and expand definition of research to be more encompassing of digital transformation product and process improvements.
- Emphasize R&D Sales Tax Exemption for those technologies that are tied to digital transformation innovations and suggest local taxing authorities provide exemption as well.
- Make greater use of New Markets Tax Credit to invest in companies within the four innovation platforms that locate in rural or distressed areas.
- Expand Ohio's Job-Creation Tax Credit program to use payroll, in addition to the number of jobs created, as a trigger measure.
- Develop financial incentives for companies that support skills-building investments for their mid-career workforces that can accelerate the process of transitioning existing workers toward new skills sets more aligned with innovation needs.
- Increase the level of funding available for the JobsOhio R&D grant program and focus targeted efforts on companies within the four innovation platforms.
- Tie international trade mission efforts to attracting new investments to the state related to the four innovation technology platforms.
- Develop a dedicated funding stream to enable rural communities to develop sites to pursue attraction and expansion opportunities within the four innovation platforms.

Strategy Two: Further Elevate the Entrepreneurial/Risk Capital Ecosystem to Drive Future Economic Growth

Action 3: Continue to invest in the regional Entrepreneurial Signature Programs (ESPs), and expand their role to ensure that innovation opportunities generated by the four Innovation Hubs are scaled in Ohio.

- Continue to invest in the regional ESPs, recognizing that the services these organizations provide are a critical component of the successful implementation of this innovation strategy.
- Leverage the ESP infrastructure to support the efforts of the four Innovation Hubs to create new start-ups/scale-up emerging companies that are commercialized as a result of their activities.
- Link emerging companies to Ohio's anchor industries as first customers and early adopters so that innovations can be deployed into the field to prove their efficacy and firmly establish these companies' roots in Ohio as they grow and scale at a more rapid pace.
- Create a Serial Entrepreneur Attraction Program to attract talent from outside the state to support emerging opportunities by offering personal income tax and/or investment incentives thereby de-risking the perceived costs of relocating to the state.
- Focus additional efforts around culture-building activities across the state by stimulating entrepreneurial networking, holding meet-up events, and promoting success stories so that entrepreneurship is more widely embraced in every region of the state.

Action 4: Continue to foster the creation of early-stage risk capital by focusing additional efforts on funding the creation of emerging firms from the four innovation platforms.

- Create pre-seed/seed/seed-plus funds specifically focused on the four innovation opportunity platforms to support new product development.
- Reinstating the Technology Investment Tax Credit to catalyze the investment of angel funding across the state focused, in particular, around the four innovation platforms.
- Create an SBIR/STTR Phase III funding program as a source of nondilutive early-stage risk capital that supports successful Phase II grantees in their efforts to commercialize their technologies.
- Provide nondisputable clarification of Ohio law to allow for public universities and entrepreneurial service/ risk capital grantees to take equity positions.

Action 5: Stimulate creation/ attraction of later-stage risk capital financing to ensure emerging opportunities are able to grow and scale in Ohio.

- Create a state-sponsored and/or supported equity investment fund to create/attract Series A and B funds to Ohio (through a fund-of-funds (FoF) co-investment model) by engaging corporations, foundations and other major investors as limited partners (LPs).
- Create a Venture Capital Managerial Attraction Program to increase the investment talent in the state.
- Create venture debt funds to provide nondilutive working capital (growth capital) that is targeted at both high-growth companies that are in need of additional financing between venture rounds as well as companies that do not meet the traditional investment profile for venture capital but represent promising opportunities within the four innovation platforms.

Strategy Three: Develop, Retain, and Attract the Talent that Ohio’s Industry Demands

Action 6: Encompass significant talent development efforts into the Data Analytics Innovation Hub.

- Focus the Data Analytics Innovation Hub, in part, on supporting the human capital that will drive the adoption of innovative processes and products by:
 - Developing professional networks where executive management can gain knowledge about implementing analytics solutions that drive innovation in their firms,
 - Developing training/skill retraining programs to meet the mid-career needs of data analytics professionals, and
 - Developing the connections between industry and academia to help design specific data analytics programs to ensure that the needs of Ohio industry are met, including the creation of a Summer Institute for Data Analytics for rising college juniors to provide them with a unique experiential learning experience as well as the establishment of a statewide Data Analytics Internship/Co-Op Program.
- Support the efforts of the Innovation Hub with a comprehensive state focus on upgrading data analytics skilled talent pools, including:
 - Leveraging the coordinating power of Office of Workforce Transformation and utilizing federal funds allocated by the Ohio Department of Job and Family Services (ODJFS) and the Ohio Department of Higher Education (ODHE), create funding mechanisms for the talent programs of the Innovation Hub as well as company-specific training programs.
 - Expanding career center/vocational training offerings to encompass additional digital analytics/ IT training and clearly articulate career pathways to students, parents, and career guidance counselors.
 - Incorporating data analytics into K-12 educational requirements to ensure that the skill sets required for all industries of the future are embedded into Ohio’s core educational offerings.

Action 7: Encompass significant talent development efforts into the NextGen Manufacturing and Materials Innovation Hub.

- Create a collaborative training facility that aggregates industry demand for advanced skills training and provides hands-on learning.
 - Partner with the career center/vocational training offerings around the state to expand their own next-generation manufacturing training offerings and clearly articulate the high demand for these careers, the level of pay, and the opportunity for career pathways to students, parents, and career guidance counselors.
 - Partner with educational institutions across Ohio to develop new work-school models to serve industry partners—apprenticeships, co-op programs, and working student programs.
-

Action 8: Encourage Ohio graduates to pursue careers within the four innovation opportunity platforms by offering financial incentives.

- Provide financial incentives for Ohio graduates with skill sets related to the four innovation platforms (including residents attending out-of-state universities) to encourage them to pursue their careers in Ohio.
 - Guarantee diversity and inclusiveness of these efforts to ensure that students across the State of Ohio participate by establishing metric goals for minority and geographic (rural) participation.
-

Action 9: Offer financial incentives for senior and mid-level professionals to relocate to Ohio for careers within the four innovation platforms—create an Ohio Alumni Outreach Program.

- Attract to Ohio senior and mid-level professionals demanded by industry by offering personal income tax and other incentives. By working to de-risk the perceived costs of relocating to the state, Ohio will catalyze the amount of talent in critical leadership positions in its most innovative firms.
 - Create an Ohio Alumni Outreach Program, utilizing the vast alumni networks of Ohio's higher education institutions and serving as an immediate connection point to the State of Ohio.
-

Sources of Funding

While the funding requirements for these critical statewide initiatives will be significant, they will also be transformative for Ohio's economy—developing an innovation ecosystem structured to leverage disruptive change and adapt to it. It is important to note that, within the State of Ohio, funding streams already exist with significant revenue to provide the vast majority of the resources required for these efforts. It is simply a matter, in some cases, of reprioritizing the focus of these existing revenues on these transformative new activities, and in others, of renewing their original purpose/mission. These existing sources of funding include the following:

- R&D Bond Funding:** The R&D Bond fund has been used to fund the Ohio Third Frontier for over a decade. Utilizing this revenue source, the Ohio Third Frontier has funded a number of innovation-based programs over the years, including efforts to enhance the commercialization of near-market technologies, the advancement of specific industry clusters, and the formation of Wright Centers of Innovation. Since 2008, the bond funding has also provided revenue to support the operations of six ESPs across the state as well as helped capitalize numerous pre-seed and seed funds. The current fund, approved by the voters in 2010, has more than \$225 million of unencumbered funds remaining that could support the regional ESPs and help expand their role to ensure that the innovation opportunities generated by the four statewide Innovation Hubs are scaled in Ohio. In addition, remaining funds could be used to continue to foster the creation of early-stage risk capital funds focused on emerging firms from the four innovation platforms. Further, it is recommended that voters be asked to renew the R&D bond fund at the earliest possible time to provide additional and sustained dollars to fund the other strategic efforts outlined herein.
- Liquor proceeds:** JobsOhio was created in 2011 as a private corporation funded through the purchase of the state's liquor business. JobsOhio paid the state \$1.4 billion to purchase the liquor enterprise and makes supplemental purchase payments to the state every year based on the total net liquor revenues it receives. JobsOhio has significant discretion in the use of its funds to advance economic development efforts in the state. While the entity's primary focus should remain on its core mission of attraction and expansion of corporate entities to and within the State of Ohio, JobsOhio has sufficient resources and should consider dedicating annually a meaningful portion of the liquor proceed revenues to fund the strategic efforts outlined herein.
- Federal workforce dollars:** As a result of the Federal Workforce Innovation and Opportunity Act, the State of Ohio receives more than \$150 million a year in federal funds to apply to workforce efforts. While restrictions exist on how the money can be applied, it is recommended that a portion of these dollars be focused on advancing the NextGen Manufacturing and Data Analytics skill sets of Ohio's workers in partnership with the Innovation Hubs.
- Private capital investments:** It will be critical to engage Ohio's industrial community in these strategic actions to catalyze their own investments in technological development within their own firms that are advanced by the Innovation Hubs, as well as advancing Ohio's innovation economy through investments in later-stage risk capital financing mechanisms.

By targeting existing revenue streams to these focused initiatives, Ohio will be able to accelerate its economy in new and bold ways.

Conclusion

This following report outlines a blueprint to accelerate Ohio's economy through a focus on driving innovation into the state's industrial base, both existing and emerging, to ensure future global competitiveness. The ability to create the envisioned innovation ecosystem has high stakes for Ohio's future. First movers in creating next-generation environments based around innovation platforms will enjoy disproportionate competitive advantages and economic growth compared with competitors. Failure to advance the four innovation platforms identified have significant long-term ramifications:

- Ohio manufacturing and production industries are especially vulnerable to disruption by new technologies and automation and represent a sizable portion of the state's industry strength. Failure to innovate will leave these companies, and hence a large portion of Ohio's economy, at great economic risk.
- The ability to serve populations with modern, innovative healthcare models has significant stakes in the state's quality-of-life attractiveness versus other states adopting novel integrated healthcare models. Failure to innovate will not only leave Ohio's emerging Future Health industrial base at risk, but will also not advance Ohio's clinical care excellence, a positive quality-of-life factor to which Ohioans currently have access.
- Smart infrastructure leadership will be a key attribute in the branding of future attractiveness of Midwest states. Failure to obtain a leadership position will put at risk Ohio's ability to compete for quality of place.
- Other regions are ahead in realizing the importance of their data analytics talent base to long-term success, and Ohio risks falling further behind without concerted effort in this area.

The stakes are high for Ohio; but, by supporting broad-based **innovation** platforms; further elevating the **entrepreneurial/risk capital ecosystem**; and developing, retaining, and attracting the **talent** that Ohio's industry demands, Ohio can turn innovation into economic growth.

Setting the Context – A Reason for Concern

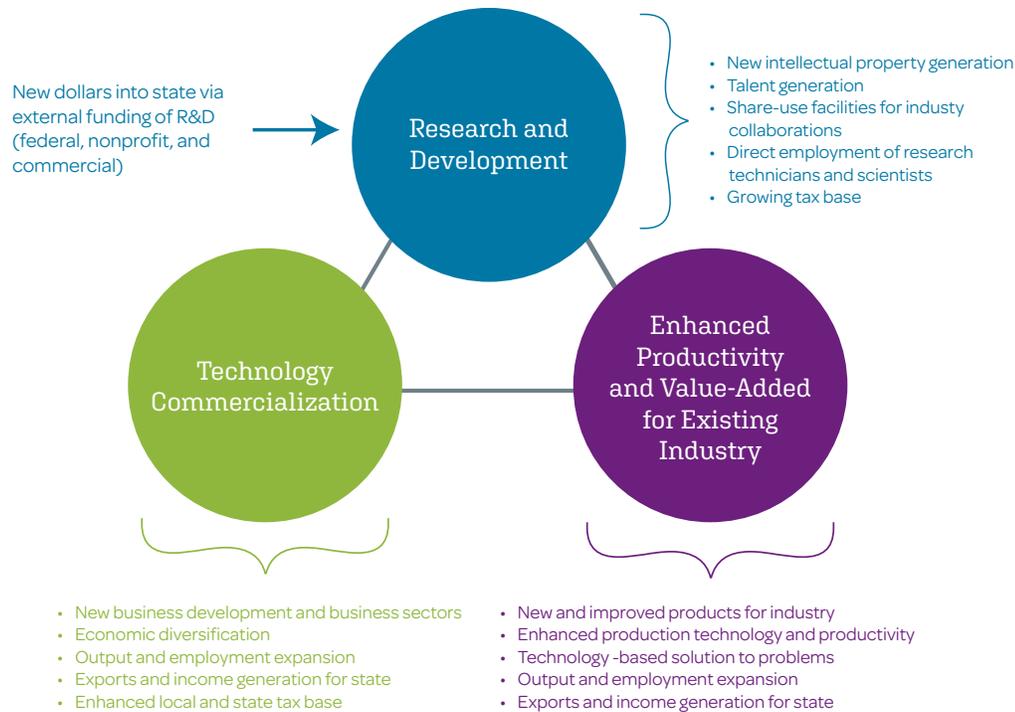
Innovation Economies Drive Economic Prosperity

The character of the nation’s economy is changing at a dramatic pace as technological advancements continue to significantly impact the economic growth and wealth of the country. The future is likely to be even more profoundly affected with the development and emergence of new fields derived from disruptive technologies. The competitive marketplace is global; consequently, factors of comparative advantage are changing. Fifty years ago, traditional comparative advantage factors included natural resources, low-cost labor, and capital. In the 21st Century, comparative advantage is not measured by tangible assets, but instead, in terms of ease of access and timely control of knowledge-intensive, value-added capabilities to produce leading-edge, next-generation discoveries, breakthroughs, and systems.

As illustrated in Figure 1, innovation and technology development prowess are key drivers of economic growth, high-quality jobs, and rising standards of living—explaining not only the differences in economic growth among nations, but also at the level of state and regional economies. As the World Economic Forum in its highly touted Global Competitiveness Report explains:

In the long run, standards of living can be expanded only by technological innovation.... This requires an environment that is conducive to innovative activity, supported by both the public and the private sectors.²

Figure 1. Innovation-led Development is a Key Driver of Economic Growth



² World Economic Forum, *The Global Competitiveness Report 2010–2011*, page 8.

Ohio's History of Significant Innovation Investment

Understanding the importance of advancing innovation to help ensure economic prosperity, the State of Ohio has a long history of investing significant resources in innovation-based investments that have helped strengthen the state's key economic industrial drivers. Driven by the severe downturn of its economy through the 1970s, Ohio was one of the first states in the nation to invest in technology-based economic development when, in 1983, Ohio's legislature created the Thomas Edison Program, a state-funded initiative to encourage universities to cooperate with businesses to link research and technology with existing and start-up companies. Over the course of the initiative, the Edison program supported the establishment of seven technology centers and nine business incubators and provided seed development funds to spur innovation efforts across the state.

In 1990, the Columbus Dispatch deemed the Edison program an "unqualified success," citing the fact that the "Ohio corporate community has taken ownership of the Edison program."³ The seven technology-focused Edison Centers worked with industry across the State of Ohio to foster university-industry collaboration emphasizing applied research leading to practical improvements in processes and products in areas such as welding, metal-forming, materials, polymers, industrial systems, and the biosciences.

As the State of Ohio moved into the 21st Century, once again its political leaders recognized that innovation and technology development prowess were the hallmarks of all high-performing, high-wealth-generating nations and states, and that, to help ensure economic prosperity, further innovation investment was needed. To help meet this need, the Ohio Third Frontier was created in 2002. As originally conceived, the Ohio Third Frontier invested resources across the continuum of innovation.

In pursuing a balanced portfolio of activities, the Ohio Third Frontier invested resources in a myriad of programs, including the following

- **Wright Centers of Innovation**, large-scale, world-class research and development (R&D) platforms designed to accelerate the pace of company and product formation in targeted areas of technology.
- **Targeted Technology Commercialization** funds related to specific industry sectors, such as fuel cells and medical imaging, which demonstrate high growth potential for Ohio. In general, these programs provided direct financial support to entities seeking to address technical and cost barriers to near-term market entry of innovative products, processes, and services that improve the competitiveness of the targeted industry sector throughout its supply chain.
- **Entrepreneurial Signature Program**, a comprehensive, regionally based network of high-value services and assistance providers that help technology-based entrepreneurs and small tech-based companies.
- **Pre-Seed and Seed Funds**, helping to capitalize professionally managed for-profit and nonprofit funds statewide, targeting investments in pre-seed-stage technology-based businesses.
- **Internship Program**, encouraging Ohio businesses to provide relevant work experiences at all levels for college students who are pursuing degrees in science, technology, engineering, and mathematics (STEM) disciplines.

³ *The Columbus Dispatch*, "Edison Program is Success—State is Seen as Beneficiary," April 2, 1990.

In 2009, an economic impact assessment of the Third Frontier was undertaken to determine the impact of the program and to help determine whether or not the program should be renewed. The analysis found in quantitative, bottom-line economic terms, the state's expenditure of \$681 million had generated \$6.6 billion of economic activity, 41,300 total jobs, and \$2.4 billion in employee wages and benefits. Qualitative changes had also resulted from Ohio Third Frontier investments, including the advancement of Ohio's entrepreneurial culture and the deepening of collaborations among major contributors to Ohio's innovation ecosystem.⁴ While the initiative has evolved since that time to focus primarily on catalyzing risk capital and entrepreneurial efforts across the state, the return on the state's investment continues to grow.

After facing the largest global recession the world had experienced since the Great Depression, Ohio once again refined its approach to economic development through the creation of JobsOhio, a private, nonprofit corporation that is designed to drive job creation and new capital investment in Ohio through business attraction, retention, and expansion efforts. JobsOhio works with six regional partners across Ohio and has consolidated Ohio's economic development functions into a private model. According to JobsOhio's 2017 annual report,⁵ the organization worked with state, regional, and local partners on 272 projects with companies that committed to invest \$9.6 billion; create 22,788 new jobs, representing \$1.1 billion in new payroll; and retain an additional 67,849 jobs.

Finally, at the urging of the business community, the State of Ohio has pursued over the years other major business climate initiatives, such as tax policy, regulatory policy, and tort reform that continue to improve Ohio's overall business climate.

The Innovation Economy Requires Constant Evolution

Today, there is great concern that the U.S. economic successes in the 1990s and early 2000s may have been part of a nonsustainable bubble, hiding the fact that the nation's economic competitive strength was being eroded by changing economic drivers, including outsourcing, declining real-dollar investment in domestic R&D, and the rise of a new breed of technology-savvy global competitors. As Harvard Business School professors, Gary Pisano and Willy Shih, explain:

The outsourcing has not stopped with low-value tasks like simple assembly or circuit-board stuffing. Sophisticated engineering and manufacturing capabilities that underpin innovation in a wide range of products have been rapidly leaving too. As a result, the U.S. has lost or is in the process of losing the knowledge, skilled people, and supplier infrastructure needed to manufacture many of the cutting-edge products it invented.⁶

The rise of a more integrated global economy seems to be unabated even in the aftermath of the severe global economic recession. McKinsey & Company in its survey of business executives reports the following:

An ongoing shift in global economic activity from developed to developing economies, accompanied by growth in the number of consumers in emerging markets, are the global developments that executives around the world view as the most important for business and the most positive for their own companies' profits....⁷

⁴ SRI International, *Making an Impact: Assessing the Benefits of Ohio's Investments in Technology-Based Economic Development Programs*, September 2009.

⁵ https://jobs-ohio.com/site/assets/files/2815/jobsohio_2017_annual_report.pdf.

⁶ Gary P. Pisano and Willy C. Shih, "Restoring American Competitiveness," *Harvard Business Review*, July 2009, page 2 of reprint.

⁷ McKinsey & Company, "Five forces reshaping the global economy: McKinsey Global Survey results," *McKinsey Quarterly*, May 2010, page 1.

In this fast-paced, global economic paradigm, innovation initiatives are no longer just an important endeavor, but an absolute necessity for the state's economic competitiveness moving forward. In an interesting paradox, the more global and integrated the economy becomes, the more local R&D know-how, entrepreneurial culture, workforce skills, and manufacturing competencies matter for economic success.

Within this Rapid Innovation Evolution, Ohio Continues to Fall Behind

Even with Ohio's proactive stance in cutting-edge innovation and economic development initiatives, global competition and continued technological advancements requires Ohio to embrace new paradigms to ensure its investments are impactful and far reaching.

Today, Ohio's citizens are concerned that the state's economy is not as strong as it needs to be and, as a result, is falling behind the nation and competitor states. Since 1968, often thought to be the height of the industrial economy, Ohio's gross domestic product (GDP) per capita (a leading indicator of a region's standard of living) has remained stagnant while the nation's continues to increase, indicating that Ohio is losing ground (Ohio's real GDP per capita in 1968 was \$46,307 and today it is \$46,826, compared with the U.S. real GDP per capita in 1968, which was \$44,224 and today it is \$50,155).

As innovation's role in driving economic growth continues to increase, Ohio's economy falls further behind. Ohio's private sector average annual GDP growth rate from 1991–2016 was 6.7 percent compared with the U.S. average annual GDP growth rate of 8.8 percent—behind by more than 2 percent per year over the 26-year period.

This slower economic pace, directly or indirectly, manifests itself in the following:

- **Slower population growth**—Ohio's total population during the 1991–2016 period grew by 6.1 percent compared with 27.7 percent for the United States overall.
- **Slower growth in per capita income**—Ohio's per capita income, in real terms (USD 2016), grew by 1.38 percent from 1991–2016, to \$44,593, compared with the U.S. growth rate of 1.63 percent reaching \$49,246.
- **Slower growth in real wages**—Ohio's average wage, in real terms (USD 2016) grew by 17 percent from 1991–2016, compared with U.S. average wages that grew by 26 percent over the same period.
- **Lower median household income**—Ohio's median household income grew by 3.2 percent during the 1991–2016 period, compared with the United States growing at 3.8 percent during the period.
- **Increase in levels of poverty**—Ohio's share of people in poverty increased by 0.3 percentage points from 1991–2016, reaching 13.7 percent, while the U.S. levels saw a decline of 1.5 percentage points to 12.7 percent.

As a point of reference, if Ohio had kept pace with the U.S. or benchmark states' average levels of growth, Ohio's current economy would be dramatically altered.⁸ As Table 1 illustrates, Ohio's performance typically lags both overall U.S. performance as well as the benchmark states' performance. For example, Ohio's 2017 GDP would be more than \$120

⁸ In consultation with the Ohio Chamber of Commerce Research Foundation, benchmarks were selected among comparison states considering several factors: Regional proximity (competitors); states with economies of similar size and structure (peers); states that have made long-term investments in their innovation ecosystem (aspirational); and states against which Ohio has traditionally compared itself. The benchmark states selected are Georgia, Indiana, Michigan, North Carolina, Pennsylvania, Tennessee, Texas, and Wisconsin.

billion greater if the state had grown at the same rate as the U.S. overall average and would be more than \$160 billion greater had it grown at the same rate as the benchmark states. Both per capita income and average private sector wages would have been measurably larger, growing at either the U.S. or benchmark states’ growth rates.

A key factor driving and/or reflecting Ohio’s economic condition is its population growth rate. Across a number of population metrics, Ohio’s growth is lagging the nation and the benchmark states. If Ohio was keeping pace, the state would have the following:

- More than 14 million people in the state at U.S. growth rates and nearly 14.7 million people at benchmark states’ growth rates.
- Substantially larger share of working age (25–64) population if growing at the U.S. growth rate (57.1 percent), and slightly larger at the benchmark states’ growth rate (52.7 percent).
- Fewer persons age 25 years or older with a bachelor’s degree or higher at the nation’s growth rate (Ohio, 26.7 percent; United States, 26.3 percent) but more at the benchmark states’ growth rate (29.0 percent). Attainment of a bachelor’s degree or higher is a key indicator of an innovation-based economy.

Table 1. Ohio’s Actual and Estimated Performance on Various Socio-Economic Measures

Measure	Ohio Performance		Growth Rate			Ohio Level IF Growth at U.S. or Benchmark States’ Rate	
	Initial Year	Most Recent Year	Ohio	U.S.	Benchmark States Average	At U.S. Rate	At Benchmarks Rate
GDP (billions; 1991-2017)	\$420.51	\$649.13	54%	83%	93%	\$771.42	\$812.51
Per Capita Income (1991-2017)	\$34,020	\$45,615	34%	40%	39%	\$47,729	\$47,123
Avg. Private Sector Wages (2001-2016)	\$45,348	\$46,983	4%	7%	6%	\$48,659	\$47,952
Total Population (millions; 1991-2017)	10.95	11.66	7%	29%	34%	14.09	14.69
% Ages 25-64 (1991-2016)	51.0%	52.2%	2%	12%	3%	57.1%	52.7%
% Ages 65 and Over (1991-2016)	13.1%	15.5%	18%	15%	23%	15.1%	16.1%
% of Persons Age 25 and Over w/ a Bachelor’s Degree or Higher (1991-2016)	18.6%	26.7%	44%	42%	56%	26.3%	29.0%

Note: Initial and Most Recent year of measure are shown in (). For both periods, dollar values are in current 2017 dollars.

Source: TEconomy Partners analysis of U.S. Bureau of Economic Analysis, U.S. Bureau of Labor Statistics, and U.S. Census data.

Intent/Purpose of Study

These key economic indicators are of grave concern to key thought leaders across the State of Ohio. Recognizing the opportunity to rethink strategic public policy initiatives in light of a new administration coming into office, the Ohio Chamber of Commerce Research Foundation, in partnership with regional Chambers of Commerce, commissioned this study to develop a blueprint for public policies that will help secure Ohio's position as a leader in the tech-based/innovation economy.

TEconomy Partners, LLC (TEconomy) (see sidebar) was retained to assist with the analysis to bring an independent, expert assessment and knowledge of best practices to develop the strategic recommendations. TEconomy has a proven track record in conducting rigorous and robust assessment studies of innovation ecosystems in numerous states—including Arkansas, Arizona, Connecticut, Georgia, Indiana, New Hampshire, North Carolina, Ohio, Utah, and Virginia—that inform the targeting of innovation-led growth opportunities found in a state as well as strategic actions to further innovation-based development.

It is important to note that Ohio, like many states across the nation, is facing numerous societal and demographic issues that are impacting the overall quality of life of its citizens—from the population shift of its rural communities to its urban centers, to the declining funding base for many public K–12 educational systems, to the escalating costs of higher education, to the increasing number of families impacted by generational reliance on welfare programs, to the growing opioid crisis. The ability to positively effect change on all of these issues will be critical to the long-term prosperity of the state and the successful implementation of many of the recommendations in this report. However, it is not within the scope of this project to tackle these very difficult issues by providing further recommendations—instead the numerous efforts that are seeking to bring smart public policy to resolve these long-term problems are applauded.

In 2015, TEconomy Partners, LLC was launched as an independent company, transitioning the complete staff and capabilities of the Technology Partnership Practice from Battelle Memorial Institute, one of the world's largest non-profit research organizations. TEconomy comprises key senior staff from Battelle's Technology Partnership Practice who have worked together for over 15 years, operating as a full-service assessment and strategy group. Our principals have a 25-year track record developing strategic plans and providing economic impact analyses. Our clients include industry associations, state and local governments, universities, non-profits organizations, business development groups, and foundations around the world. At a national level, TEconomy's public policy services help our clients, such as BIO and PhRMA navigate a range of issues, needs and opportunities.

Ohio's Economic Industrial Drivers

Manufacturing has been, is, and will continue to be a significant driver of Ohio's economy. Built upon a historic legacy of innovation and quality production, Ohio's manufacturers continue to employ over 685,000 workers, in more than 15,400 establishments across the state, and pay \$60,000 per year, on average, to these workers. Combined, Ohio's manufacturing-related GDP reached \$105.7 billion in 2016, accounting for 17 percent of the state's economy (44 percent more concentrated than the U.S. average) and generated more than \$49 billion in exports.

Ohio's manufacturing legacy and importance are well understood, touching every corner of the state:

- Global leader in polymers, metals, and other advanced materials development, production, and product manufacturing.
- Important production and supplier base to global automotive and aerospace industries.
- Key producer and component supplier to U.S. industrial equipment and machinery sectors.
- Important niche production in a wide variety of areas ranging from medical equipment, to food processing, to industrial chemicals, to consumer products.

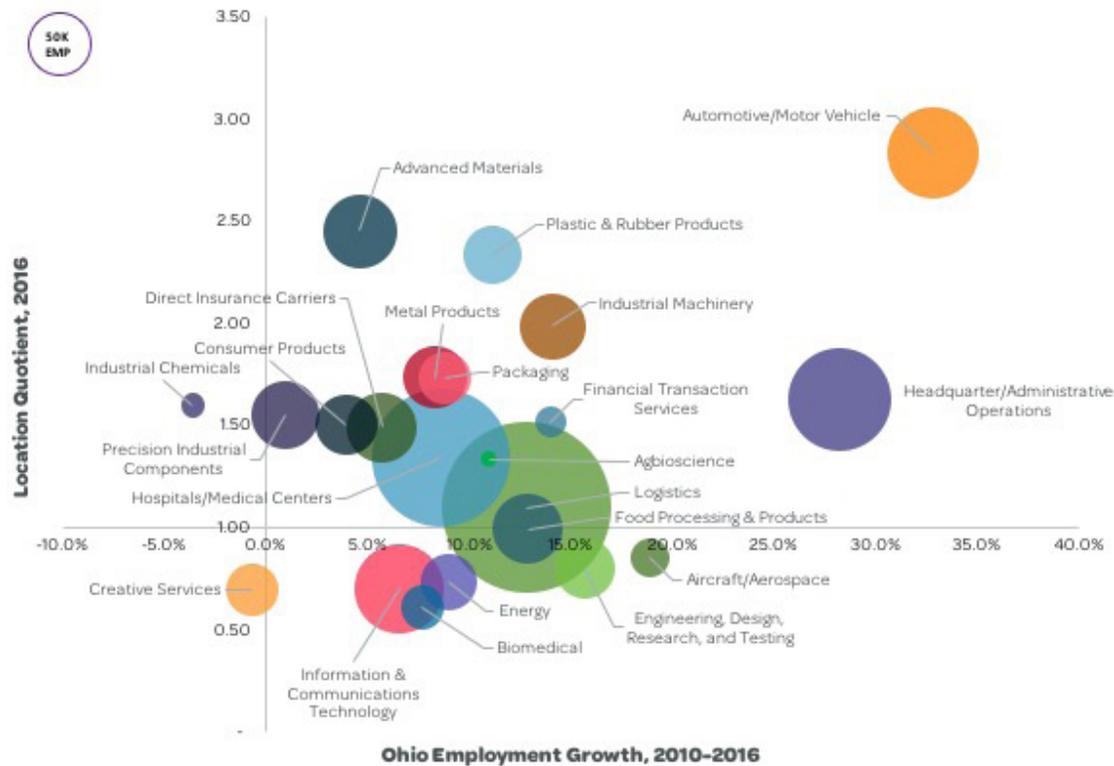
However, like the U.S. and global economies, Ohio's economy has also evolved and diversified into additional industrial drivers within various service sectors. These diversified sectors include the following:

- Global leaders in healthcare services and delivery.
- National leaders and providers of insurance and financial services located in many parts of the state.
- Significant and integrative employment across a wide variety of engineering, technical, consulting, and research services as well as logistics services including distribution, warehousing, and transportation.
- Home to the national headquarters of many Fortune 500/multinational companies.
- These other aspects of Ohio's industrial structure have diversified the state's economy with the following:
- Medical centers, hospitals, and other healthcare services share of the state's GDP reaching \$25.6 billion in 2016, accounting for 4 percent of the state's economy, and is 33 percent more concentrated than the U.S. average.
- Insurance and financial services share of the state's GDP reaching \$57.6 billion in 2016, accounting for 9 percent of the state's economy, and is 22 percent more concentrated than the U.S. average.
- Professional, scientific, and technical services accounting for \$31.3 billion or 5 percent of the state's economy.
- Combined wholesale distribution, warehousing, and transportation accounting for \$57.5 billion and 9 percent of state GDP.
- Corporate headquarters and other regional administrative offices, including those related to other sectors mentioned above, accounting for 3 percent of the state's GDP reaching \$20.2 billion, and is 67 percent more concentrated than the U.S. average.

With this economic perspective, it is important to note almost all key industry clusters examined showed post-recession employment growth. These clusters, shown in Figure 2 (the description of the chart's contents follow the figure), consist

of aggregated industry sectors around production value chains in the Ohio economy. As shown, only two clusters showed actual post-recession employment declines—industrial chemicals and creative services.

Figure 2. Post-Recession Performance of Key Ohio Industry Clusters



Note: The horizontal axis indicates level of employment growth, and the vertical axis indicates level of concentration (using a measure called a Location Quotient), with values above 1.00 indicating that the cluster is more concentrated in Ohio than it is nationally. A value of 2.00 would indicate the cluster is two times more concentrated in Ohio. The size of the bubble represents the employment level of the cluster in the state.

Source: TEconomy’s analysis of U.S. Bureau of Labor Statistics’ Census of Employment and Wage data enhanced by IMPLAN.

Furthermore, these industrial clusters represent not only a strength for the State of Ohio, but represent areas of significant specialization across all regions of the state (Table 2). Eight of the industry clusters represent areas of significant specialization in three of the five regions, five represent areas of specialization in four of the five regions, and advanced materials is highly specialized in every region of the state.

Table 2. Regional Representation of Key and Representative Ohio Industry Clusters

Ohio Private Sector Industry Clusters and State/Regional Location Quotients	State of Ohio	Ohio Chamber of Commerce Regions				
		Central	Northeast	Northwest	Southeast	Southwest
Industrial Machinery	1.98	0.84	2.26	2.86	1.75	2.07
Advanced Materials	2.45	1.31	3.39	3.63	3.40	1.54
Packaging	1.73	1.18	1.78	2.92	2.06	1.64
Aircraft/Aerospace	0.85	0.12	0.56	0.32	0.00	2.29
Automotive/Motor Vehicle	2.84	2.10	1.94	8.84	0.72	2.21
Biomedical	0.61	0.78	0.59	0.19	0.42	0.76
Engineering, Design, Research, and Testing	0.80	0.95	0.62	0.55	0.37	0.97
Precision Industrial Components	1.55	0.87	2.41	1.45	0.70	1.44
Consumer Products	1.50	1.13	1.35	3.31	1.21	1.26
Energy	0.73	0.65	0.54	1.27	2.36	0.49
Information and Communications Technology	0.70	0.92	0.54	0.27	0.30	0.79
Logistics	1.10	1.17	0.98	1.13	0.81	1.03
Direct Insurance Carriers	1.49	2.46	1.21	0.44	0.19	1.73
Financial Transaction Services	1.51	5.25	0.42	0.36	0.74	1.00
Headquarter/Administrative Operations	1.62	2.27	1.53	0.90	0.38	1.90

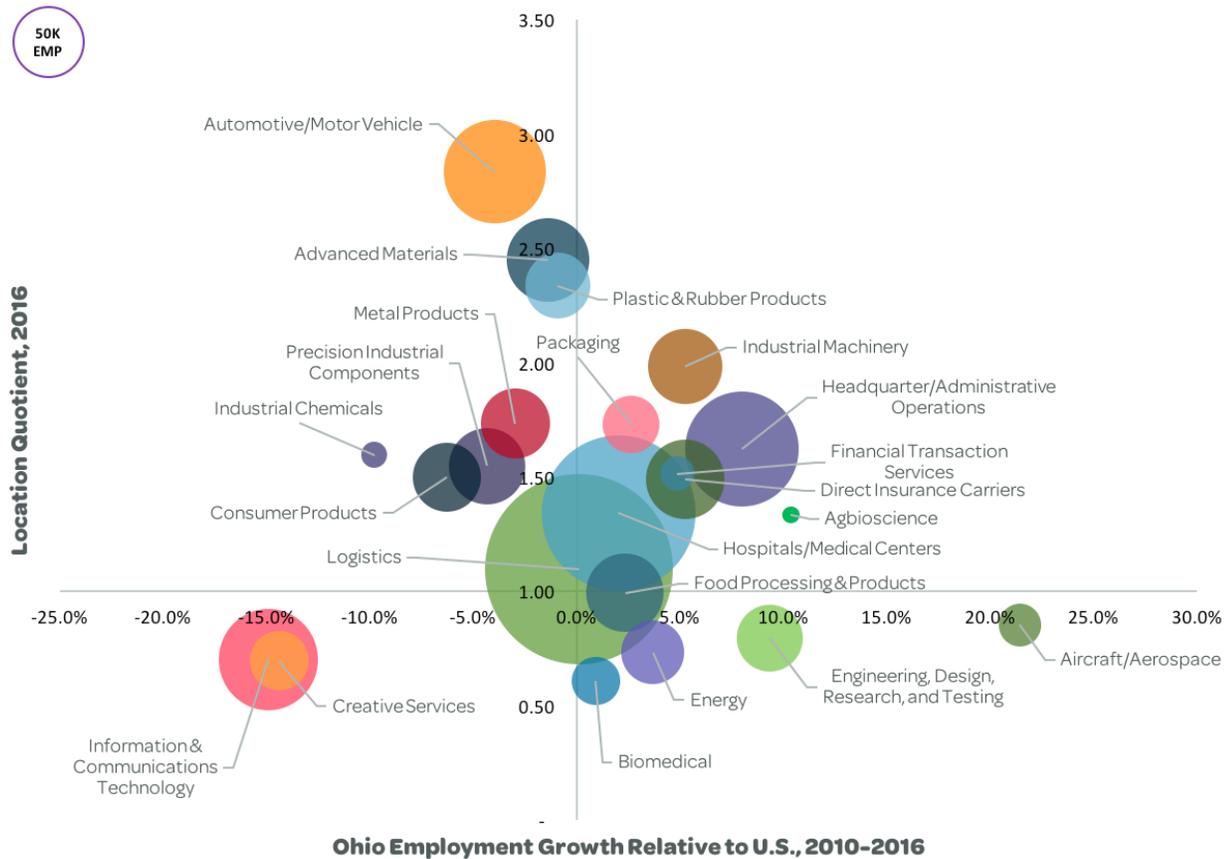
Note: Values above 1.00 indicate the cluster is more concentrated in the region than it is nationally. A value of 2.00 would indicate the cluster is two times more concentrated in the region than it is nationally. Values bolded indicate a regional specialization (location quotient of 1.20 or greater).

Source: TEconomy's analysis of U.S. Bureau of Labor Statistics' Census of Employment and Wage data enhanced by IMPLAN.

The significant challenge for Ohio lies more in the relative and comparative pace of this growth and employment recovery from the Great Recession, and the extent to which Ohio's future still consists of "making things." As shown in Figure 3, several clusters, including key areas of Ohio's historic strength and significant employment (e.g., automotive and advanced materials), failed to keep pace with national growth and are potentially losing market share to firms

in other states or countries. Other important and diverse sectors are currently outpacing the nation, in terms of employment growth, including aerospace, industrial machinery, and significant service-oriented sectors.

Figure 3. Post-Recession Performance of Key Ohio Industry Clusters Relative to U.S. Cluster Growth Rates



Source: TEconomy's analysis of U.S. Bureau of Labor Statistics' Census of Employment and Wage data enhanced by IMPLAN.

It is important to note that the data depicted in Figures 2 and 3 represent the current status based on prior performance and cannot predict future viability. Due to technological advancements, areas of convergence, and the potential for disruptive technologies, sectors can accelerate in growth, be improving from a productivity perspective while shedding employment, or become obsolete.

Though each cluster's performance is impacted by specific circumstances related to broad market factors, key overarching considerations across all of Ohio's industrial drivers are further cause for concern, including the following:

- Lagging investment in R&D. Overall,** Ohio's firms invest \$10,125 per \$10 million GDP in R&D activities compared with \$16,551 per \$10 million GDP nationally. This gap is getting wider as post-recession (2010–2015) growth in R&D has also lagged U.S. growth, 20 percent to 34 percent, respectively.

- **Lagging innovation**, as measured by patents per GDP. Ohio’s firms generate fewer patents per \$100 million GDP (0.89) compared with the United States (0.94). Though seemingly a subtle numerical difference, this value is significant with Ohio also lagging most of the benchmark states in this measure.
- **Lower productivity levels.** Overall, Ohio’s firms’ productivity, as measured by value-added per employee, is 94 percent of the U.S. average, and for manufacturing specifically, productivity is 88 percent of the U.S. average. Recent growth (2010–2016), however, shows Ohio outpacing the U.S. growth rate for both total industry (all firms) and manufacturing, which is a significant positive sign, but requires attention as more needs to be done to ensure this trend continues.

An Innovation Paradigm Shift

Together, these factors—the diversification of Ohio’s economic drivers; uneven growth rates across many clusters; significant concerns over levels of research, innovation, and productivity growth—warrant a new approach to fostering innovation. It is paramount that Ohio embrace the increasing role that both innovation and technological convergence will play across all sectors of the economy and treat it as an opportunity—or risk Ohio’s industrial and economic future.

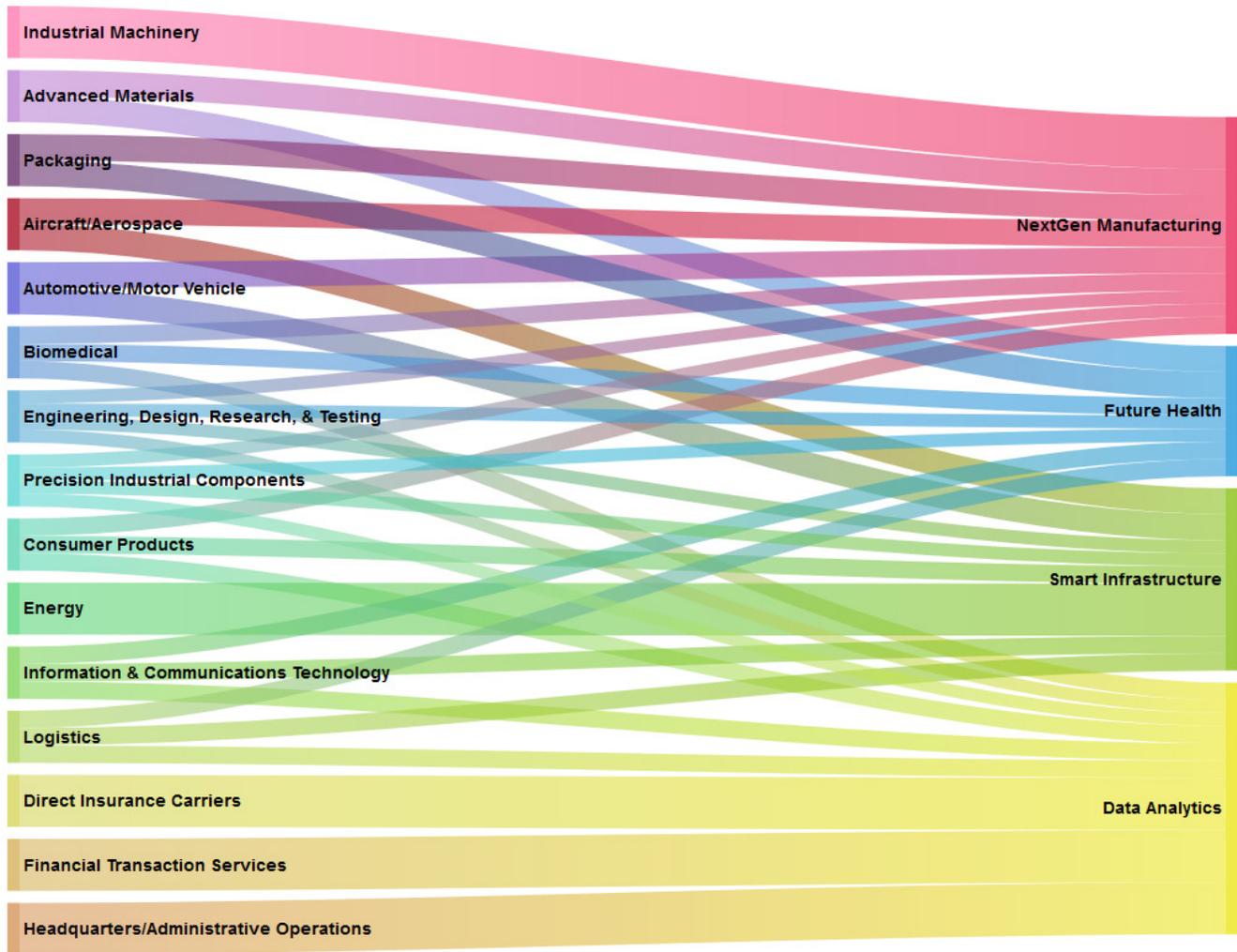
Industry sector and/or cluster approaches can work well for key components of traditional economic development (such as business retention, expansion, and attraction), but can often miss the intended mark for programs emphasizing innovation, productivity improvements, and entrepreneurship. Fostering an enhanced innovation climate in Ohio, one that truly accelerates the development, adoption, and implementation of new innovations requires a new paradigm. With the pace of technological change and convergence, the impact of disruptive technologies across many clusters and economic drivers coupled with limited supporting resources from the public and private sectors, an approach that focuses on common innovation challenges and turns them into opportunities provides the strongest and most robust path forward.

A critical dimension of any new approach is the recognition of the potential impacts of disruptive technologies on many of Ohio’s key clusters. These technologies will dramatically alter the operating environment and future of Ohio’s industry drivers. While aspects such as automation have become second nature in many manufacturing sectors, the requirements and sophistication will increase dramatically over the next decade and will continue to spread into service sectors at an extreme pace. Most importantly, factors that have been viewed as “far into the future,” such as digitization, Internet of Things (IoT), big data, autonomous operation, and artificial intelligence, are here now, currently changing global production, processes, and product design.

To elevate and accelerate Ohio’s economy, this new paradigm seeks to strategically realign Ohio’s innovation investments to focus not on industry clusters, but instead on transformational innovation platforms—areas of convergence, where innovation and disruptive technologies can and will impact many of Ohio’s traditional industry clusters. As Figure 4 visually illustrates, Ohio’s key industry drivers are being impacted by four innovation platforms that will enable their continued growth and economic viability:

- Next-Generation Manufacturing and Materials
- Future Health
- Smart Infrastructure
- Data Analytics.

Figure 4. Mapping Key Industry Clusters to Ohio's Innovation Opportunity Platforms



Source: TEconomy Partners, LLC

Ohio's Innovation Opportunity Platforms

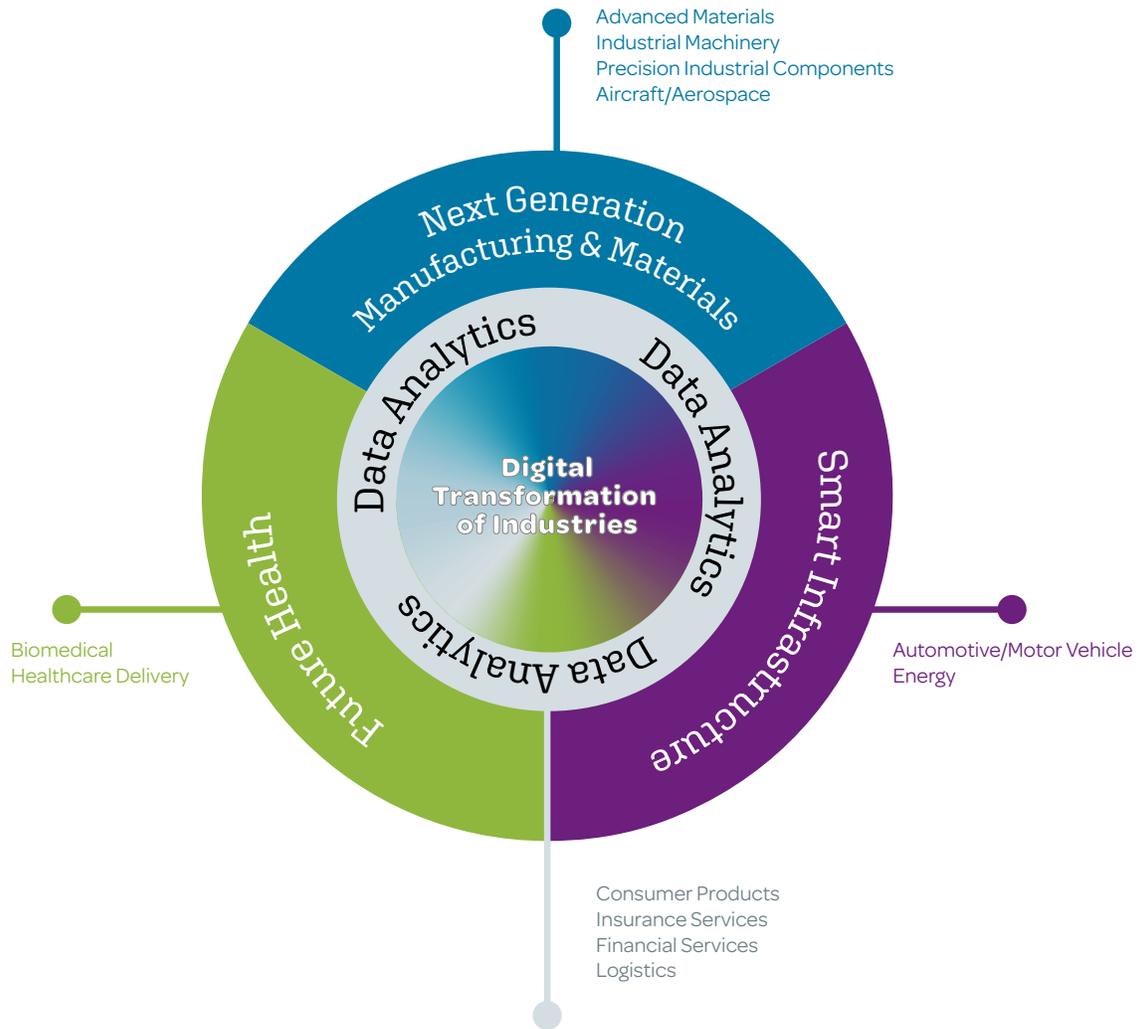
Ohio has a wide variety of industry clusters and innovation assets that collectively form a significant innovation economy. These assets can be leveraged together through several comprehensive innovation platforms to produce impacts that are greater than the sum of their individual parts through economies of scale and building off the benefits in innovation convergence present across multiple industry sectors. By focusing on innovation platforms that demonstrate convergence rather than specific industry clusters, which operate more independently, Ohio can drive underlying wellsprings of innovation that meet diverse sets of industrial needs and generate enabling technology solutions in more comprehensive ways.

As mentioned in the previous section, the following four innovation opportunity platforms leverage Ohio's collective strengths into key opportunity areas for future growth:

- **Next-Generation Manufacturing and Materials**
- **Future Health**
- **Smart Infrastructure**
- **Data Analytics.**

These platforms incorporate multiple state industry clusters into a new innovation investment strategy that seeks to accelerate the transformation of Ohio's industries and position the state for future economic growth (Figure 5). Detailed descriptions of each platform area, the current state of innovation and market opportunities, and implications for the state's path forward in pursuing each opportunity are laid out in the sections below.

Figure 5. Ohio's Four Innovation Opportunity Platforms



Source: TEconomy Partners, LLC

NextGen Manufacturing and Materials

What Is It?

A fundamental shift is happening throughout global manufacturing and production industries as new automation, data collection, and materials technologies are being increasingly incorporated into traditional assembly and processing operations. Next-generation manufacturing and materials represents the broad portfolio of technologies that are expected to revolutionize the way that products are made, ranging from incorporation of more advanced raw materials inputs to analytics-driven predictions of useful life for downstream finished parts and systems.

The technology platforms that make up next-generation manufacturing and materials are aligned with advancing and consolidating the traditional steps of the manufacturing process and include the following:

- Digital product design and modeling, which allows manufacturers to design and test in virtual environments with both the manufacturing process and use life of products in mind.
- Novel advanced materials with highly customizable properties and highly precise means of being shaped into parts and components while maintaining durability and consistency.
- New manufacturing processes that replace traditional subtractive manufacturing, revolving primarily around the scaling of technologies in additive manufacturing and three-dimensional (3D) printing.
- Industrial automation and robotics systems that perform increasingly complicated fabrication and assembly tasks.
- Embedded sensor and instrument networks within production systems and machinery that collect and report data in real time to help diagnose and dynamically react to problems as well as build out large-scale analytics tools for manufacturing operations.
- Postprocessing and finishing technologies that rely on combinations of novel finishing materials such as coatings and polymers, sensing and materials analysis, and automation to ensure consistency and quality in products across varying production run sizes.

Taken together as a whole, the convergence of these technology platforms within modern manufacturing operations will lead to a more wholly integrated “smart manufacturing” environment, with information from all stages of the production process interacting and creating feedback loops that allow a production line to “tune” itself without any stoppages or retooling requirements. These smart production environments also represent a new vision for the role of manufacturing in supporting industry, where just-in-time orders and highly variable production run sizes can be efficiently delivered at increasingly local scales to customers of all sizes. Leaders in adopting innovations in this space can expect to gain significant advantages over competitors in terms of operating costs and play a key role in supporting “maker” industry innovation ecosystems.

Why Ohio?

Ohio has historically supported a large base of manufacturing companies and employment, and the industry still serves as a major driver of economic activity in the state today. Basic manufacturing industries encompassed over half a million jobs and made up almost 15 percent of the state's workforce in 2016, while advanced materials and downstream processing industries support several hundred thousand additional employees.

Embracing and supporting innovation in next-generation manufacturing is a natural fit for Ohio and supported by a number of key characteristics of state's current position:

- Ohio has a broad base of manufacturing industries and key companies that are critical to the state's economy. Key supporting industry clusters in the manufacturing space demonstrate highly specialized employment levels relative to overall U.S. trends and have slightly exceeded national growth rates despite high regional and international competition, while industrial R&D spending volume is also high and specialized, all indicators that the industry continues to play a vibrant and active role in the state economy.
- Ohio universities and research institutions are active in advancing talent and new innovations in manufacturing applications and have the capacity to support further growth. While innovation indicators such as academic R&D spending and research and intellectual property (IP) generation have not kept pace with U.S. growth trends, they still display significant activity levels and indicate that manufacturing represents a specialized element of the state's innovation activity.
- Ohio's growth in venture capital investment in manufacturing-related companies represents an exciting trend that can potentially lead new entrepreneurial development. The significant growth in venture capital investment in manufacturing-related companies emphasizes signs of an emerging entrepreneurial ecosystem that complements larger established companies and can be leveraged to drive further technology and start-up generation.

These indicators (Table 3) demonstrate Ohio's reliance on manufacturing as a key economic driver for the state as well as ongoing innovation and investment that can be leveraged to accelerate the state's position under a comprehensive innovation platform.

Table 3. Indicators of Ohio's Current Position in Supporting Innovative Growth in NextGen Manufacturing Applications, 2010—latest available data

Supporting Capacity Indicator	Ohio Position	Competitive Specialization Index, relative to U.S. trend	Ohio Growth Trend (U.S. trend, 2010—latest available data)
Key Supporting Industry Cluster Employment Base	~534K employees	1.62	13% (10%)
Level of Aligned Industrial R&D Spending	\$2.5 billion	1.78	49% (71%)
Level of Aligned Academic R&D Spending	\$434 million	1.50	18% (20%)
Level of Aligned Research Generation Activity (Publications)	~27K publications	1.10	32% (28%)
Level of Aligned IP Generation Activity (Patenting)	~2.4K patent awards	2.12	-9% (23%)
Level of Venture Capital Spending in Aligned Industry Applications	\$82 million	2.20	1,449% (211%)

Source: TEconomy Partners, LLC

The state is home to a number of key industry and research assets that have fostered the state's growth in the area and drive capacity to continue innovative advancement (Table 4). The state's legacy strengths in advanced materials and precision industrial components are represented across the broad portfolio of automotive, aerospace, materials processing, and other product original equipment manufacturers (OEMs) that have significant local operations. Several companies have invested in signature R&D centers to support in-state manufacturing operations, such as GE Aviation's Additive Technology Center, which opened in 2015 and serves as a focal point for regional activities in advancing 3D printing and design of aircraft engine components.

Almost all state research and technical universities are also advancing degree programs in engineering and advanced materials to meet talent pipeline needs. Case Western Reserve, University of Dayton, and Youngstown State University all support dedicated centers of excellence in manufacturing and materials-related sciences that generate innovative activity. The Ohio State University, in addition to supporting a dedicated center of manufacturing excellence, also recently announced the investment of a \$59 million Advanced Materials Corridor. The state is also home to a signature national research asset in the America Makes National Additive Manufacturing Innovation Institute (NAMII), which supports a variety of applied research capacities for its members through access to cutting-edge additive manufacturing equipment and capabilities as well as prototyping and technology validation.

Table 4. Key Ohio Industry Stakeholders and Research Assets Aligned with Next-Generation Manufacturing

Examples of Key Industry Stakeholders	Examples of Key Research and Innovation Assets
<ul style="list-style-type: none"> • Automotive Industry Cluster OEMs: Ford, GM, Honda, FCA, Delphi • Aerospace Industry Cluster OEMs and Research Labs: GE, Parker Hannifin, NASA Glenn • Arconic • Lincoln Electric Company • Lubrizol • PolyOne • Vallourec • The Lanterman Group • rp+m • Humtown Products • Hapco/Strangpresse • Battelle • Northeast Ohio Additive Manufacturing Cluster • Youngstown Business Incubator 	<ul style="list-style-type: none"> • America Makes—National Additive Manufacturing Innovation Institute • Polymer and Advanced Materials initiatives at nearly every Ohio university • Youngstown State University—Center for Innovation in Advanced Manufacturing • Ohio State University—Center for Design and Manufacturing Excellence • Case Western Reserve University—Additive Manufacturing Studio • University of Dayton Research Institute • GE Aviation’s Additive Technology Center • Ohio Manufacturing Extension Partnership (Ohio MEP)

Source: TEconomy Partners, LLC

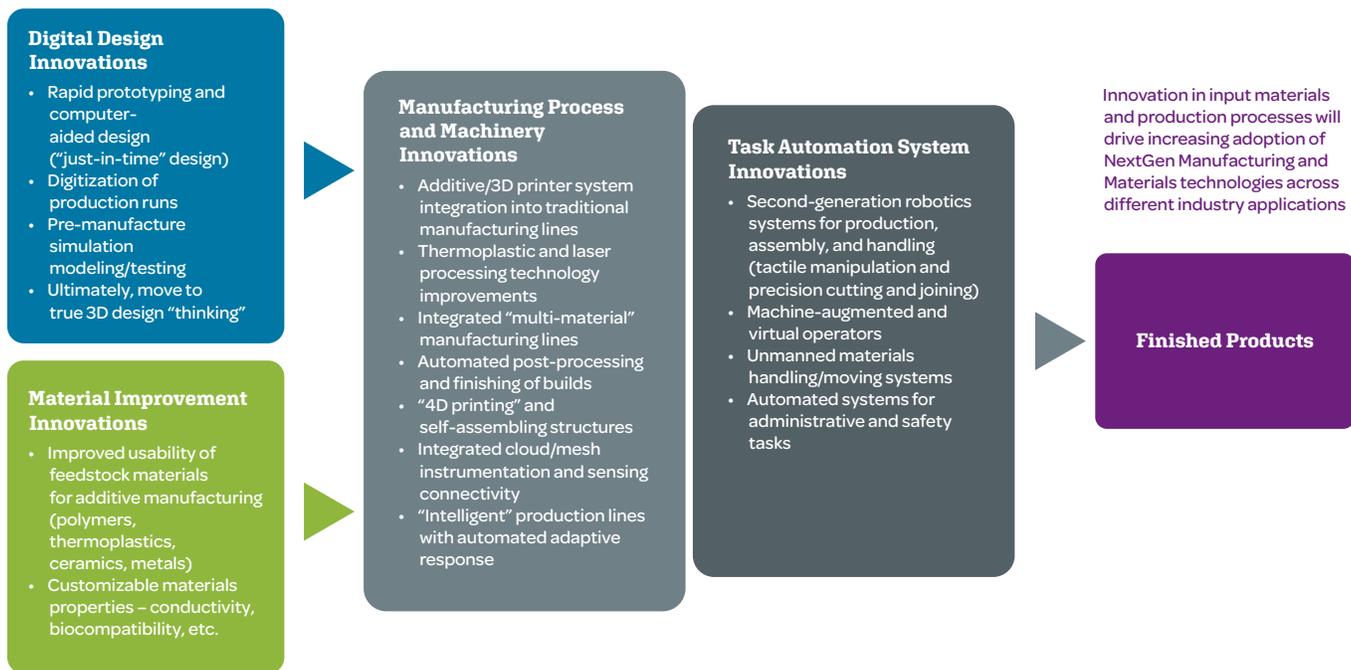
Innovation Trends and Market Outlook

While the state's legacy strengths in manufacturing and innovation assets position it well to capitalize on the next generation of innovative development, several trends reshaping the broader manufacturing technology landscape demonstrate the need for renewed focus to bridge the gap between current industry technology integration levels and the needs of tomorrow.

Novel innovative technologies in manufacturing currently tend to revolve around improvements of existing processes via integration rather than replacement of the equipment and facilities already in operation. This drives innovative advancements in several core areas across a wide variety of manufacturing industry verticals, with various industries currently at different stages of maturity in adopting and integrating these technologies into individual portions of their production processes. These key technology areas, shown in Figure 6, are as follows:

- Innovations in the upfront digital design of products, including the ability to implement rapid prototyping, digitization of detailed production models and components into virtual templates, incorporation of premanufacture simulation and testing tools, and ultimately a move to end-to-end virtual design thinking. These technologies are primarily driven by the increasing use of software and analytics products tailored toward specific manufacturing industries.
- Innovations in advanced materials that serve as inputs to the manufacturing process, in particular novel feedstock materials for additive manufacturing processes such as polymers, thermoplastics, ceramics, and metals, but also including customizable materials properties around durability, conductivity, biocompatibility, and many other traits. These technologies are primarily driven by advances in materials science that enable improvements to current materials.
- Innovations in the production and material working systems involved in the manufacturing process, including the development of additive and 3D printing systems and improvements to shaping and forming technologies such as thermoplastic and laser processing technologies. Innovations also include the instrumentation of manufacturing machinery and integration of connected sensors to gather data on manufacturing processes and decision support tools used to provide automated feedback to production equipment. These technologies are primarily driven by engineering and integration solutions that provide more automated and "intelligent" production lines that help bring down costs to manufacturers.
- Innovations in task automation technologies, including the use of second-generation robotics systems for production, assembly, and handling; the introduction of new machine-augmented or virtual operator systems and collaborative robotics; and a variety of other industrial automation systems that address repetitive physical labor tasks within production industries. Automation technologies can also begin to extend to unmanned materials handling vehicles within manufacturing sites as well as indirect site management tasks related to staffing, logistics, and safety. These technologies are driven by similar technology advances and cost considerations as innovations in production and material working systems.

Figure 6. Dynamics of Next-Generation Manufacturing and Materials Innovation Trends



Source: TEconomy Partners, LLC

Several market factors driven by demand for new kinds of downstream manufactured products are continuing to seed development of new manufacturing technologies that can be deployed by industry:

- A widespread shift toward flexible manufacturing operations is underway as new technologies allow manufacturing industries to become more localized and customized in the way they make products. New innovations allow companies to scale production using much smaller operations footprints, which is driving all but the largest companies toward a model of smaller manufacturing “cells” rather than large mass production lines. The availability of digital tools and networked devices simultaneously lets producers “virtualize” many tasks, leading to the use of “cloud manufacturing” instead of large support operations. In combination with new materials, this flexible, or “smart,” manufacturing approach will continue to allow manufacturers to move away from traditional mass production models without compromising quality or efficiency.
- An increasing demand for product customization on the part of customers of manufactured goods has forced production industries to implement new technologies. Intermediate customers and end users want to not only implement more complex designs that they can create using digital tools, but also maintain consistency across smaller production run sizes and incorporate part consolidation measures. The trend of on-demand services has also spilled over into manufacturing industries, with increasing need for just-in-time production of limited numbers of highly tailored products instead of longer-term commitments for larger quantities of product. On top of logistical challenges, many highly customized materials properties cannot be effectively incorporated into

large-scale manufacturing operations or must be produced in more limited quantities due to scarcity or cost. The combination of these customer-driven demands is forcing manufacturers to implement new technology solutions to adapt their business models.

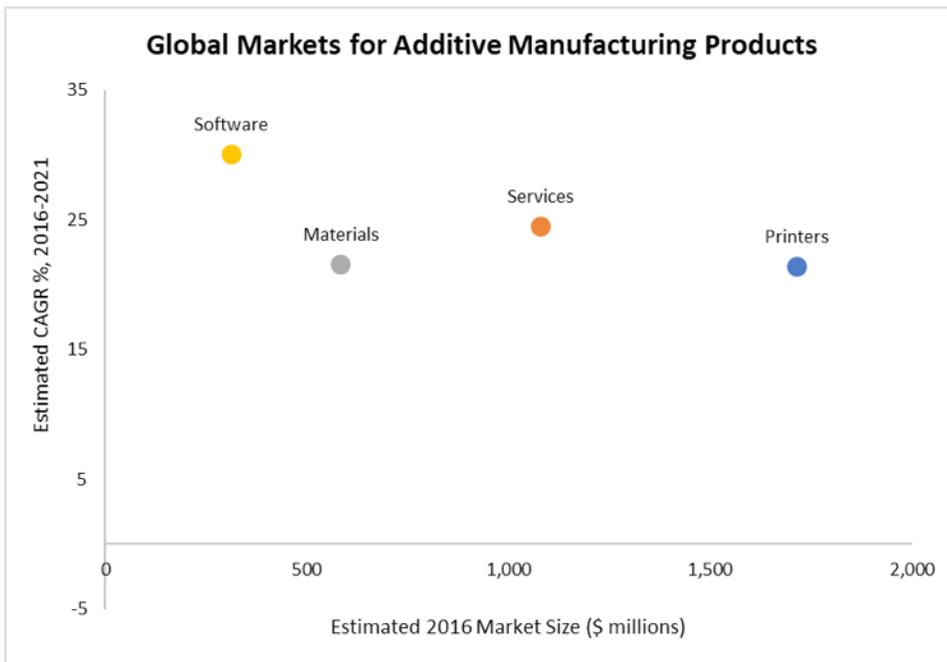
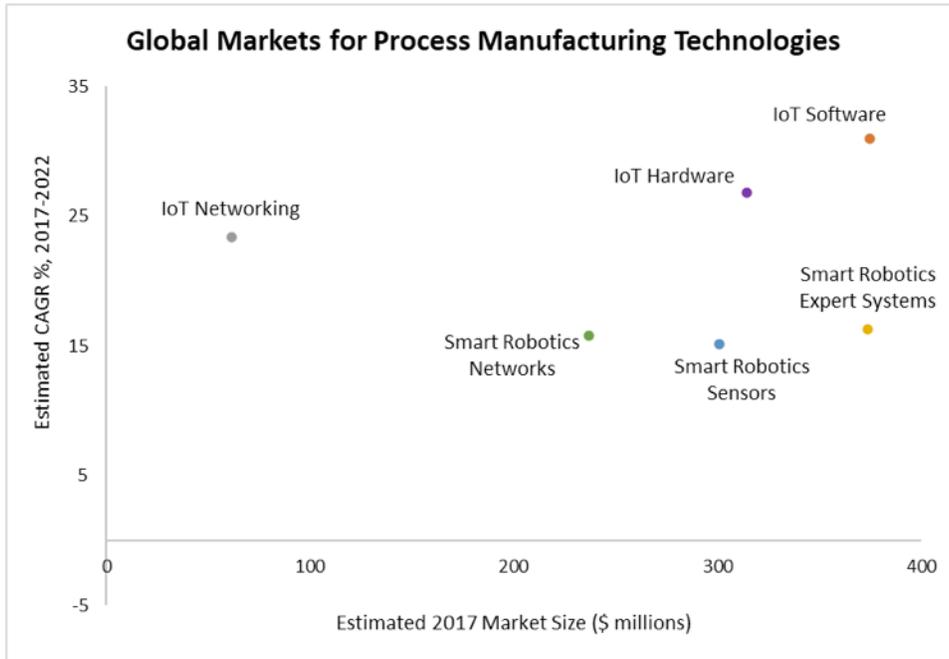
- Changes in the cost-effectiveness of traditional versus additive manufacturing are also bringing online an entirely new set of approaches for creating products that address some of the trends above. Ongoing innovation and investment in additive manufacturing and 3D printing technologies are expected to address the currently higher relative cost of machines and materials compared with traditional approaches that present a significant barrier to adoption for many large enterprise manufacturers. Key cost drivers alongside cheaper capital investment required for 3D printing systems will also be the potential for significant waste reduction in scrap materials versus subtractive manufacturing processes as well as the potential for significant reductions in tooling and other production-line inefficiencies such as part obsolescence.

While the need for developing new manufacturing technologies is clear, markets for these technologies have not yet reached a state of maturity where they can function as independent industry clusters. This is partially due to the ongoing disruptive nature of technologies in this space, with novel products and services still being developed around additive manufacturing that have the potential to revolutionize any given industry vertical based on successful demonstration of scalability. The emerging nature of the market for the core technologies in next-generation manufacturing is demonstrated by its relatively small total market size, with global markets for novel process manufacturing technologies totaling \$1.7 billion in 2017 and global markets for additive manufacturing equipment and products totaling \$3.7 billion in 2016.⁹ However, these areas are forecasted to demonstrate rapid growth over the next 5 years with average compound annual growth rates of 23.2 percent and 21.4 percent, respectively, underscoring the need to begin investing in these technologies to maintain first-mover status as a supplier (Figure 7). The markets for process manufacturing technologies segmented very evenly across hardware and software that support Internet of Things (IoT) connected sensors and instruments for manufacturing as well as smart automation and robotics systems. Initial end-user markets for additive manufacturing are expected to be driven by the need for new machinery and will at first be reliant on boutique applications in defense, electronics, energy, construction, and education markets that make up a forecasted 26 percent total market share before transitioning to more widespread consumer goods, automotive, aerospace, and medical device markets.

However, the key driver of growth in this area is not expected to be sales of next-generation manufacturing technologies themselves, but rather the much larger downstream effect on manufacturing industries themselves as they are able to produce higher quality goods more quickly and at lower cost. While it is not possible to anticipate the full effect of these technologies on product markets across the manufacturing space, the effects are expected to be transformative and result in large economic gains.

⁹ BCC Research: *Smart Manufacturing: Technologies and Global Markets*, Granato, 2016; *Internet of Things Technologies for Process Manufacturing: Global Markets*, Korzeniowski, 2018; *Smart Robotics in Manufacturing: Global Markets to 2022*, Sullivan, 2018; *Global Markets for 3D Printing*, McWilliams, 2016.

Figure 7. Global Market Prospects for Process Manufacturing and Additive Manufacturing Technologies



Source: BCC Research: Smart Manufacturing: Technologies and Global Markets, Granato, 2016; Internet of Things Technologies for Process Manufacturing: Global Markets, Korzeniowski, 2018; Smart Robotics in Manufacturing: Global Markets to 2022, Sullivan, 2018; Global Markets for 3D Printing, McWilliams, 2016.

Implications for Ohio's Innovation Economy

The stakes are high for the State of Ohio if it cannot successfully navigate the transition to a smart manufacturing ecosystem. The critical mass of manufacturing-related employment in the state means that each introduction of new manufacturing and materials technologies to the market has the risk of generating large economic impacts if there are disruptive implications for the state's competitive position. As production lines continue to convert to more digitized operations and additive manufacturing technologies begin to become cost effective at scale, Ohio must be a leader in innovation to maintain its legacy industry base.

With a robust stable of large potential corporate adopters already located in the state that are beginning to invest heavily in next-generation manufacturing and materials, maintaining the specialized strength of Ohio's research and entrepreneurship enterprise in this area then becomes critically important to retaining and growing these established companies and building out larger industry innovation clusters around them. The America Makes NAMII facilities provide a significant "stake in the ground" in terms of a signature research facility focused around bridging the gap to widespread scalable 3D printing usage, and additional public-private partnership investments and initiatives by the state can build out a more comprehensive regional network of additional signature facilities and skilled talent pipelines.

Future Health

What Is It?

The area of future health captures an aspirational vision of an evolutionary and fully integrated healthcare delivery system that stretches from the supply chain of medical products and devices through the process of patients interacting with the healthcare system to long-term population health impact monitoring and response. Enabling the various portions of the healthcare system to interact with and respond to each other will be a key driver of quality of care and ultimate patient health outcomes going forward, as well as having significant financial implications for lower healthcare costs and driving new therapeutic discoveries.

Healthcare is experiencing an ongoing revolution driven by breakthrough therapeutic innovations, technology adoption trends, and a shifting regulatory environment across key fields of medicine over the past decade. The following are key technology developments:

- The availability of novel high-performance computational biology and bioinformatics tools.
- Successful development and approval for market of targeted therapeutics designed to treat patients based on their individual genetic or other biological traits, especially in areas of oncology and genetic disease.
- Shift toward full incorporation of electronic health record (EHR) platforms into clinical workflows based on cost and regulatory policy pressures.
- Demonstration of artificial intelligence–assisted diagnosis and risk assessment “assistant” prototype technologies in clinical settings.
- The incorporation of advanced analytics solutions into healthcare product manufacturing and supply chains to improve efficiency.

To date, these new innovations have largely been focused on improving specific portions of healthcare system logistics, the patient experience, or therapeutic research process; but, healthcare delivery systems across the country are beginning to move toward integrating operations and research together into comprehensive ecosystems that allow scalable deployment of new interventions that can have wide-reaching impacts. The lifeblood of this vision of an integrated future health ecosystem is the ability to connect information from various stages of healthcare delivery under centralized data-driven digital architecture that are resilient and secure while also being accessible to suppliers, clinicians, patients, and researchers to drive interactivity and cross-cutting innovation.

This vision for a future health ecosystem would better integrate and link a wide range of current medical industry verticals under a more connected framework that benefits from a comprehensive rather than siloed view of diffusion of innovation. A truly integrated system could ultimately grow to include the following elements:

- Medical industry suppliers, including medical device and drug manufacturers, basic medical product providers, and medical supply-chain management companies.
- Medical research industries driving new discoveries, including university medical centers, private research and testing labs, and biological specimen and tissue banking centers.

- Hospital and healthcare delivery networks, ranging from primary care to specialists.
- Healthcare support industries, including healthcare data record management, back-office documentation, claims, and billing support, and fraud and abuse prevention industries.

Why Ohio?

Ohio currently hosts a significant healthcare delivery and clinical research workforce, with 14 of the top 50 employers in the state working in healthcare¹⁰ and total employment in 2016 that has grown to approximately the same size as the state's combined manufacturing industry clusters. Combined with world-class research institutions and a growing population that will generate increasing demand for high-quality healthcare services, this area is also a clear fit for driving future growth in the state.

The state's current position (Table 5) shows that it already has the foundation to build out broad innovative capacity in this space:

- Ohio's healthcare industry is already anchored by a critical mass of healthcare delivery infrastructure that serves as a foundation for innovation. The state has industry clusters in both the biomedical sciences and healthcare delivery, with over 465,000 combined employees, major company headquarters and operations, and a specialized healthcare delivery workforce.
- Ohio is home to outstanding clinical research establishments that have national recognition and generate major innovation activity. The presence of both academic medical centers and private research hospitals anchors a large clinical research network in the state. These hubs of research activity generate a large volume of new IP that is highly specialized as well as significant research spending.
- Significant industry investment since 2010 demonstrates an ongoing commitment to the next generation of healthcare innovation. Both industry-funded R&D and venture capital investment levels in healthcare-related business far exceeded national growth trends and represent a combined \$2.7 billion in resources funding translational research and new company growth.

Healthcare already plays an important role in the state's economy and generates an established core of innovation that can serve as the foundation for shaping a regional healthcare ecosystem.

¹⁰ *JobsOhio Healthcare Industry Profile, 2018.*

Table 5. Indicators of Ohio's Current Position in Supporting Innovative Growth in Future Health Applications, 2010–latest available data

Supporting Capacity Indicator	Ohio Position	Competitive Specialization Index, relative to U.S. trend	Ohio Growth Trend (U.S. trend, 2010–latest available data)
Key Supporting Industry Cluster Employment Base—Biomedical Science	~22.5K employees	0.62	8% (7%)
Key Supporting Industry Cluster Employment Base—Healthcare Delivery	~443K employees	1.30	4% (10%)
Level of Aligned Industrial R&D Spending	\$1.8 billion	1.31	192% (34%)
Level of Aligned Academic R&D Spending	\$1.2 billion	1.10	8% (18%)
Level of Aligned Research Generation Activity (Publications)	~121K publications	1.16	20% (4%)
Level of Aligned IP Generation Activity (Patenting)	~6.6K patent awards	2.16	45% (53%)
Level of Venture Capital Spending in Aligned Industry Applications	\$1.5 billion	1.78	290% (144%)

Source: TEconomy Partners, LLC

As shown in Table 6, Ohio has a number of key industry stakeholders and research assets in this area. Companies with significant operations in the state represent a wide portfolio of different medical industry verticals, ranging from medical devices to pharmaceuticals to health information technology (IT). Businesses also range from large enterprise operations such as healthcare logistics company Cardinal Health and managed care provider ProMedica to emerging companies generating significant momentum around promising technologies such as Abeona Therapeutics, which recently opened a commercial good manufacturing practices (GMP) facility for gene and cell therapies, and Aprecia Pharmaceuticals, which utilizes 3D printing technology approved by the U.S. Food and Drug Administration (FDA) to manufacture pharmaceuticals. The presence of the healthcare industry also stretches across nearly all regions of Ohio.

The state's research enterprise has four primary anchor institutions, each with areas of nationally recognized specialty: Ohio State University's Wexner Medical Center, Cleveland Clinic, Cincinnati Children's Hospital, and Nationwide Children's Hospital. In conjunction with other state research universities, these signature programs and facilities generate significant national and self-funded research spending and together form a regional network of clinical research infrastructure.

Table 6. Key Ohio Industry Stakeholders and Research Assets Aligned with Future Health

Examples of Key Industry Stakeholders	Examples of Key Research and Innovation Assets
<ul style="list-style-type: none"> • Cardinal Health • STERIS • Invacare • Philips Medical Systems • West-Ward Pharmaceuticals Corp. (Roxane Laboratories) • Ethicon • Abbott • GOJO • Midmark • CoverMyMeds • Numerous Hospital System and Healthcare Delivery Organizations in Midwest Health Collaborative 	<ul style="list-style-type: none"> • Cleveland Clinic • Cincinnati Children’s Hospital • Nationwide Children’s Hospital • The Ohio State University’s Wexner Medical Center • University of Cincinnati • Case Western Reserve University

Source: TEconomy Partners, LLC

Innovation Trends and Market Outlook

Although the state has significant innovation assets that are already active and thriving, developing the ambitious vision of a future health innovation ecosystem requires ongoing investment to work out solutions in both specific healthcare and medical industry verticals as well as the fundamental technologies that enable connectivity between those industries.

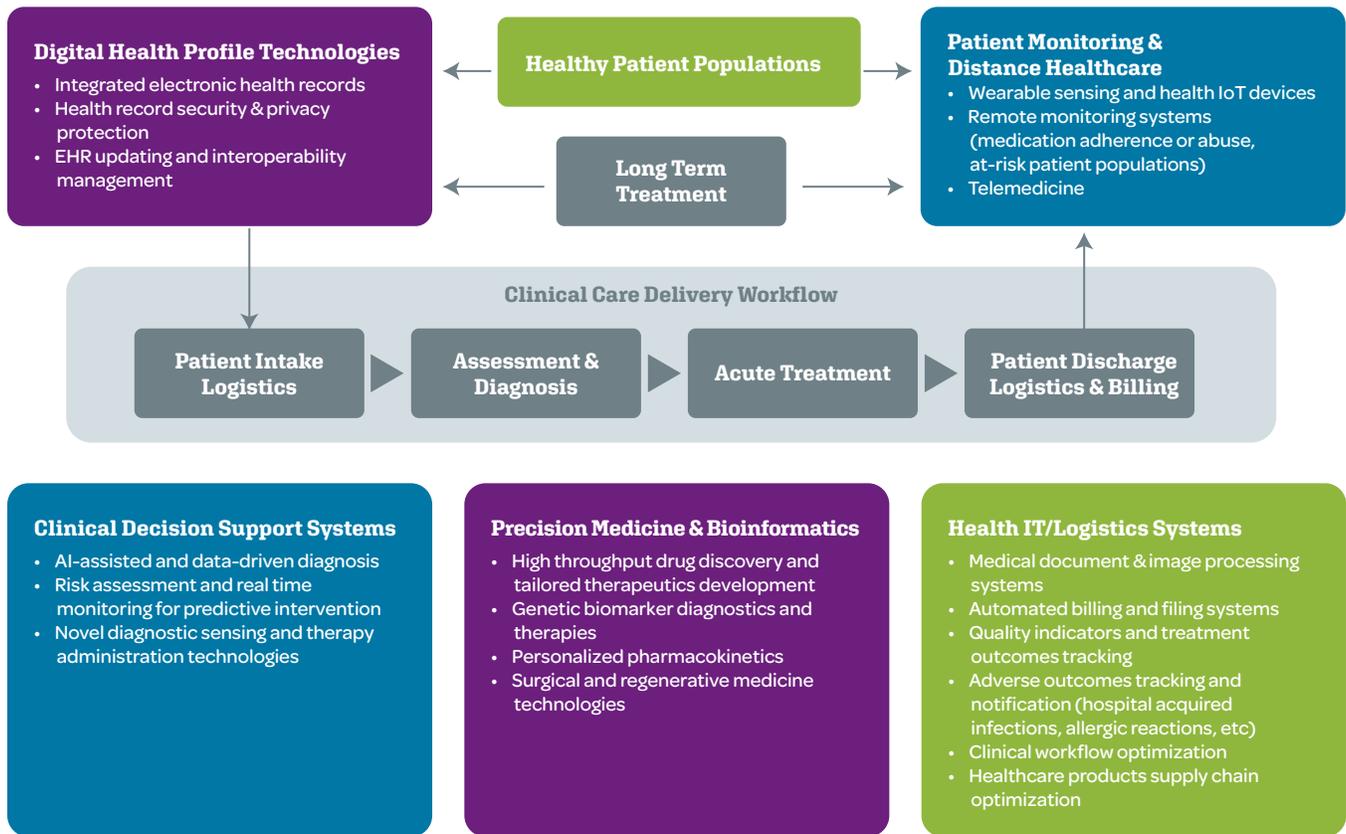
The ongoing transformation of the healthcare industry makes it difficult to focus on any one specific technology, and instead requires focus across a portfolio of new products and services that all improve the ability of the healthcare system to serve its patient populations. As such, innovations in the future health space tend to fundamentally rely on integration of disparate sources of medical data to create positive feedback loops in long-term health outcomes. The following key technology platforms, shown with their dynamics in Figure 8, each embody this focus and will be important to driving innovation in this space:

- Innovations in digital medical record technologies that help create a digital profile of a patient’s health that can be integrated into multiple stages of the healthcare delivery system in the form of EHRs. Innovative advancements are focused around the gathering and management of large volumes of EHR data, maintaining the privacy and security of EHR databases, and managing interoperability and transmission of EHR information between devices and

systems. These technologies are primarily driven by the increasing use of electronic records in clinical settings due to regulatory frameworks and enabling downstream technology innovations based on reliable patient data.

- Innovations in clinical decision support systems that aid doctors within clinical settings in making better-informed care decisions for individual patients. These technologies are often driven by artificial intelligence analytics approaches that utilize digital medical records and real-time monitoring data from patients to recommend diagnoses or assess risk profiles that in turn can drive predictive intervention in advance of development of disease or illness. This area of innovation also includes novel diagnostic sensing and therapy administration technologies that can automatically adjust medication delivery based on patient vital signs and notify healthcare workers of changes in a patient's condition. These technologies are primarily driven by advances in analytics methodologies and greater digital patient data collection as well as increasing patient volume demands on limited healthcare worker resources.
- Innovations in precision medicine and bioinformatics that encompass a suite of technologies allowing doctors to better tailor therapeutics to individual patient biology. Approaches in this area include high-throughput drug discovery, genetic testing and therapeutics engineered for patients with certain biomarkers, personalized drug formulations based on patient pharmacokinetic profiles, and surgical and regenerative medicine technologies customized to achieve certain treatment outcomes. These technologies are primarily driven by advances in medical science and high-performance computing that enable researchers to develop improved treatments for disease.
- Innovations in health IT and logistics systems products and services that support the back-office operations of healthcare and enable improved efficiency in the healthcare system. These technologies can include automated processing systems for medical documents and images; automated billing, claims, and filing systems; quality-of-care indicators and treatment outcomes tracking; clinical trials and research logistics management; adverse outcomes tracking and notification services (such as hospital-acquired infections, allergic reactions to medication, etc.); clinical workflow analytics and optimization products; and healthcare products supply-chain optimization and fraud or waste detection. These technologies are being driven by the need for healthcare systems to outsource or automate administrative tasks to better focus on the care delivery process.
- Innovations in patient monitoring and distance healthcare, including wearable medical sensing and other connected health devices, remote monitoring systems for patients in applications such as medication adherence or abuse and high-risk patient emergency event monitoring, and telemedicine or other communications-enabled distance healthcare delivery. These technologies are being driven by a need to serve ever-expanding patient populations in more convenient ways across larger geographic footprints.

Figure 8. Dynamics of Future Health Innovation Trends



Source: TEconomy Partners, LLC

The following key market factors driving the underlying revolution in healthcare delivery are pushing technologies into the clinical setting:

- The integration of digital health technologies into the clinical workflow has various causes including regulatory requirements, the need to use limited healthcare resources more efficiently, and a desire to drive down costs. Traditional clinical workflows are being altered by the ongoing transition to all-digital EHR systems as well as availability of a multitude of innovative new treatment options enabled by easier access to patient data. In turn, this increased flow of digital information is expected to drive increased reliance by clinicians on EHR-based technologies to manage the volume of information across aging patient populations with increasing care needs. This trend creates a high demand for technologies that can function as “intelligent assistants” to clinicians to aid in diagnosis and treatment options that produce best outcomes given individual health histories, biomarkers, and environmental factors.
- A move toward quality indicator outcomes in determining success rather than patient volumes is being enabled by proof-of-concept technologies and the aforementioned increase in integration of digital health technologies into the clinical setting. This shift toward emphasis on long-term treatment outcomes is also a response to the

need to reduce cost burdens by focusing on preventative rather than reactive medicine. The focus on quality indicators for patients necessitates more integrated, complementary tracking of health data at the individual level across multiple geographic and provider network locations that patients use as well as the many potential devices and therapeutics with which patients interact. Many current innovative solutions are focused around the key challenge of bridging interoperability gaps between various groups of connected devices and EHR systems present in clinical settings as well as pushing information out to other healthcare services that patients utilize.

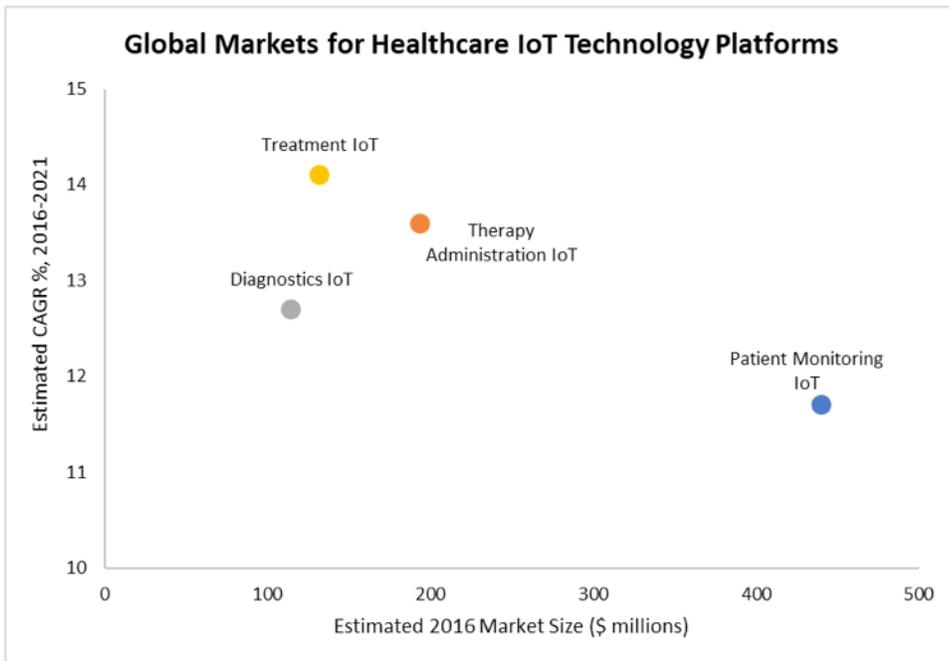
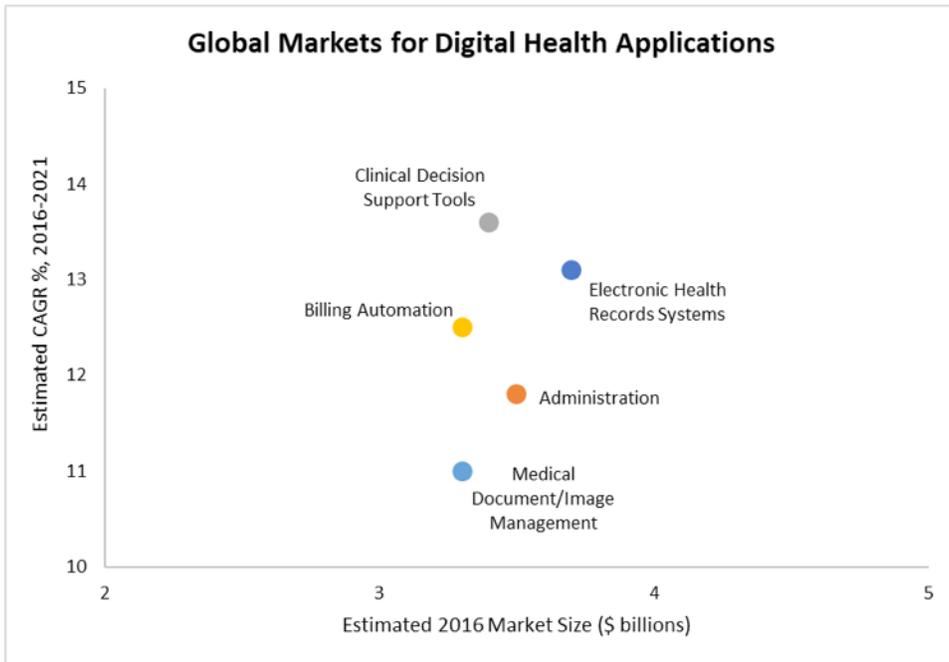
- The increasing use of precision medicine technologies in a clinical setting is a natural consequence of the developments in medical science and translational research over the past decade. As ongoing trends in basic biosciences research continue to highlight the important role genetic and other biomarker-based tailoring of personalized medicines will play in the next wave of therapeutic products and services, industry is renewing its focus on commercializing these discoveries into novel therapeutics to serve patient markets. Making tailored treatments available to individuals at the clinical level will require significant investment in both the front-end diagnostic technologies of fast, on-demand bioinformatics and biocomputational capabilities as well as complementary fast-turnaround therapeutic synthesis and manufacturing technologies. Both of these treatment components will require an integrated healthcare environment to operate efficiently.

Based on the many factors driving the growing need for healthcare-related solutions, the various end markets for innovations in the future health area are both large and forecasted to demonstrate consistent returns. Also, a wide diversity in end markets can serve various aspects of the healthcare delivery process as well as markets for the underlying technology platforms driving connectivity and interoperability of healthcare data. To develop a comprehensive innovation ecosystem that produces products and services across this span and fully realizes the returns from gains in healthcare-related markets, it is important to consider investment across a broader portfolio of healthcare delivery technologies rather than specializing too narrowly in specific medical device or pharmaceutical markets.

As an example of the typical types of end-market prospects served by broader enabling technologies in future health innovation, global demand for sensor and medical device systems developed for healthcare monitoring was \$0.9 billion in 2016 with a compound annual growth rate of 12.7 percent that is expected to remain consistent well past 2021. Another example is in healthcare analytics applications, where global markets totaled \$2.4 billion in 2016 with a forecasting compound annual growth rate of 17.7 percent through 2021 (Figure 9).¹¹ Other enabling technologies with similar market profiles include genetic diagnostics and sequencing, high-throughput drug discovery technologies, and other bioinformatics technologies for precision medicine. It is worth noting that these enabling technology platforms are also expected to result in quality-of-life improvements and healthcare cost reductions across patient populations for healthcare systems that adopt them that are difficult to quantify but represent enormous potential economic impacts that generate follow-on savings effects for businesses and government.

¹¹ BCC Research: *Healthcare Analytics: Technologies and Global Markets*, Maliwal, 2017; *Internet of Things Sensors in Healthcare: Global Markets and Technologies*, Sullivan, 2018; *Global Markets and Technologies for Electronic Health Records*, Sullivan, 2018.

Figure 9. Global Market Prospects for Digital Health and Healthcare IoT Technologies



Source: BCC Research: *Healthcare Analytics: Technologies and Global Markets*, Maliwal, 2017; *Internet of Things Sensors in Healthcare: Global Markets and Technologies*, Sullivan, 2018; *Global Markets and Technologies for Electronic Health Records*, Sullivan, 2018.

Implications for Ohio's Innovation Economy

While Ohio's industry and research institutions have recognized the need for investment in innovative development and are already focused on developing and deploying new technologies, the resources required to complete the transformation of the healthcare industry are immense and need to be maintained over a long-term timeline to ensure success. A key theme for Ohio to emphasize is the convergence and consolidation toward a next-generation healthcare ecosystem around enabling technologies in healthcare IT and data management.

Given Ohio's broad mix of healthcare-related industries across supply chain, research, and primary care areas, substantial opportunity exists to coordinate efforts that more closely tie together these elements into a regional future health innovation network focused on translating new technologies quickly into clinical care. Through identifying and emphasizing specific technologies that bind these links in the healthcare value chain, incentives for collaborative industry research partnerships can help to align the different industry segments naturally around new innovative products and services. Examples of focus areas where targeted research partnership incentives might be deployed could include integrating healthcare product supply chains with the state's advanced materials and manufacturing base or better integrating research and clinical delivery organizations around common healthcare IT standards and products. Additionally, novel payment and healthcare delivery models are being tested throughout the country and potentially represent an opportunity for the state to incentivize a more integrated innovation ecosystem. The state can take efforts to identify and implement an innovation model for payment and services that fits the state's current position and aspirational vision for developing this ecosystem based on best-practice research from sources such as the Centers for Medicare and Medicaid Services' (CMS) Innovation Center. Alternative payment models, new quality indicators, and EHR technology use requirements can all be intelligently deployed within new regulatory guidelines to help incentivize closer ties between sources of innovation in basic sciences and endpoint clinical delivery through coordinated care architectures that reward effective translation of ideas into patient impacts across partner organizations.

Smart Infrastructure

What Is It?

The systems used to support modern living and working environments are increasingly becoming more automated and connected, creating a new class of technologies that fall under the umbrella of “smart” infrastructure. These types of systems are becoming a key component of public investment and improvement that supports enhanced livability, economic development, and sustainable growth. Utilizing embedded technologies that can dynamically respond to environmental conditions, communities can increasingly be managed as a single “ecosystem” of assets and infrastructural elements under a system-of-systems model facilitated through the use of advanced IT, analytics, and controls. Connected devices and sensor networks are already being integrated into almost every facet of modern residential, commercial, and public infrastructure to enable better monitoring and remote response to evolving conditions, and now require innovative deployments of overarching management technology platforms to help realize improved quality of life for residents and businesses.

Smart infrastructure represents a diverse portfolio of connectivity and automation technologies that enable and support these advanced environments:

- Energy management platforms such as smart grids, energy storage, and renewable energy collection and energy harvesting.
- Instrumented structures and utilities such as smart metered homes and buildings; embedded supervisory control and data acquisition (SCADA) systems; and integrated sensors for traffic, water, lighting, and other public utility management.
- Mobility technologies such as vehicle automation (including driverless vehicles), connected transport systems and networks, electric vehicles, and shared-use platforms that utilize mobility-as-a-service models.
- Remote sensing systems made up of networks of sensor units and connected data collection devices being used for surveillance, monitoring, and resource management.
- Unmanned systems and drones that enable and support smart infrastructure applications in areas ranging from agricultural technology to national security.
- Command and control systems that leverage information flow management and analytics technologies to dynamically respond to changing environments in real time.

The ability to combine these various types of connected assets into a single ecosystem of responsive infrastructure is at the core of smart infrastructure innovation, making interoperability and information sharing between very different groups of systems and technologies that each have their own standards and operating models a key technical challenge for new innovations to address.

Why Ohio?

Ohio's position in having capacity to support smart infrastructure is indicative of broader national trends in this space. Market fragmentation among the various industries that work in smart infrastructure systems as well as increasing localization of technology deployment and regulatory governance mean that few regions of the country can claim to have competitive advantage in specialized workforces or research investment in this space at present. However, Ohio demonstrates several key environmental factors that make it a highly attractive state for smart infrastructure innovation to take root.

Although the state's current levels of industry and innovation demonstrate average capacity to support growth in this space (Table 7), several other factors indicate that this area can potentially begin to play a role in driving significant impacts:

- Ohio has demonstrated recent success in building resources to support smart infrastructure innovation. Spearheaded by the selection of Columbus as a United States Department of Transportation (U.S. DOT) Smart City Challenge grant recipient, many initiatives are underway across the state to build and leverage investment toward smart infrastructure projects.
- Ohio has all of the elements to build an ecosystem to support deployment of smart infrastructure technologies and develop signature technology demonstration sites. The state has extensive commercial and commuter transportation networks, potential smart city environments, significant energy investments/infrastructure (both renewable and fossil-based), and aligned industry applications that need innovative new technologies and can serve as a regional network of piloting, prototyping, and demonstration assets.
- The opportunity exists for Ohio to significantly enhance its competitive position in this space through strategic development of capacity. Because the smart infrastructure space is still very competitive without breakaway leaders at a regional level, Ohio has the potential to become a regional hub for innovation by adopting a visionary strategy that can drive coordinated investment.

Many of the same factors that give Ohio strength in capacity for growth in smart manufacturing and future health make the state fertile ground for advancing smart infrastructure that complements and accelerates those areas as well.

Table 7. Indicators of Ohio's Current Position in Supporting Innovative Growth in Smart Infrastructure Applications, 2010—latest available data

Supporting Capacity Indicator	Ohio Position	Competitive Specialization Index, relative to U.S. trend	Ohio Growth Trend (U.S. trend, 2010—latest available data)
Key Supporting Industry Cluster Employment Base	~291K employees	0.84	13% (16%)
Level of Aligned Industrial R&D Spending	\$921 million	0.56	28% (43%)
Level of Aligned Academic R&D Spending	\$297 million	0.95	13% (22%)
Level of Aligned Research Generation Activity (Publications)	~22K publications	0.83	32% (31%)
Level of Aligned IP Generation Activity (Patenting)	~2.7K patent awards	0.75	22% (48%)
Level of Venture Capital Spending in Aligned Industry Applications	\$822 million	0.77	135% (206%)

Source: TEconomy Partners, LLC

As shown in Table 8, Ohio has a number of key industry stakeholders and research assets in this area. The state has a variety of automotive, aerospace, and engineering companies that are pursuing elements of smart infrastructure technologies, such as autonomous vehicles and drone platforms, and could be further aided by an enabling environment. Other state industries, such as energy, agriculture and national security, generate additional demand for innovative solutions in this space. Logistically, the state also serves as a regional transportation route for goods moving through the Midwest and has several large energy distribution and generation companies that already maintain and develop on-the-ground energy infrastructure, as well as significant renewable energy efforts.

Several cities have already established and begun to develop smart city initiatives. In addition to the \$40 million in federal funds awarded by the U.S. DOT Smart City Challenge, the State of Ohio is investing \$45 million into the Transportation Research Center (TRC) to enhance its autonomous vehicle testing capabilities. The state is also investigating potential regional high-speed rail and hyperloop routes and deploying advanced vehicle communication technologies along demonstration routes through the Ohio Department of Transportation. Although more limited work has been done to date to comprehensively link these transportation-related efforts with smart city initiatives and other applications in the energy, utilities, and agriculture space, these elements all have the potential to create a powerful joint smart infrastructure ecosystem through proper coordination.

Table 8. Key Ohio Industry Stakeholders and Research Assets Aligned with Smart Infrastructure

Examples of Key Industry Stakeholders	Examples of Key Research and Innovation Assets
<ul style="list-style-type: none"> • Automotive OEMs and Their Supply Chains • Aerospace OEMs and Their Supply Chains • Energy Providers: AEP, Ohio Edison, Cincinnati Bell, IGS Energy • Renewable Energy Providers and Supply Chain • Architectural and Engineering Firms: HNTB and WSP • Construction Firms: Fishel, Kokosing • Ohio Department of Transportation, Ohio Turnpike • Hyperloop Initiatives under Consideration: <ul style="list-style-type: none"> • Mid-Ohio Regional Planning Commission (MORPC)—Hyperloop Midwest Connect from Pittsburgh to Columbus to Chicago • Northeast Ohio Areawide Coordinating Agency (NOACA)—Hyperloop from Cleveland to Chicago 	<ul style="list-style-type: none"> • Drive Ohio, including recent executive order authorizing autonomous vehicles testing • Transportation Research Center (partnership of OSU, State of Ohio, and Honda) • OSU Center for Automotive Research, which includes the U.S. DOT University Transportation Center • Cleveland Foundation and IoT Collaborative • Ohio Federal Research Network • Smart Columbus Pilot • Smart Cincy Efforts • Unmanned Aerial Vehicle (UAV) Master Lab at the University of Cincinnati • OSU Aerospace Research Center • Numerous renewable energy research efforts

Source: TEconomy Partners, LLC

Innovation Trends and Market Outlook

As noted above, the key to driving innovative growth in this area is the combination of groups of connected technologies under an integrated management system. Innovations in sensing, connectivity, and decision support tool technologies serve as the interactive hub for enabling other “spokes” in innovative technology platforms in specific areas of smart infrastructure and allowing them to integrate within an overall operational management framework (Figure 10). More detailed technology platforms that are developing solutions include the following:

- Innovations in transportation and mobility technologies guided primarily by recent advancements in automated and driverless vehicle technologies. Other innovative technologies that enable “microtransit” solutions are also gaining momentum, such as shared-use and on-demand transportation platforms. Other advancements in electric vehicle systems and supporting infrastructure as well as automation of traffic control and vehicle parking and storage solutions have varying degrees of cross-cutting interplay with innovation in mobility technologies. These technologies are primarily driven by the shift toward investment in driverless systems by major automotive manufacturers as well as the desire for lower-cost and cleaner transportation options.

- Innovations in energy management systems that efficiently generate, distribute, and store power to meet consumer demand and enable a more resilient grid. Key among these technologies is the scalable deployment of microgrid and distributed energy systems that are enabled by smart metering of power systems within the local grid and consumer endpoint infrastructure. Combined with the availability of new innovations in renewable energy generation, such as solar and wind systems and other energy-harvesting technologies, solutions in energy demand response are being driven by the complex interaction of components of the grid. These technologies are primarily driven by utility company desire for less waste and lower costs as well as the availability of smaller-scale renewable energy systems.
- Innovations in surveillance and security systems that are allowing better real-time response to crime and emergencies. Using networks of connected camera and other sensing technologies, image analysis and pattern recognition analytics are enabling automated crime detection and prediction technologies and “crowdsensing” pedestrian monitoring products and services. Rapid deployment of emergency and disaster response resources is aided by the existence of these types of sensing platforms that can better assess the appropriate needs and supply first responders with better information. These technologies are primarily driven by advancements in machine vision analytics applications and the increasing volume of data collected from video sources.
- Innovations in utilities and public services management that are helping to create more efficient use of public sector resources and sustainability of environmental resources. Such technologies range from various E-government solutions in identity management and administrative processing; to management of fleets of publicly owned vehicles and other assets via embedded location sensors; to environmental monitoring platforms for water resources, waste collection, and pollution. These technologies are driven primarily by demand from citizens for improved return on investment of public dollars and high-quality living environments.
- Innovations in unmanned systems and drone technologies that are enabling new monitoring and data collection methods. Novel types of unmanned systems, driven primarily by advancements in increasingly miniaturized unmanned aerial systems, allow observers to collect all types of data from new perspectives and in ways that traditional human observers or sensors are unable to replicate. Drone “observers” are being utilized in agricultural, security, military, entertainment, and a variety of other industries to automate tasks and create data products that can then be used to form better decision-making insights.

The innovative technology solutions that are used to tie together these seemingly disparate groups of connected resources under a smart infrastructure ecosystem include the following:

- Innovations in sensing and connectivity systems that enable data collection and communication over networks. Sensors are increasingly deployed as networks that cover larger areas and include a variety of electro-optical components that support IoT applications in smart metering and instrumentation. The way that these sensors interact with one another and with centralized databases and control systems via specific communications protocols is also an area of advancement, in particular the challenge of ensuring robust cyber-physical security.

These types of technologies can range from advanced optics to power electronics to novel types of antennas and network routing hardware.

- Innovations in smart infrastructure integration and management, driven primarily by the availability of new command and control solutions that use advanced analytics to handle large flows of real-time data from networks of connected devices and provide decision support and oversight capabilities to managers of infrastructure systems. A key component of these types of technologies is the ongoing transition of commercial, residential, and utility structures and their subsystems to SCADA architectures and the subsequent demand for technologies to manage the resulting flows of data. Another critical applications area relates to communications interoperability and information translation so that different systems can “understand” one another and operate as integrated units.

Figure 10. Dynamics of Smart Infrastructure Innovation Trends



Source: TEconomy Partners, LLC

Due to the breadth of technologies and ambitious vision for a fully connected environment, this area represents a more long-term effort to replace outdated systems and consolidate technologies that have traditionally operated

in communications silos. However, several key market factors have begun to accelerate this process and drive value creation for innovations that can address these challenges:

- The rapid expansion of networking and wireless traffic capacity in both urban and rural areas has helped lay the foundation for these innovations to begin to reach maturity. Massive expansions in the available coverage and capacity of wired and wireless communications infrastructure over the past decade on the part of telecommunications providers have enabled new innovative solutions that previously may have been impossible to implement. Upcoming deployment of even faster 5G and additional fiber network capacity is expected to benefit the IoT space and further accelerate the use of connected devices. Regulatory environments have not yet caught up with this rapid expansion of infrastructure, but many smart city initiatives across the country are now beginning to incorporate connectivity considerations into municipal codes and zoning as well as new infrastructure projects.
- A diverse and ever-growing industry and residential demand for connected environments is creating strong incentives for development of new technologies, with scalability and consistent access being key concerns for businesses and increasingly technology-savvy resident populations. Demand is currently more intense in some industries and geographic locations than others and is not evenly spread across applications areas that are all at different stages of development maturity, making specialization in any one technology area very difficult and at risk of disruption. Instead, regional competitiveness for industry and workforce has created competitive advantage incentives for investment in infrastructure that enables test-bed prototyping and validation environments that can serve multiple applications verticals simultaneously and let next generation solutions emerge naturally for further development.
- The role of data collection capacity as a new capital resource for driving growth for many industries has become clear over the past decade, upending the value proposition of some aspects of traditional economic site investment. The ability to collect large amounts of data through smart infrastructure platforms is now key to driving new solutions and functions as a valuable incentive—first adopters of a smart infrastructure innovation ethos will be able to leverage this resource to drive industry attraction. However, supporting this innovation platform requires sustained investment and vision to successfully create and deploy smart-infrastructure-enabling technologies that in turn drive attention by industry; and strategic use of public investment is often key to helping mitigate initial barriers to entry. Another key barrier to effectiveness of solutions in the short term is the creation of smart, viable interoperability standards and systems for connected devices by state and local policymakers, as the technology market is currently very fragmented, and consolidation will occur over time.

The end-user markets for smart infrastructure are incredibly varied and continue to shift as new solutions are validated and commercialized. Growth prospects and market share profiles vary widely within the smart infrastructure space depending on the industry vertical and technology maturity level. As such, successful efforts to grow robust smart infrastructure markets will rely on signals of demonstrated commitment to building capacity to invest in and develop innovative solutions over the long term to help mitigate investment risk by companies. Support and incentives for

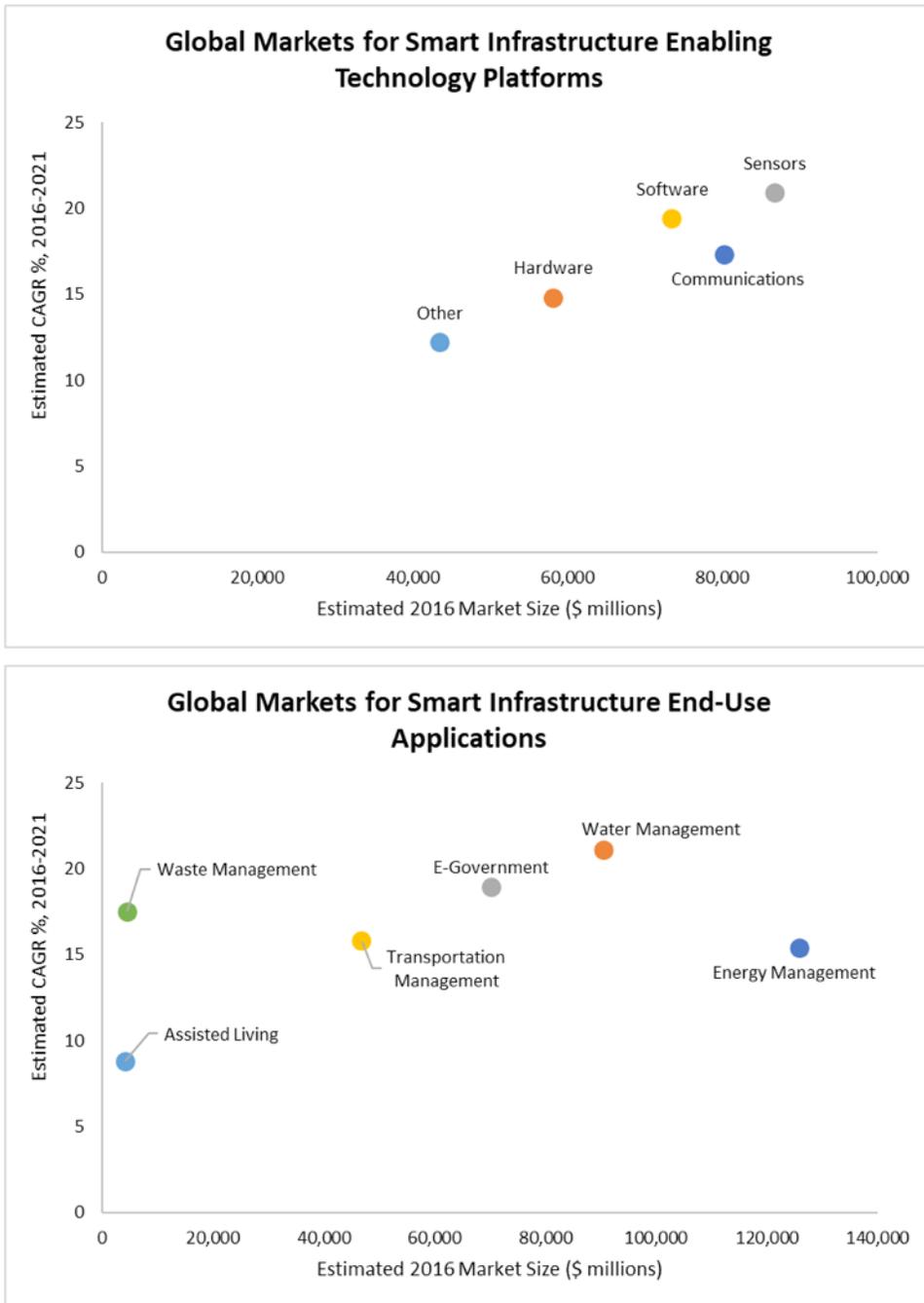
this area must drive products and services across multiple market verticals simultaneously with a common focus on technology integration and interoperation rather than specialization in any one niche area or IoT or sensing.

As noted above, smart infrastructure technology platforms are currently highly fragmented and siloed across industries, but as the market forces continue to drive consolidation under combined hardware and software products that can serve many different customer bases, industry leaders will be attracted to locations where they can undertake widespread product and service deployments. Global market assessments for both underlying technology types and end-use applications in core smart infrastructure products and services demonstrate this fragmentation yet still have immense potential market sizes, with a total combined 2016 market size estimated at \$342 billion in revenue and growth potential of 17.7 percent each year through 2021 (Figure 11).¹²

Note that these forecasts do not include the potential markets for follow-on industry clusters that can take root once the foundation for a smart infrastructure ecosystem is in place. The global market for IoT networking solutions that support larger-scale deployments of these technologies was valued at \$392 billion in 2017, with a 21.6 percent compound annual growth rate, while the global market for sensor technologies was valued at \$95 billion in 2015 with a growth rate of 10.1 percent. Significant clustering of supporting industries like these can be expected once a region gains recognition as a signature location for deployment of smart infrastructure projects.

¹² BCC Research: *Smart Cities: Growing New IT Markets*, Sullivan, 2018; *Internet of Things Networks: Technologies and Global Markets to 2022*, Muratori, 2018.

Figure 11. Global Market Prospects for Smart Infrastructure Technologies and End-User Markets



Source: BCC Research: Smart Cities: Growing New IT Markets, Sullivan, 2018; Internet of Things Networks: Technologies and Global Markets to 2022, Muratori, 2018.

Implications for Ohio's Innovation Economy

Smart infrastructure represents a visionary opportunity for Ohio to fill the growing need for leadership in this space and emerge as a regional hub of innovation. The very localized nature of smart city initiatives and the typically narrower focus of innovation initiatives around deploying smart technologies into highly specific industry verticals leaves a gap that wider innovation strategies can fill. The state could make smart infrastructure the centerpiece of a bold, signature effort to tie together the disparate groups of industry sectors that supply and implement these technologies and help brand a statewide identity around being a proving ground for automation, sensors, and connectivity.

Data Analytics

What Is It?

Data analytics is at the core of an ongoing transformational paradigm shift in the way businesses operate and the way in which technologies interact with the world. Many recent trends around the adoption of solutions in “big data” and “artificial intelligence” are fundamentally driven by underlying data analytics methodologies that gather, interpret, and provide predictions based on flows of data. Companies across almost all modern industries are integrating data analytics innovations into their operations at an accelerating pace and at global scales. This wide-reaching impact is the result of the advent of affordable, scalable, high-performance computing resources that can efficiently manipulate massive amounts of data and simultaneous advances in the basic science of statistical modeling techniques that can provide new insights and predictive tools. For the first time, rather than looking backward to assess outcomes and impact after the fact, these data analytics tools are helping to drive real-time, dynamic feedback loop processes that help improve outcomes as events are unfolding.

Data analytics innovations are made up of three primary pillars of functional technology that work together to provide insights to users:

- Data storage and management technologies that include both physical storage hardware and virtual cloud storage that allows users to store massive amounts of data but also the networking infrastructure that lets users send and receive data accurately and securely. These technologies are often collectively referred to as big data platforms.
- High-performance computing technologies that allow rapid and efficient manipulation of data sources at scale as well as technologies that increase the cost effectiveness of their use. These can include physical computer hardware or virtual on-demand computing resources.
- Data modeling technologies that include various approaches for gleaning insights from large data sources and making predictions to address user questions. These are often the end-state products of many of the applications used in business today, and include tools such as data visualization, machine learning, and artificial intelligence models.

Analytics technologies are having a sweeping effect across businesses and transforming the ways in which they interact with their users and customers. This trend is both revolutionizing existing industries such as financial services, consumer goods, manufacturing, logistics and supply chain operations, medicine, and agriculture while also beginning to create new industry verticals such as bioinformatics, decision support software and intelligent assistants, machine “vision” products, and social media and digital marketing. Its far-reaching impacts are not yet fully realized, but it is clear that it will play a foundational role in driving growth in any significant innovation ecosystems of the next decades.

Why Ohio?

As the incorporation of data analytics into almost all facets of modern business continues to unfold, Ohio industries cannot afford not to strive for excellence in this innovation area. In fact, a large portion of Ohio companies have already developed, deployed, and continue to refine a variety of analytics solutions in their current operations, especially those industries whose primary goods and services rely on providing improved insights and performance to their consumers (Table 9).

- Many Ohio service industries already rely on analytics technologies as a critical element of their everyday operations. Key customer-facing industry clusters in the state with major headquarters operations in consumer products, healthcare, information technologies, banking, insurance, and logistics already rely on innovations in this space to drive value for consumers and collectively support over 814,000 jobs.
- Data analytics is beginning to play an increasingly important role in revolutionizing Ohio's legacy production industries. Ohio's manufacturing, materials, and other industrial production support clusters are advancing efforts to bring analytics more fully into their core businesses and will need to accelerate this transition or find themselves at significant risk of disruption by new companies and competitor regions.
- Despite the importance of data analytics to Ohio's economy, the state does not display specialized strength in innovation and needs to improve its competitive position. The state's major research universities and key industries have recognized the importance of talent pipelines and signature innovation assets in this space and have begun to invest in improvement efforts, but more support is needed to accelerate the pace of upgrading the state's position.

Current growth rates in key indicators are not keeping pace with overall U.S. trends, which threaten to undercut the state's industrial ability to produce new innovative products and services, particularly with respect to R&D investment and IP generation. Ohio's industries are poised to realize significant gains if the state can upgrade its position in more foundational research activity.

Table 9. Indicators of Ohio's Current Position in Supporting Innovative Growth in Data Analytics Applications, 2010–latest available data

Supporting Capacity Indicator	Ohio Position	Competitive Specialization Index, relative to U.S. trend	Ohio Growth Trend (U.S. trend, 2010–latest available data)
Key Supporting Industry Cluster Employment Base	~814K employees	1.07	13% (13%)
Level of Aligned Industrial R&D Spending	\$1.4 billion	0.41	44% (62%)
Level of Aligned Academic R&D Spending	\$1.8 billion	1.09	6.6% (18%)
Level of Aligned Research Generation Activity (Publications)	~43K publications	0.92	20% (8%)
Level of Aligned IP Generation Activity (Patenting)	~3.9K patent awards	0.61	-1% (55%)
Level of Venture Capital Spending in Aligned Industry Applications	\$1.3 billion	0.67	357% (302%)

Source: TEconomy Partners, LLC

As shown in Table 10, Ohio has a number of key industry stakeholders and research assets in this area. Ohio's position in data analytics is highlighted primarily by the presence of industry leaders in financial, banking, and insurance services who use these technologies to attract and retain customers. Marketing, logistics, and administrative operations for a number of major consumer goods companies are also currently rooted in the state and help to generate a critical mass of analytics talent and signature headquarters facilities. Recent evidence shows that this critical mass is generating private sector momentum, with Ohio rising to rank 15th in the nation in 2018 in the Cyberstates Innovation Score, which measures per capita activity in tech industry patenting, start-ups, and new business establishments and 10th in the nation in estimated tech industry employment.¹³ However, complementary research enterprise assets and activity are not as prevalent and the state's employment base in associated industry clusters is mostly focused on downstream services rather than upstream innovation. Thus, Ohio's current position is as a "consumer" of data analytics that effectively deploys its downstream applications at major companies but has struggled to be a breakout innovation leader due to constraints around the consistent supply of skilled talent and innovation thought leaders. Developing areas of differentiated industry applications in data analytics research and talent that complement rather than directly compete with other major innovative hubs in this area, such as Silicon Valley or the San Francisco Bay area, will be critical to ensuring that Ohio remains globally competitive and can attract the innovation capital it needs to foster growth.

¹³ CompTIA Cyberstates 2018 report, <http://www.cyberstates.org/>.

Table 10. Key Ohio Industry Stakeholders and Research Assets Aligned with Data Analytics

Examples of Key Industry Stakeholders	Examples of Key Research and Innovation Assets
<ul style="list-style-type: none"> • Financial Services: Chase, KeyBank, Vantiv/Worldpay, Huntington, Fifth Third, Alliance Data • Insurance Products/Services: Nationwide, Progressive, SafeAuto • Consumer Goods and Retail: Procter & Gamble, Kroger, Limited Brands • Smart Manufacturing: GE, Honda • Logistics and Support: Teradata, Tata, OnBase, IBM, Cardinal Health, Oracle 	<ul style="list-style-type: none"> • Nationwide’s Innovation Lab • Procter & Gamble Innovation Center • Fuse by Cardinal Health • Columbus Collaboratory • Fintech71 • OSU’s Translational Data Analytics Institute (TDAI) • Ohio Supercomputer Center

Source: TEconomy Partners, LLC

Innovation Trends and Market Outlook

Data analytics functions as an enabling innovation platform for a variety of downstream applications areas. Innovations in fundamental data science methodologies and tools will continue to be pushed down to more tailored applications in different industry verticals, so enabling the flow of solutions adapted for specific industry needs is critical to successful translation of concepts to market.

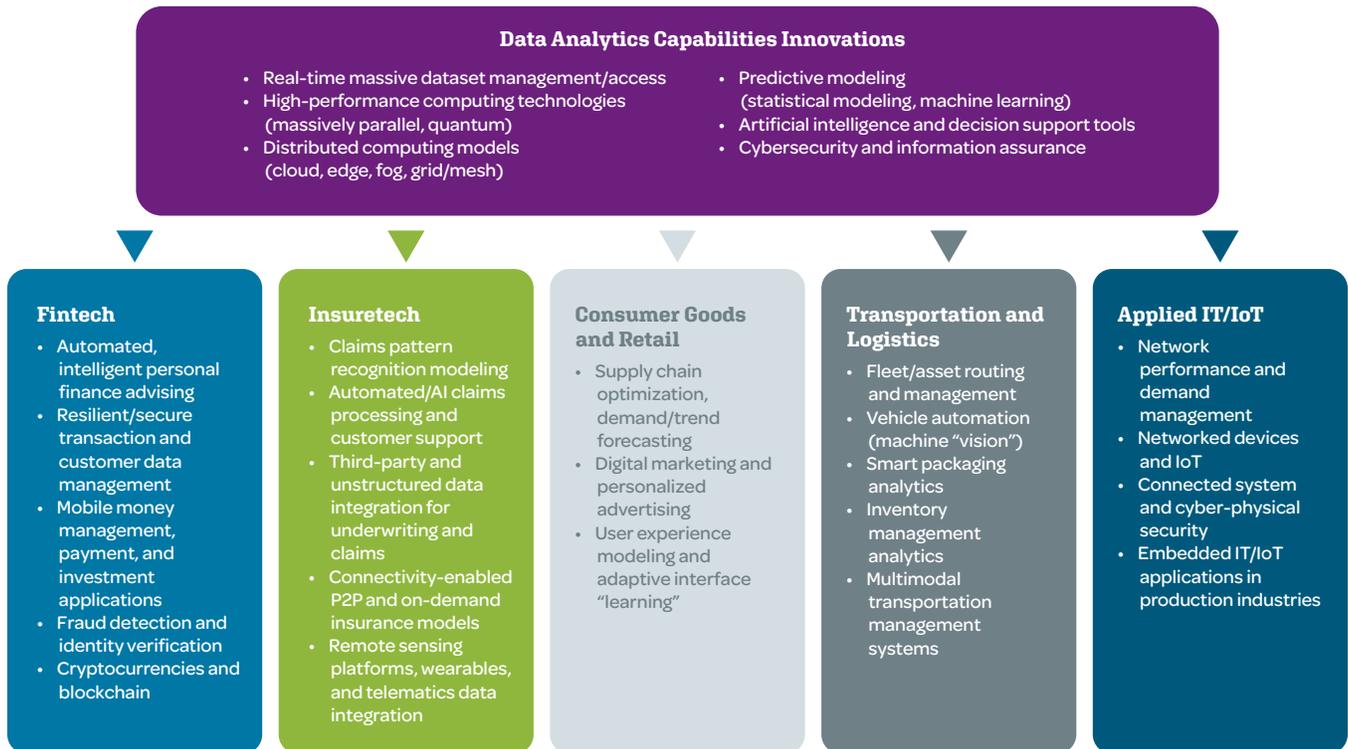
Primary research in data analytics fields is most likely to drive innovations in the underlying functional technologies of data storage, high-performance computing, and novel data-modeling techniques. Some examples of capabilities innovations being advanced include the following:

- Methods for efficient real-time access to and management of massive databases that use fewer computational resources.
- Advancements in high-performance computing hardware systems and operational efficiency such as massively parallel processing and quantum computing.
- New distributed computing architectures that use cloud, edge, fog, and grid/mesh computing approaches to provide better access to computational resources.
- Novel modeling approaches that increasingly utilize pattern recognition and machine learning techniques such as clustering models and neural networks.
- Improvements to artificial intelligence models that automatically provide recommendations based on data inputs and iteratively “learn” from outcomes to recursively improve their prediction power.
- Cybersecurity, information assurance, and identity management architectures and vulnerability assessment that identify and mitigate weaknesses in data-driven computing systems.

As initial innovative capabilities in data analytics are validated, they are often quickly translated into specific applications areas using available databases for validation and prototyping. These initial steps typically lead to downstream innovations that utilize innovative data analytics approaches or tools to address issues within the context of more specific industry sectors. The following are key sectors, shown in Figure 12, where data science innovations are typically translated into applied products and services:

- Financial technologies (Fintech) that enable banks and other financial asset management businesses to provide services to users and attract new customers. Key applications include automated and intelligent personal finance advising, secure transaction and financial data management, mobile money management, fraud detection and resolution, and applications utilizing cryptocurrencies and blockchain technologies.
- Insurance technologies (Insuretech) that help insurance companies provide more tailored products to their customer bases and improve administrative efficiency. Key applications include pattern recognition and classification models for claims database insights; automated claims filing and processing; third-party and unstructured data integration for underwriting and claims; connectivity-enabled peer to peer (P2P) and on-demand insurance products; and integration of information from remote sensing devices, wearables, and telematics.
- Consumer goods and retail analytics solutions that help companies better reach target customers and optimize their supply chains. Key applications include digital marketing and personalized advertising technologies, customer and user experience modeling, supply chain optimization, and consumer-demand and other trend forecasting.
- Transportation and logistics analytics solutions that enable management and automation of collections of supply chain and transportation assets. Key applications include vehicle fleet or other mobile system routing and management, vehicle automation and machine vision systems, inventory and warehouse management analytics, smart packaging and shipping services, and optimization of multimodal transportation and shared-use infrastructure.
- Applied IT and IoT analytics solutions that provide insights from the streams of data being generated by collections of connected devices. Key applications include network performance management, interfaces for networked devices and other IoT products, cyber and cyber-physical security analytics, and third-party analytics products and services that provide insights from embedded IT and IoT hardware in manufacturing and production industries.

Figure 12. Dynamics of Data Analytics Innovation Trends



Source: TEconomy Partners, LLC

The widespread acknowledgement by industry of the value in data analytics and the rapid integration of applied solutions into operations demonstrate the significant market opportunity for innovations in this area. Several ongoing trends are expected to reinforce and, in some cases, accelerate this process in conjunction with trends in more specific industry verticals. Across all industries, the demand for innovations in data analytics is being driven by the following:

- Exponential growth in information flow based on proliferation of technologies that increase the ability to collect and store data points and metrics on environmental and behavioral characteristics. In turn, this has generated massive amounts of data that have the potential to be leveraged by industry and has coincided with the development of relatively cheap processing power and data storage that has led to accessible analytical computing and big data management software solutions that companies are eager to operationalize. The key factor currently driving innovation in analytics products and services is the need to intelligently mine these potentially overwhelming amounts of data and leverage insights toward actionable industry solutions that have real impact on bottom-line company financials.
- The push for integration of data analytics into legacy industries where analytics has not traditionally played a central role in decision-making. Analytics and supporting IT capabilities have quickly become essential in-house operations for modern business even across low-tech industries and function as an underlying enabler of process

innovations for these industries. The demand for analytics solutions by production industries is currently driven by fear of disruption by new companies that can effectively leverage these technologies to do more with less. As noted in other innovation platforms, industry already recognizes the value of integration of analytics capabilities into manufacturing, agriculture, logistics, and infrastructure/utilities operating models. Mid-tier service industries in education, finance, and healthcare, which were early adopters of some of these solutions, are also now experiencing a second wave of innovation in analytics solutions that is once again driving reassessment of traditional business models.

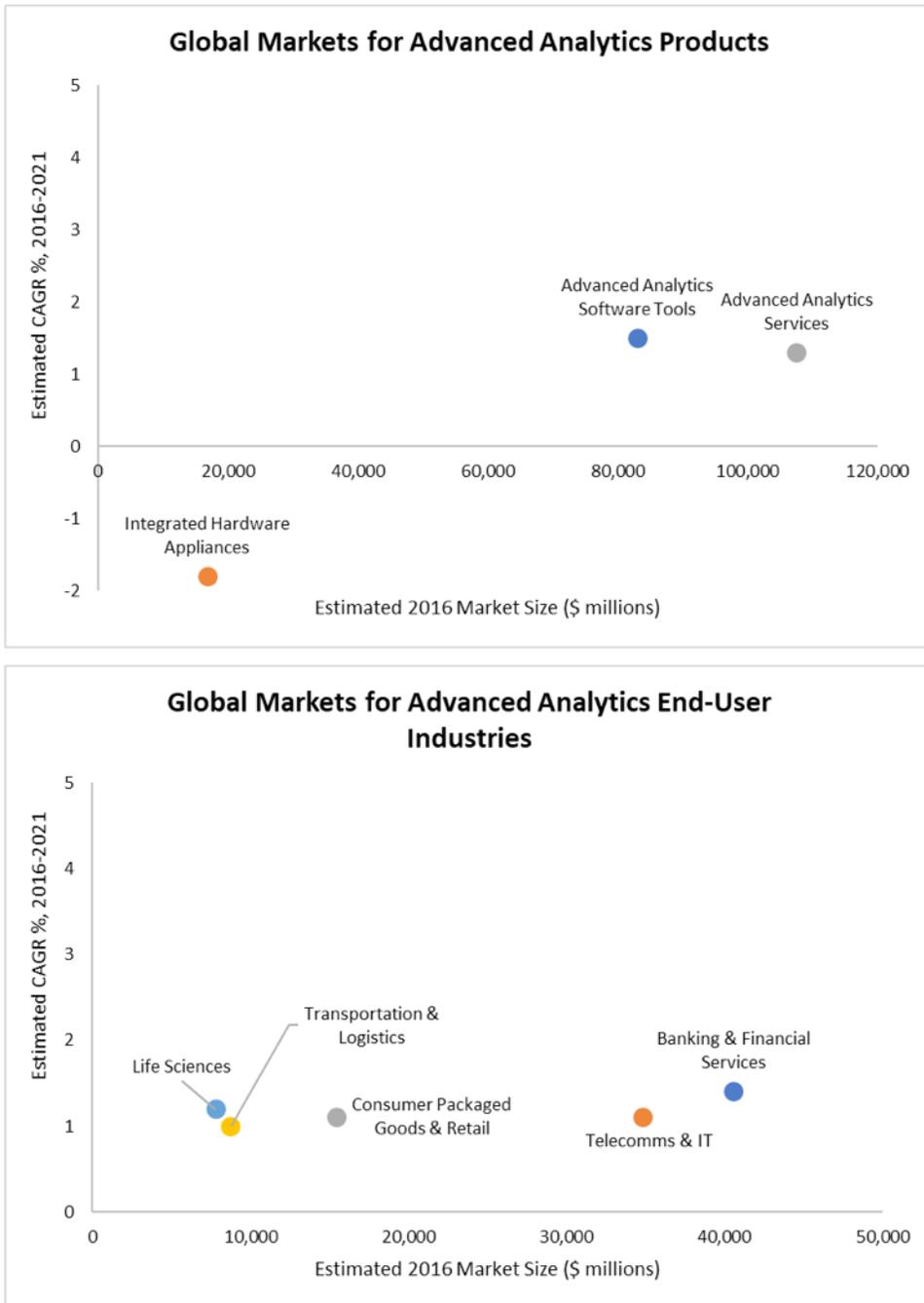
- A scarcity of pipelines for skilled data analytics talent in applied areas that can help companies transition to analytics-driven business models, which is reinforcing competitive advantages for companies that have fully embraced this trend. As the capital resources required for analytics becoming increasingly cheap due to virtualization and high-performance computer advancements, a key enabler of development of innovative solutions for industry will be a skilled talent base that understands both the fundamental data science techniques and the nuances of specific markets that industries serve. High demand by industry is currently outpacing the supply of talent that works in developing applied solutions in nontech industries, a challenge faced by companies nationwide. As a result, regions that have access to a skilled analytics talent base and emphasize development of applied knowledge within specific industry innovation verticals will have the opportunity to capture large market shares as shifts in business operations continue to occur and industry clusters around reliable workforce pipelines.

The estimated market sizes for data analytics technologies remain vast, reflecting the extent to which products and services have already diffused into business operations. There is also no “pure play” market for analytics solutions, as these technologies overlap significantly with numerous other markets where they either serve as a fundamental enabler of other technologies or a means of creating the end-state product or service with which customers interact. As such, the market for data analytics is also represented in markets for all other innovation platform areas and across almost any other markets for modern goods and services with a potential that cannot be overstated.

Considering the more limited market for third-party analytics products in different industry application areas, the global market sizes still remain significant at an estimated \$207 billion in 2015 (Figure 13).¹⁴ However, these markets appear to have reached saturation points as the ongoing “tech boom” of the past decade has created a crowded competitive landscape and a glut of available product options. Despite lower overall growth prospects of only around 1.1 percent compound annual growth through 2021, the dynamic, disruptive structure of the analytics industry creates a high natural churn rate on which leaders in developing new innovative solutions can capitalize. Financial services and communications industries are expected to be the most significant initial end users; but, as analytics technologies become more embedded across a number of other industries, this balance could shift.

¹⁴ BCC Research: *Advanced Analytics Technologies: Global Markets*, Banerjee, 2016.

Figure 13. Global Market Prospects for Data Analytics Technologies and End-User Markets



Source: BCC Research: Advanced Analytics Technologies: Global Markets, Banerjee, 2016.

Implications for Ohio's Innovation Economy

Data analytics represents an area that Ohio must invest in to remain competitive in tomorrow's innovation-driven economy. While the innovation landscape is crowded and competitive, the technologies and capabilities being driven by these technologies are so ubiquitous and impactful in modern business that states must invest in the area to remain economically competitive in the years to come.

Digital Transformation in Ohio's Industries: A Vision for Tomorrow's Economy Built around Innovative Convergence

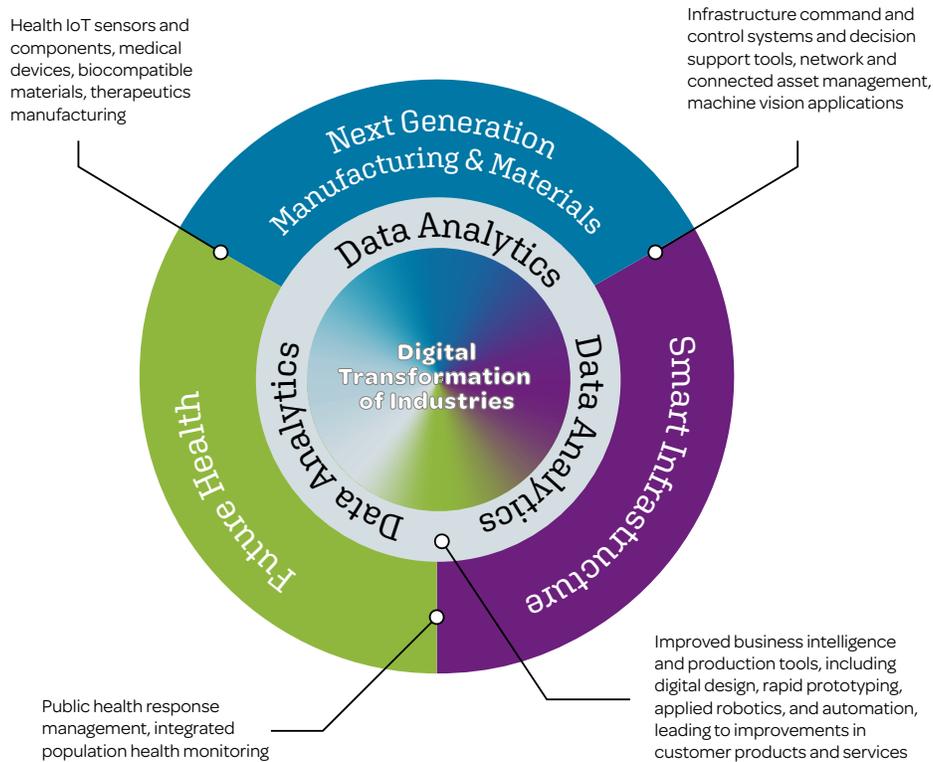
A common theme driving momentum in innovative research and technology development in today's economy is the concept of convergence. This idea describes the process of historically independent technology areas in research and industry becoming increasingly intertwined and codependent based on common innovation platforms. A thought leader in this area, William Bainbridge, describes the concept as involving a "deep integration of knowledge, tools, and all relevant activities of human activity to allow society to answer new questions, to create new competencies and technologies, and overall to change the respective physical or social ecosystems."¹⁵ He also notes that "Convergence of science and technology means more than simply the creation of multidisciplinary teams to address hard problems, in which effective communication takes place across distinct fields. Importantly, it also requires development of new concepts and new methodologies for research, design, and collaboration that bridge across fields in time while preserving their distinctive characters and aims at overarching goals."¹⁶ The ability to capture innovative convergence through a complementary innovation platforms strategy has positive reinforcement effects across the independent industries it connects and generates economic impacts that are greater than any one area of focus could create on its own.

The four innovation platform opportunity areas for Ohio outlined in this report each demonstrate these convergence effects in the way they interact with one another to create combination technology solutions, driven by the underlying digitization of industries (Figure 14). As demonstrated through many of the dynamics of innovation within each platform, regional economies across the United States are undergoing a fundamental shift toward environments that utilize the integrated combination of connected hardware, massive data collection and management, and analytics-driven solutions to drive new growth. This "digital transformation" capitalizes on the trend toward converging technologies and is already having real economic impacts on industry clusters throughout the country in their ability to generate new products and services. For Ohio, this means that these areas will become critical to the state's continued economic prosperity and competitiveness in the global economy.

¹⁵ W.S. Bainbridge and M.C. Roco, "Science and technology convergence: with emphasis for nanotechnology-inspired convergence." *J. Nanopart Res.* 18:211, 2016.

¹⁶ W.S. Bainbridge and M.C. Roco, eds. *Handbook of Science and Technology Convergence*, 2016.

Figure 14. Examples of Innovative Convergence Areas within Ohio Opportunity Areas



Source: TEconomy Partners, LLC

At the intersections of the innovation opportunity area platforms, the beginning stages of revolutionary new applications that will drive the economy of the future are being introduced. Platforms that reinforce and complement each other across rather than within cross-cutting industry clusters are critical to developing applied solutions since convergence trends mean that industries increasingly require combination technologies and multidisciplinary knowledge to succeed. Platform-based initiatives can have immediate economic impacts through direct investment in new technologies and company growth; but, due to the nature of convergence, these initial impacts can also have transformational downstream effects and create “virtuous cycles” of follow-on innovative development.

For each platform, fully embracing the opportunity to create a transformative innovation ecosystem can have profound impacts on the future of the state’s economy and quality of life:

- Investing in next-generation manufacturing and materials can allow the state to create a world-class smart manufacturing environment that serves a variety of industry verticals and maintains Ohio’s specialized workforce advantages. In a state innovative ecosystem that sees widespread deployment of additive and other production technologies and novel advanced materials, manufacturing operations will, on average, become smaller but also

more numerous as they spread out and relocate closer to consumers in flexible operations, bringing employment options back to communities experiencing economic hardship. Workers will experience large increases in the level of technical skills and be able to utilize more flexible training and continuing education models, and industry as a whole will be able to produce highly customized products with minimal waste using on-demand, cloud-based design templates and design consultants. Large industry operations will still be present and heavily clustered around signature shared-use facilities developing new innovations, where high-quality engineering and digital design talent can interact seamlessly with cutting-edge industry prototyping and testing. New career paths will also spring up around the need to mine the large amounts of data being produced by heavily instrumented production operations, with other regional economies looking to Ohio case studies for how to implement wide-scale manufacturing IoT technologies.

- Organizing the medical and healthcare industries around an integrated future health vision will allow the state to spur development of integrated care environments and see the widespread adoption of digital health platforms. As precision medicine solutions begin to more quickly be incorporated into clinical use, local bioscience industry clusters will grow around signature private and academic medical centers and attract innovative companies interested in access to patient populations and the ability to test their technologies in applied settings. Personalized medical devices, drug combinations, and diagnostics will begin to become standards of care as healthcare manufacturer and supply chain companies integrate data from digital health profiles. Novel ways of utilizing health data will lead to innovative quality metrics and payment models that can be adopted across a network of providers, leading to lower healthcare costs and more effective treatments for patients. Increases in connected health will allow high-quality treatment to be delivered remotely within patients' homes and cut down on medical product abuse while improving early diagnoses of problems. The state can eventually implement a true population health system of networked industries and healthcare data that demonstrates long-term reductions in levels of serious disease and attracts skilled workforces eager to take advantage of the availability of high-quality healthcare options.
- Successfully branding Ohio as a world-class smart city and smart infrastructure test-bed environment and widespread investment in connected infrastructure will make the state a regional hub for new innovation opportunities. The state will build a reputation as a signature destination for testing unmanned and automated systems, as well as pioneering approaches to revitalize aging infrastructure and energy grids while incorporating advanced data collection systems that allow advancements in civil engineering and utilities management. A wide network of demonstration and testing sites will draw industry R&D operations to locate in the state and in turn grow clusters of supplier industries that want to locate regionally. Major metropolitan areas will utilize state-of-the-art command and control facilities to manage traffic, energy, and emergency response systems in an integrated way, leading to improvements in safety and efficiency. Public services will become increasingly digitized as well, dramatically cutting down on waste and fraud and enabling remote access. The overall perception of the state's focus on smart infrastructure will attract skilled talent bases that want to take advantage of highly connected and sustainable live-work-play environments and further reinforce the brand of the state as an innovation hub.

- Creating a high-quality data analytics innovation ecosystem will result in improved business intelligence and insights for the companies of the state, in turn leading to improvements in customer products and services that generate industry growth. The presence of visionary thought leaders in specialized areas of data science will create a more vibrant entrepreneurial ecosystem around next-generation finance, insurance, digital marketing, consumer experience, logistics, and health IT companies that sustains a broad base of tech start-ups. Employment opportunities within the highly active data analytics industry will offer the opportunity for potential data scientists to experience innovations across a wide variety of different industries, producing a new generation of thought leaders and entrepreneurs who give the state a regional reputation for an innovative culture and attract supporting venture capital networks eager to invest in high-quality start-ups. Over time, the state will find more specialized areas of data analytics to continue building critical mass that complements other national hubs of activity and leads to establishment of nationally recognized corporate R&D innovation centers that seek to leverage the talent base. Prospective students seeking to gain applied education in data sciences will pursue programs in state due to the ability to get hands-on experience and promising job prospects, further building out the ecosystem.

Achieving this aspirational vision of the future where digital transformation has spread across Ohio's industries is within reach if the state adopts a forward-thinking focus on innovation platforms. However, the risks are high if the state is not able to successfully transition to a new economic reality. The broad set of Ohio's manufacturing industries are highly vulnerable to disruption by new technologies, and failure to invest in innovation can potentially lead to significant declines in employment and migration of industry operations to regions of the country with the types of facilities and talent bases they require to implement smart manufacturing models. In healthcare, failure to articulate and act on a clear vision for future health risks a fragmentation of state healthcare providers and research enterprises into competitive silos and continuing declines in the quality of health for Ohioans. The state would also be more vulnerable to rising healthcare costs and less able to respond to public health emergencies such as the opioid crisis. Not investing in smart infrastructure could lead to the state becoming a consumer rather than a leader in innovation, leading to a need to "import" new technologies from other regions of the country to revitalize infrastructure at higher costs and without beneficial job generation impacts on the local economy. Finally, failure to embrace a forward-thinking perspective on data analytics will result in the state being left behind in job growth and new business formation by states that are making significant investments in bolstering their data analytics workforces and innovation capacities. The net result of not engaging with convergent innovation platforms over the long term will undermine the competitive position of Ohio industries in a global marketplace, risk significant employment losses from out-migration of industry, and make the state much less attractive to increasingly mobile skilled talent bases.

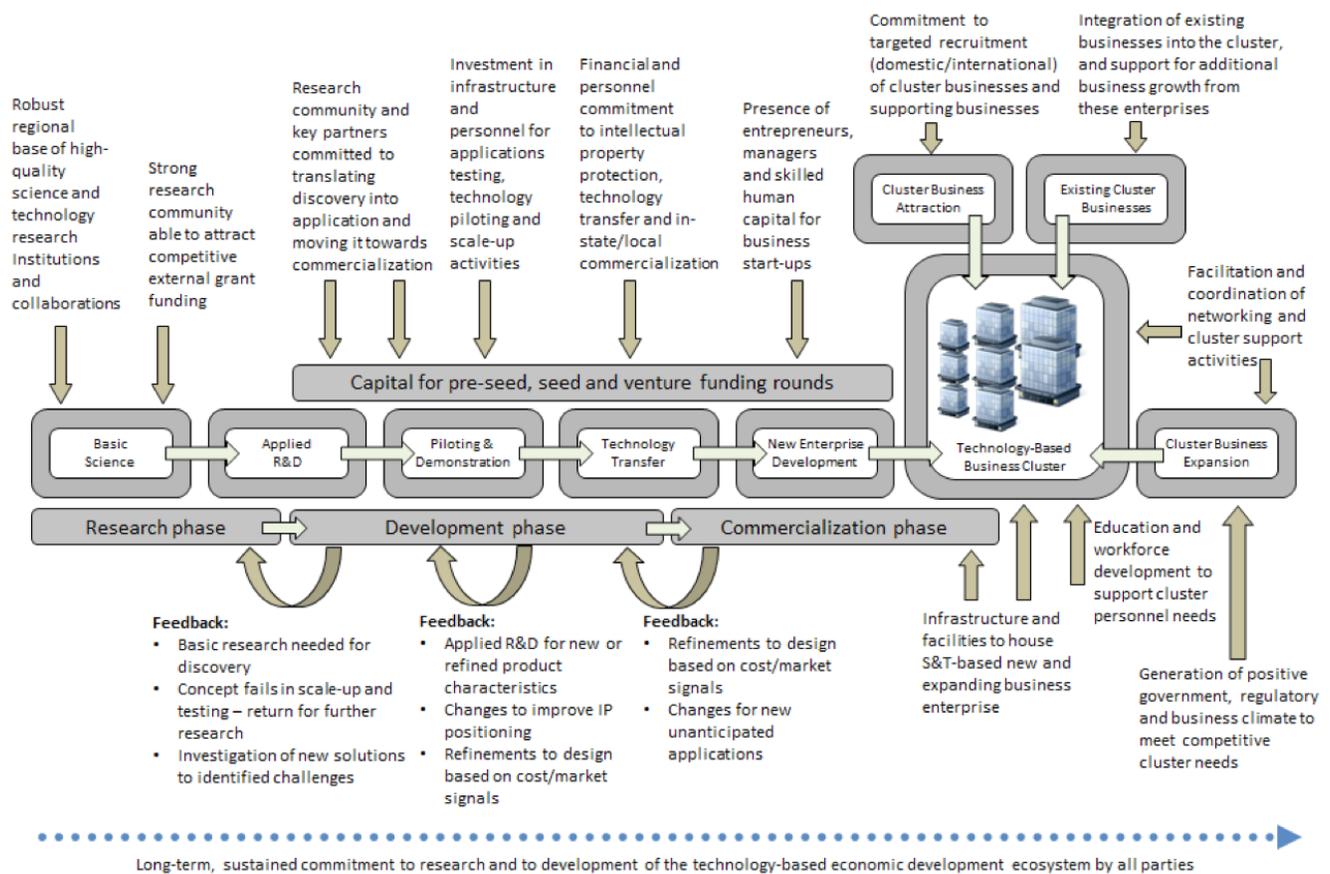
Strategic Recommendations to Accelerate Ohio's Economy

Drivers of the 21st Century Economy

Economic development in general is not easy to achieve; technology-based economic development is an even greater challenge. For technology-based economic development to occur, an entire interconnected sequence of positive economic factors must be in place to strengthen the drivers of advanced industries and traded sectors, namely, innovation, capital, and talent. If any stage of this innovation continuum either inadequately addresses the economic needs or is missing altogether, a sustainable technology-based economy able to generate quality jobs is unlikely to develop. To succeed, it takes a high-functioning innovation ecosystem (Figure 15) that is able to do the following:

- Translate R&D activities into new products;
- Move technology commercialization into high-growth businesses; and
- Provide a competitive advantage in which emerging firms develop, existing businesses grow, and out-of-state businesses are attracted.

Figure 15. A Robust Innovation-Based Economic Development Ecosystem



Source: TEconomy Partners, LLC

The public sector must be willing to support collaborations between private and public sectors, serving as facilitator and catalyst to be able to develop an impactful innovation continuum. Its economic development policies must be sensitive to, and targeted at, advanced industries in new and different ways. Economic experts argue that, to compete in the future, a state must have an economic base composed of firms that do the following:

- Constantly innovate based on knowledge;
- Maintain their competitiveness by focusing on innovation, time to market, quality, and cost;
- Integrate the technological revolutions into the workplace, both in terms of how they do business and in terms of the businesses and markets in which they choose to participate;
- Network with other firms and institutions, establishing alliances by collaborating; and
- Reward and invest in their primary resources: talented individuals and teams.

The State of Ohio has a critical role to play in ensuring that its innovation ecosystem is structured to leverage disruptive change and adapt to it. To accelerate Ohio’s economy, it is proposed that the state focus its innovation investments on three strategic priorities. The emphasis should be on leveraging and complementing existing efforts while catalyzing long-term economic growth across the state. Specifically, the three strategies should focus on the following:

- **Infusing cutting-edge innovation into Ohio’s industrial economic drivers through focus on the four identified platforms to ensure that existing industries remain globally competitive and new industries emerge;**
- **Further elevating the entrepreneurial/risk capital ecosystem to drive future economic growth; and**
- **Developing, retaining, and attracting the talent that Ohio’s industry demands.**

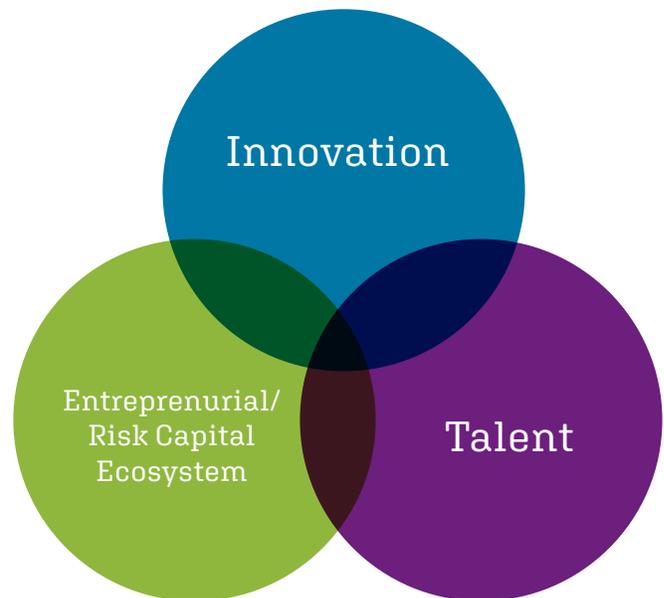


Table 11 provides a summary of the recommended action plan to accelerate Ohio’s innovation economy.

Table 11. Recommended Action Plan: Accelerating Ohio's Economy

Strategy	Baseline Action for Ohio to Consider
<p>Strategy One Foster the Infusion of Advanced Innovation Processes, Products, and Techniques throughout Ohio's Industrial Base</p>	<p>Action 1: Create four statewide Innovation Hubs that focus on the innovation opportunity platforms and represent public-private partnerships.</p> <hr/> <p>Action 2: Review and update Ohio tax code to create additional ways to incent Ohio companies to invest in new products and process improvements.</p>
<p>Strategy Two Further Elevate the Entrepreneurial/ Risk Capital Ecosystem to Drive Future Economic Growth</p>	<p>Action 3: Continue to invest in the regional Entrepreneurial Signature Programs (ESPs) and expand their role to ensure that innovation opportunities generated by the four Innovation Hubs are scaled in Ohio.</p> <hr/> <p>Action 4: Continue to foster the creation of early-stage risk capital by focusing additional efforts on funding the creation of emerging firms from the four innovation platforms.</p> <hr/> <p>Action 5: Stimulate creation/attraction of later-stage risk capital financing to ensure emerging opportunities are able to grow and scale in Ohio.</p>
<p>Strategy Three Develop, Retain, and Attract the Talent that Ohio's Industry Demands</p>	<p>Action 6: Encompass significant talent development efforts into the Data Analytics Innovation Hub.</p> <hr/> <p>Action 7: Encompass significant talent development efforts into the NextGen Manufacturing and Materials Innovation Hub.</p> <hr/> <p>Action 8: Encourage Ohio graduates to pursue careers within the four innovation opportunity platforms by offering financial incentives.</p> <hr/> <p>Action 9: Offer financial incentives for senior and mid-level professionals to relocate to Ohio for careers within the four innovation platforms—create an Ohio Alumni Outreach Program.</p>

Strategy 1: Foster the Infusion of Advanced Innovation Processes, Products, and Techniques throughout Ohio’s Industrial Base

Rationale

Technological evolution and its associated economic disruption is a given in today’s fast-paced, global markets. There is simply too much advancement taking place in science and engineering, translational sciences, and R&D-based technological innovation for industries to remain static—those that remain so will quickly become obsolete. Today’s markets demand new, better, faster, and cheaper products and processes; and companies are leapfrogging one another in a constant race to innovate, secure market share, and capture new market spaces. In this environment companies must do the following:

- Embrace change and be prepared to accept the risks that exist at the leading-edge of innovation, or
- At least be nimble to adapt to innovations as they become mainstream.

Innovation is being driven by technological convergence. The phenomenon of technological convergence is not new. Many products contain multiple components that have had unique development pathways prior to converging into a novel product (for example, GPS, mobile telephony, photography, and mobile internet connectivity converging into a smart phone). A more current phenomenon, however, is the large-scale convergence that brings together distinct industry sectors, which historically have operated largely independent of one another, that today are starting to coalesce around areas of mutual interest. In this new paradigm, technologies and companies from one sector converge with those from another (or several others) to provide a combined solution to market needs and opportunities. An example is the growing field of autonomous mobility services that is being advanced through collaboration between automotive companies, alternative forms of power and propulsion sources, automation/sensors technology pioneers, and data analytics.

Ohio’s Current Situation

As the previous sections have stressed, the ability of Ohio companies to develop new innovative products and employ innovative processes into their business models will be critical to the state’s ability to grow and prosper economically. However, when key innovation indices are examined, Ohio is not performing well compared with either the nation or the benchmark states.

The data in Table 12 indicate that Ohio lags behind the United States and most benchmarks in both industrial R&D and university R&D expenditures—a key driver of innovation.

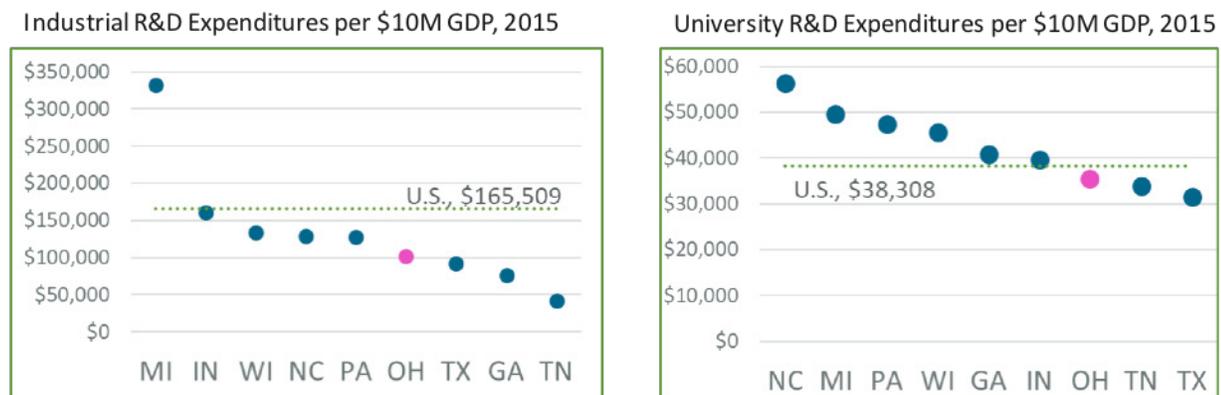
Table 12. Comparison of Industrial and University R&D Expenditures in Ohio and the United States, and Ohio's Rank among the Benchmark States, 2014–2015

Measure	Definition	Ohio	U.S.	Ohio Rank
Industry R&D	Avg. Industrial R&D Expenditures (USD Millions), 2014–2015	\$8,995	\$348,275	4
	Industrial R&D Expenditures per \$10 million GDP, 2014–2015	\$143,748	\$188,702	6
	Percent Change, 2010–2013 to 2014–2015	21.0%	16.3%	2
University R&D	Avg. University R&D Expenditures (USD millions), 2014–2015	\$2,156	\$67,934	5
	University R&D Expenditures per \$10 million GDP, 2014–2015	\$34,452	\$36,808	7
	Percent Change, 2010–2013 to 2014–2015	0.6%	4.8%	8

Source: National Science Foundation, Higher Education Research and Development Survey, Business R&D and Innovation Survey, and TEconomy's analysis.

While Ohio ranks near the middle of the benchmarks in industry R&D, it is lagging behind the nation and therefore missing opportunities for growth. Furthermore; when university R&D is examined, Ohio compares closer with the U.S. average, but lags farther behind the leading benchmark states (Figure 16).

Figure 16. A Comparison of Industrial and University R&D Expenditures in Ohio, the United States, and the Benchmark States, 2015

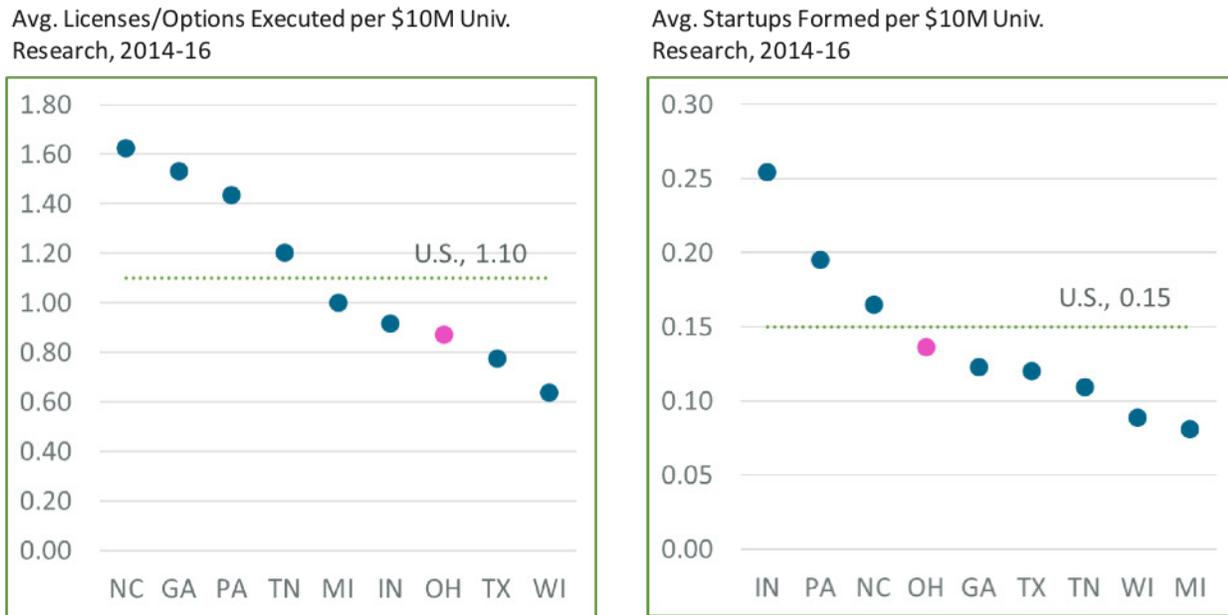


Source: National Science Foundation, Higher Education Research and Development Survey, Business R&D and Innovation Survey, and TEconomy's analysis.

When patenting activity is examined, a key measure of the value of a state's research, it is discovered that Ohio lags just behind the United States and other benchmarks in invented patents adjusted for GDP. However, Ohio is losing ground,

having experienced the lowest growth in average number of patents invented annually among the benchmarks and the nation (Figure 17).

Figure 17. A Comparison of Patenting Activity in Ohio, the United States, and the Benchmark States, 2014–2016



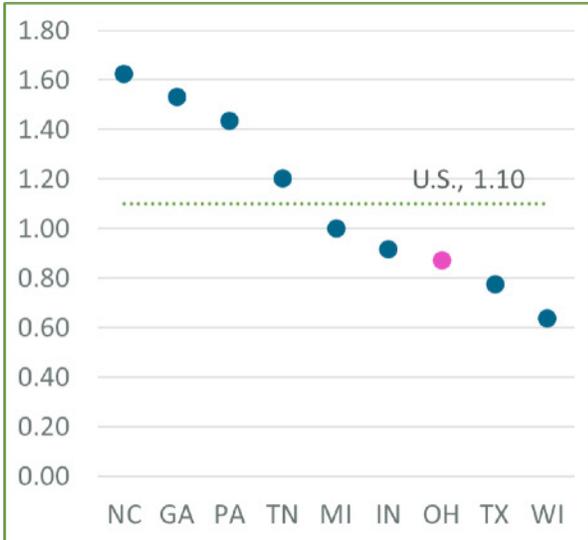
Note: Using “invented in” state data for patent metrics to provide a better insight into the level of innovators in the state. Includes any patent with one or more inventors residing in the state in question. Includes all types of patents (e.g., utility, design, plant, etc.).

Source: U.S. Patent and Trademark Office. TEconomy calculations.

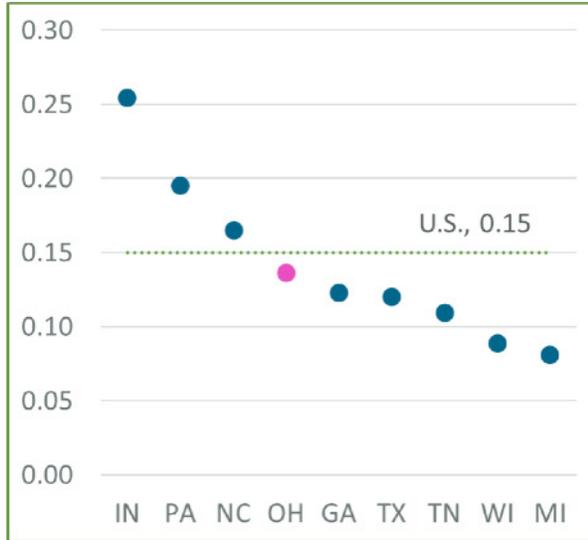
Finally, when the number of licenses, options, and start-ups are examined that result from intellectual property created—a measure of the value of the IP, Ohio does not perform well. Ohio ranks in the bottom third in terms of licenses and options executed and behind the nation. The state also lags just behind the United States in start-up formation and falls in the middle of the benchmarks (Figure 18).

Figure 18. Comparison of Licenses/Options Executed and Start-Ups Formed in Ohio, the United States, and the Benchmark States, 2014–2016

Avg. Licenses/Options Executed per \$10M Univ. Research, 2014-16



Avg. Startups Formed per \$10M Univ. Research, 2014-16



Source: Association of University Technology Managers Surveys, 2014–2016. TEconomy calculations.

To help drive improvement in these innovation metrics, Ohio must align its innovation-based programmatic investments and policies to focus on infusing cutting-edge innovation into Ohio’s industrial economic drivers through focus on the four identified platforms to ensure that existing industries remain globally competitive and new industries emerge. The following recommendations seek to obtain that goal.

Strategic Recommendations

Action One: Create four statewide Innovation Hubs that focus on the innovation opportunity platforms and represent public-private partnerships.

Ohio should create four statewide Innovation Hubs that address the full innovation ecosystem of needs by advancing and deploying cutting-edge innovation within the opportunity platforms. This statewide organizational approach to pursuing strategic innovation opportunities offers the advantage of supporting strategic areas of innovation, while bringing together numerous industrial partners, public and private research institutions, and the public sector in a unique partnership to advance Ohio’s economy.

While Ohio has already made significant investments in a number of these innovation platforms, the activities are often not connected nor of a scale to have statewide impact. The proposed Innovation Hubs will work statewide to leverage these disparate efforts to develop critical mass and statewide relevance.

By focusing on specific areas of innovation that are relevant to large sectors of Ohio’s industrial economy and encompass numerous projects and organizations, these targeted development initiatives will accomplish the following:

- Advancing technological convergence and innovation capacity, with a strong focus on building innovation capacity across Ohio’s economic industrial drivers;
- Attracting and generating top talent and broader-skilled technical workforce that industry needs; and
- Fostering the growth of existing firms, creation of new firms, and attraction of firms.

The statewide Innovation Hubs will focus on “industry-facing” activities and specialized shared-use facilities to advance new product development, process improvements, and commercialization of new technologies through active connections to serial entrepreneurs, angel investors, and seed-stage venture capital funds.

Additional benefits of these dedicated Innovation Hubs are their ability to support the following:

- Branding and proactive outreach that creates and sustains a market leadership position for Ohio and helps generate business attraction leads for Ohio.
- Addressing workforce and new talent generation from development of new curriculum and degree programs at the postsecondary level to experiential learning and internships that connect students with industry to creating career academies, summer programs, and career awareness at the K–12 education level.

Learning from the Oregon Innovation Council and the North Carolina Biotechnology Center (see text box), it is important for accountability and for ensuring strong economic development connections that each Innovation Hub be advanced as an industry-led, nonprofit organization, with broad representation of Ohio’s industry leaders representing both large-, mid-, and small-sized firms, as well as participation by research institutions, educational partners, and relevant governmental agencies.

The selection of statewide Innovation Hubs to advance innovation opportunity platforms should be based on a competitive process that fosters consortium applicants. While the effort should be competitive, the goal will be to bring together excellent ideas that meet the needs of industry from every region of the state. Therefore, planning grants should be considered to foster collaboration.

While it is envisioned that every Innovation Hub will be uniquely different, with the organizational design predicated by the needs of industry, potential key services and focus areas of each Innovation Hub might include the following:

- Product development and design services, including serving as a design group, creating concepts, developing preliminary designs, fabricating and testing prototypes, documenting designs, and identifying manufacturing resources and alternatives.
- Market research to identify customers’ wants, market trends, and product options.

- Ideation of new product and process ideas by serving as facilitators of brainstorming sessions among industrial thought leaders, and then providing engineering and design services.
- Supply chain development, including matching customers with suppliers and vendors.
- Export assistance, including providing assistance to accessing global customers through trade ambassadors and international trade missions. This can also work in reverse by serving as the “soft-landing” site for international companies seeking to expand their U.S. presence.
- Talent training/retraining programs as well as serving as a link to relevant offerings being provided by academic institutions.

One long-standing example is the North Carolina Biotechnology Center. North Carolina legislature in 1984 took the lead in establishing a dedicated, private, nonprofit, industry-led development organization for advancing biotechnology, with the formation of the North Carolina Biotechnology Center. The Center represented the world’s first government-sponsored commitment to advancing biotechnology-based economic development with a focus on public-private partnerships and filling key gaps to ensure the growth of this industry in the state. Over the years, NCBiotech became the state’s key mechanism to catalyze life science industry development working across the full ecosystem of programs. The Center is focused on developing the biotechnology sector statewide by supporting research, business, and education. NCBiotech provides funding for collaborative research projects, financial assistance in the form of grants and loans to early-stage bioscience companies, and support for an array of bioscience education initiatives. The NCBiotech also offers more soft-support efforts that serve as a connective tissue for growing biotechnology in the state with: portals and other assistance aimed at connecting early-stage companies with larger corporations, venture financiers, angel capitalists, and university licensing offices; an industrial fellowship; monthly networking forums and an annual in-state biotech conference; listings of available commercial wet-lab space; and entrepreneurial education produced in cooperation with the Council for Entrepreneurial Development. NCBiotech has also been instrumental in business attraction of bioscience companies for North Carolina. It serves as the marketing arm that helps identify and qualify leads.

Oregon, through the Oregon Innovation Council (Oregon InC), used a competitive state grant process to advance larger-scale industry-university research and innovation consortia, known as Signature Research Centers, in targeted strategic growth areas. The state funding enabled the formation of industry-led innovation organizations, involving multiple companies and multiple universities. Perhaps the most successful one is the Oregon Nanoscience and Microtechnologies Institute (ONAMI) representing a collaboration of four Oregon universities (Oregon Health and Science University, University of Oregon, Oregon State University, and Portland State University), a national laboratory (Pacific Northwest National Laboratory), industry, and the investment community. Among its activities is providing matching funds for federal and private collaborative research projects, enabling industry access to a collection of university-based shared-user facilities, and furthering commercialization and new company formation.

It is envisioned that each Innovation Hub would receive one-time capital funding from the state to invest in equipment, pilot plants, and design labs in their specialty focus areas. In addition, operating funding

will be needed for a minimum of the first 5 years as the Hubs come on line and develop fee-for-service products and services. It is important to note that, even once fully operational, some level of public support will be needed to augment activities in particular for small and medium-sized enterprises (SMEs).

It is envisioned that the physical design of each Innovation Hub will be different depending on the needs of industry. While there may be a physical location created, depending on the current physical assets of partners, much of the work will be conducted through a virtual network. In addition, particularly as it relates to hands-on product development, skills training, and business creation efforts, different regions of the state may choose to make investments in regional locations to better serve key industrial drivers. This is highly encouraged as it allows for regional buy-in and local tailoring of programs to meet unique needs. However, it will be important to help ensure critical mass and density of activity that these regional efforts occur under the broader statewide efforts and are not duplicative nor competitive with the statewide initiatives.

Additional specificity for each Innovation Hub is provided in the following narrative.

NextGen Manufacturing and Materials Innovation Hub

Ohio needs to ensure that manufacturing firms, of all sizes, across the state are both using innovations that are redefining the sector and are also participating in growing supply chains around the production of new technologies. While the state has significant research strengths in a host of relevant technologies—including robotics, additive, new materials, and data analytics—these advancements are not yet being deployed into local supply chains as a rate that will impact Ohio’s overall economy.

The NextGen Manufacturing and Materials Innovation Hub should seek to leverage America Makes (see text box) and expand its efforts by doing the following:

- Addressing the complex, manufacturing-related technology transition challenges that arise between early-stage research and technology adoption.
- Undertaking market-scouting and deal-matching services to address the state’s gaps in awareness of supply chain relationships.
- Pursuing company-based product development efforts.
- Focusing on the commercialization of breakthrough innovative technologies.
- Leveraging NIST MEP to provide manufacturing by providing new product development and process improvement services to Ohio’s SMEs.

America Makes

First of now 14 manufacturing institutes that comprise the Manufacturing USA program, America Makes is the national accelerator for additive manufacturing and 3D printing and is involved in materials, material processing, and lightweighting.

America Makes developed a rigorous member-driven technology development road map process based on systems engineering principles to categorize and address the complex barriers hindering the use of additive manufacturing.

By end of 2016, America Makes had more than \$97 million in R&D projects either completed or underway that involved 180 unique engaged industry and academic organizations.

Deloitte, in its 2017 program evaluation of Manufacturing USA, identified that 9,424 relationships between organizations were established across 753 formal members of Institutes and others, totaling nearly 1,200 companies, academic institutions, nonprofits, and government agencies.

Key challenges that the NextGen Manufacturing and Materials Innovation Hub must address include accelerating the pace of innovation funding by industrial and research engines of the state; ensuring that the innovations are being deployed into the field, particularly by SMEs; and ensuring that training programs are well aligned with skill sets required, including applied knowledge of digital design tools, connected manufacturing environments, and 3D printer templates and systems. Lastly, the “maker” innovation environments that are currently producing some of the most exciting developments in this space fundamentally thrive on signature shared-use demonstration and prototyping facilities, so the state should explore options to establish additional facilities that can serve as natural innovation hubs in the next-generation manufacturing space in industry-intensive regions of Ohio that do not currently have these assets.

Future Health Innovation Hub

Ohio’s current excellence in healthcare and medical innovation is driven by the presence of major healthcare provider administrative and headquarters locations as well as signature university and private-research medical centers. While this allows the state to drive a significant volume of innovation efforts through these institutions, increased competition within sources of public dollars for bioscience R&D and the trend toward consolidation and acquisition in healthcare provider industries mean many of these entities can just as easily find themselves as competitors to one another rather than collaborators on a situational basis. Careful coordination and communication of the vision of an integrated healthcare system to stakeholders to achieve buy-in and consistent engagement is a critical element and requires the establishment of a Future Health Innovation Hub that serves as a consortium of healthcare innovation industry partners to keep collaborative networks active.

It is envisioned that, by leveraging significant investments by the Ohio Third Frontier, Ohio’s medical research institutions, the private sector through initiatives it has launched, as well as the efforts of BioOhio, the Innovation Hub will accomplish the following:

- Focus on a “clinical pull” model (see sidebar) in which an intimate understanding of unmet medical needs is the starting point and then the focus is on identifying collaborators to work on developing and advancing solutions to the problem.
- Leverage the network developed by BioOhio to ascertain the greatest interests/needs of the industrial/clinical base.
- Leverage existing efforts within the state to work with start-ups/emerging companies.
- Pursue company-based product development efforts.
- Focus on the commercialization of breakthrough innovative technologies.

Smart Infrastructure Innovation Hub

Smart infrastructure technologies are by their nature not designed to be a one-size-fits-all solution, so initiating an Innovation Hub principally requires coordination of a variety of ongoing and future initiatives under one organizational umbrella. The following efforts could be linked and augmented via a statewide Innovation Hub:

- Various smart city initiatives throughout the state.
- State transportation infrastructure upgrade initiatives.
- State utility and environmental infrastructure upgrade projects.
- Energy and utility provider innovation initiatives such as power-company pilot programs for smart metering and residential solar.
- Efforts to win public grants or build private funding for signature demonstration sites for unmanned systems, automated vehicles, advanced infrastructure materials, and wireless or sensing platforms.
- Regional transportation initiatives, primarily next-generation rail development.
- Major research projects being done at university centers of excellence, research labs, and shared-use facilities.
- Major R&D efforts at signature industry facilities or development efforts for establishment of new facilities by state industry partners.

Providing common regulatory guidance, device and communications interoperability standards, and pilot project funding via dedicated initiatives within the broader coordination effort can then help support a comprehensive rather than fragmented smart infrastructure environment and help mitigate administrative or systems integration barriers as the extent of innovation activity scales.

Consortia for Improving Medicine with Innovation and Technology (CIMIT)—Massachusetts

First of now 14 manufacturing institutes that comprise the Since 1998, CIMIT’s mission has been to foster collaboration among clinicians, technologists, and entrepreneurs to accelerate innovation and catalyze the discovery, development, and implementation of innovative healthcare technologies. It has a strong “clinical pull” model.

Results:

- 600 peer-reviewed and facilitated collaborative projects undertaken.
- 250 solutions developed.
- 78 of the solutions have had a commercial exit with 87 percent still in the market and 61 percent commercialized through a start-up, 20 percent licensed, and 19 percent developed with an industry collaborator who commercialized.

Proximity to advanced test facilities, demonstration sites, and transportation corridors is a critical driver of industry interest in this space and a key factor when making site location decisions for new and existing business operations. The state can help enhance the ability to attract and retain innovative companies through ensuring that connectivity and embedded sensing are being implemented consistently across the types of initiatives listed above as well as in zoning and construction standards to provide a widespread ability to collect data. The state can also help businesses mitigate the burden of managing data and connected assets by developing plans for a network of several dedicated data storage and command and control innovation facilities. These signature facilities can implement cost-sharing models with industry partners to provide ready access to large data integration capabilities and connectivity to a wide range of state and private assets delivering data, as well as hosting innovative development of command and control technologies that companies can leverage to develop solutions. A concerted internal and external marketing effort to brand the state as a test bed is also a key component of success in generating competitive advantage, and can emphasize high levels of access to “plug-and-play” infrastructure and facilities for industry to use, state projects generating large amounts of data that industry can access, open and transparent regulatory frameworks for smart technology, and favorable business conditions as key factors that appeal to industry.

Finally, the ability to create live-work-play environments attractive to millennials and other skilled talent is greatly improved by adoption of smart infrastructure projects that enhance modern living environments and advance the perception of the state as a thought leader. The impact of demonstrated investment in combination with branding and marketing of Ohio’s strengths in this area will have ripple effects through other segments of the economy in attracting a skilled labor force and increasing regional competitiveness.

It is envisioned that, by leveraging significant investments found across the state, the Innovation Hub will accomplish the following:

- Pursue federal and other research funding opportunities that support precompetitive research.
- Develop emerging technologies to solve industry needs and make available to institute members.
- Leverage investment in TRC to provide a testing and commercialization center able to test smart infrastructure technologies.
- Undertake market-scouting and deal-matching services to address the state’s gaps in awareness of supply chain relationships.
- Pursue company-based product development efforts.
- Focus on the commercialization of breakthrough innovative technologies.

New York Battery and Energy Storage Technology Consortium

The New York Battery and Energy Storage Technology Consortium (NY-BEST), created in 2010 by the New York State Energy Research and Development Authority (NYSERDA), has more than 150 members across a diverse community of manufacturers, academic institutions, utilities, technology and materials developers, engineering firms, systems integrators, and end users. Its Test and Commercialization Center offers testing for small single-cell batteries to larger megawatt battery systems, product development, performance validation, certification testing, environmental testing, battery lifetime testing, mobile in-field testing, and onsite product commissioning.

NY-BEST draws on the expertise of DNV GL, a global company with extensive energy advisory, testing, inspection, and certification expertise, to serve its 150 members. The \$23 million cost of the facility is supported by a public-private partnership, with \$5.3 million coming from NYSERDA, \$1 million from Empire State Development, and up to \$16 million from DNV GL. In addition, NY-BEST has partnered with the Rochester Institute of Technology to offer its members the Battery Prototyping Center, involving laboratory facilities for cell assembly and moisture-sensitive experiments. The center is another public-private partnership, with funding support from NYSERDA, Empire State Development, and SoLith, an engineering company for lithium-ion battery production automation.

Data Analytics Innovation Hub

Another key consideration is the ability for analytics innovations to meet applied industry needs that drive demonstrated short-term value in their business models. This means that, while supporting a core of scientific research in data sciences is key to driving the flow of new innovations to industry, complementary investment in R&D initiatives that harness those initial advances into applied research in specific industry verticals is a critical element to achieving long-term success. Creating a Data Analytics Innovation Hub that catalyzes applied research efforts and the deployment of those innovations in Ohio industries such as manufacturing, healthcare, financial services, consumer goods, and transportation can help engage industry interaction as well as accelerate the flow of analytics products and services that industry can more quickly integrate into its operations.

It is envisioned that, by leveraging significant investments found across the state, including leveraging the lessons learned at the Columbus Collaboratory, the Innovation Hub will accomplish the following:

- Advance increased networking and executive education for Ohio companies to better integrate data analytics into their businesses.
- Undertake market-scouting and deal-matching services to address the state's gaps in awareness of supply chain relationships.
- Pursue company-based product development efforts.
- Leverage the analytic assets of the state, including the Ohio Super Computer Center.
- Focus on the commercialization of breakthrough innovative technologies.

North Carolina's Renaissance Computing Institute (RENCI)

Since 2004, RENCI has worked to stimulate long-term investments that will help position North Carolina as a major force in advancing data science research and education. RENCI develops and deploys data science cyberinfrastructure that helps researchers in academia, government, and business use data to drive discoveries, innovate, make informed decisions, and spur economic development.

Action 2: Review and update Ohio tax code to create additional ways to incent Ohio companies to invest in new products and process improvements.

While Ohio has overhauled its tax code in recent years, resulting in a number of provisions that encourage capital investments, R&D spending, and other incentives that foster innovation, it will be important for Ohio to conduct a review of the tax code in light of the proposed innovation opportunity platforms to find additional ways to incent Ohio companies to invest in new products and process improvements. All state tax codes represent a state's history. Ensuring that a state's tax structure is built for future industries requires a concerted effort of reviewing such issues as sales and use tax treatment of R&D, supplies, and laboratory equipment; exemptions regarding personal and real estate; corporate and other tax code provisions regarding treatment of equity; and the salability and transferability of tax credits by young firms with limited tax liabilities. Below are just a few of the ideas that could be incorporated as Ohio builds a more innovation-driven economy:

- Increase level of R&D credit for companies within the four innovation platforms and expand definition of research to be more encompassing of digital transformation product and process improvements.
- Emphasize R&D Sales Tax Exemption for those technologies that are tied to digital transformation innovations and suggest local taxing authorities provide exemption as well.
- Make greater use of New Markets Tax Credit to invest in companies within the four innovation platforms that locate in rural or distressed areas.
- Expand Ohio's Job-Creation Tax Credit program to use payroll, in addition to the number of jobs created, as a trigger measure.
- Develop financial incentives for companies that support skills-building investments for their mid-career workforces that can accelerate the process of transitioning existing workers toward new skills sets more aligned with innovation needs.
- Increase the level of funding available for the JobsOhio R&D grant program and focus targeted efforts on companies within the four innovation platforms.
- Tie international trade mission efforts to attracting new investments to the state related to the four innovation technology platforms.
- Develop a dedicated funding stream to enable rural communities to develop sites to pursue attraction and expansion opportunities within the four innovation platforms.

Currently, both tax incentives and the state's economic development tool kit tend to focus on fixed-asset financing and may need to be adjusted to address other forms of capital formation; provide incentives to encourage firms to develop, design, and use technology in their businesses; and encourage collaboration with other firms and higher education institutions. A comprehensive overall review would catalyze the continued modernization of Ohio's tax code to focus on catalyzing innovation across Ohio's industrial base.

Strategy 2: Further Elevate the Entrepreneurial/Risk Capital Ecosystem to Drive Future Economic Growth

Rationale

The economic vitality of Ohio depends upon its capacity to foster the formation of new entrepreneurial-led businesses and sustain their growth as they scale up and generate new, high-paying jobs in their communities. Dating back to the late 1970s and the work of David Birch at the Massachusetts Institute of Technology (MIT), it is well understood that entrepreneurial development is critically important to overall job growth in the economy. In his groundbreaking 1979 report, *The Job Generation Process*, Birch used longitudinal data compiled from Dun & Bradstreet establishment credit reports to uncover that 60 percent of all jobs in the United States were generated by firms with 20 or fewer employees. But, Birch pointed out that not all small firms were job generators. Instead, it was the smaller, younger establishments under 4 years of age, led by independent entrepreneurs, and not new establishments from existing corporations, that created most of the jobs. In fact, most of the job growth of young firms occurs within a relatively small number of firms—the Gazelles.¹⁷

Birch's early findings have been largely confirmed by more recent studies. One of the more recent and widely cited studies, led by John Haltiwanger from the University of Maryland and Ryan Decker now at the Federal Reserve, examined the 1980–2010 period using comprehensive business databases maintained by U.S. Census that encompass all firms in the private, nonagricultural sector with at least one employee. The study found the following:¹⁸

- Annual job creation by new firms started each year averaged 2.9 million jobs annually from 1980–2010, well exceeding the overall net job creation of 1.4 million jobs per year from existing businesses.
- Since some existing firms grow while others decline or fail, it is misleading to imply that all net job creation is due to start-ups. Overall new firm employment averages one in six of the 16.3 million gross new jobs created annually between 1980 and 2010. Still, without the job growth from new firm start-ups, overall employment from the base of existing businesses would have declined by 1.5 million on average each year from 1980–2010.
- Most importantly, this updated study confirmed Birch's finding that a small cohort of largely younger firms (Gazelles) stand out as high-growth businesses and accounted for an average of 50 percent of new jobs created each year between 1980 and 2010.

As the Decker/Haltiwanger study summarizes:

¹⁷ Findings from David Birch are summarized in Richard Greene, "Tracking Job Growth in Private Industry," *Monthly Labor Review*, September 1982; and Hans Landstrom, "David L. Birch's Contributions to Entrepreneurship and Small Business Research," 1996 Award Winner, *Global Award for Entrepreneurial Research*.

¹⁸ Decker, Haltiwanger, et al., "The Role of Entrepreneurship in U.S. Job Creation and Economic Dynamism," *Journal of Economic Perspectives*, Volume 28, Number 3, Summer 2014, pages 3–24.

The contribution of startups and young businesses to job creation involves rich dynamics. Most business startups exit within their first ten years, and most surviving young businesses do not grow but remain small. However, a small fraction of young firms exhibit very high growth and contribute substantially to job creation.¹⁹

For a new start-up to realize significant growth, it typically needs to focus on serving customers and markets that go beyond the local residents and businesses in its community—or what is termed “traded-sector” activities. Traded sectors are the drivers of economic growth. Traded sectors include industries and employers that produce goods and services that are consumed outside the region where they are made, thereby bringing new income from beyond local residents into regions of Ohio.

In contrast, business activities that are not involved in traded-sector activities typically focus on meeting the local needs of local families and businesses and do not bring new income into a region—these are often referred to as “sheltered” industries. Examples of sheltered industries include restaurants, retail stores, dry cleaners, and state and local government services. While these sheltered industries are critical to the quality of life in Ohio, they rely on purchases from local residents and businesses as their primary market, and so they do not generate new income but instead benefit from a growing economy.

On average, while both local and traded sectors include large and small, young and old, and high- and low-wage firms, historically, the traded sector differs from the local sector in several important ways:

- The amount of output (or value-added of the product or service being produced) per job is higher in traded-sector industries, thereby driving economic growth in a region; and
- Workers in the traded sector tend to be better educated and earn higher average wages, thereby increasing per capita income in a region.

The work of Birch and others reinforces the key point that, while most entrepreneurs start by forming small businesses, not all small businesses are entrepreneurial. The needs of small businesses and entrepreneurs may be similar at first during the start-up phase, but they quickly diverge. Small business owners create companies to generate wealth and provide employment and income for themselves and potentially a few others; entrepreneurs are interested in creating new products or services that lead to further investment and growth. Most small businesses serve a local or small regional market, whereas entrepreneurial companies often are focused on traded sectors serving the national and global marketplace. As a result, the growth of a region depends upon having new businesses that are focused on traded-sector activities to bring new income and economic activity into a region that can grow the overall economy and not just recycle existing income found in the region.

The bottom line is that entrepreneurially led start-ups targeted on traded-sector activities are needed in every region of Ohio to sustain economic growth. A report prepared for the Office of Advocacy of the Small Business Administration (SBA) found that regions with significant entrepreneurial dynamism experienced greater economic prosperity

¹⁹ *Ibid.*, page 4.

compared with regions that did not. “They had 125 percent higher employment growth, 58 percent higher wage growth and 109 percent higher productivity.”²⁰ As a result, states and regions that recognize the benefits of entrepreneurship and the role it plays in today’s knowledge-based economy are developing policies and programs to establish an environment that creates, attracts, and retains entrepreneurs, and an infrastructure to support them.

Ohio’s Current Situation

Ohio has long recognized the importance of catalyzing entrepreneurial development. From the creation of the initial Edison Incubators in the 1980s to the significant investments by the Ohio Third Frontier in the six regional ESPs in 2006, as well as numerous early-stage risk capital initiatives over this same time period, Ohio has invested significantly in efforts to catalyze entrepreneurial dynamism within traded sectors advanced by cutting-edge innovation. While each of these individual programmatic initiatives have obtained significant returns on investment, the overall macro entrepreneurship “needle” isn’t moving at the anticipated pace.

When Ohio’s rate of entrepreneurial churn is compared with the benchmark states and the nation, it is discovered that Ohio ranks last in new firm formation and in middle in share of employment in young firms, behind U.S. levels in both measures (Figure 19). Among the benchmark states, Ohio ranks fourth on the Inc. 5000 list of fastest-growing companies, 2014–2016.

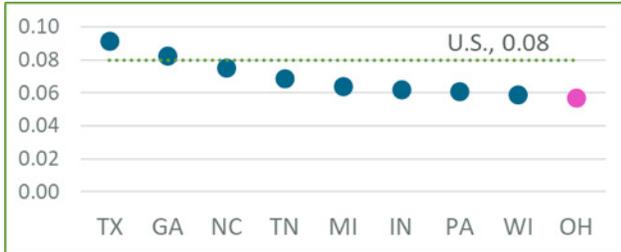
Entrepreneurs

- Advance innovative ideas that serve unmet market needs into new high-growth potential companies
- Focus on traded sectors serving the national and global marketplace
- Create dynamic and flexible new industries and firms to replace those that are no longer viable in a rapidly changing global economy
- Provide most new employment opportunities, especially in high-paying jobs
- Create wealth that is reinvested in new enterprises and, through demonstrated philanthropic activity, in communities.

²⁰ *The Innovation-Entrepreneurship NEXUS: A National Assessment of Entrepreneurship and Regional Economic Growth and Development.* Powell, Ohio: Advanced Research Technologies, LLC, April 2005, page 2.

Figure 19. Ohio's Entrepreneurial Churn

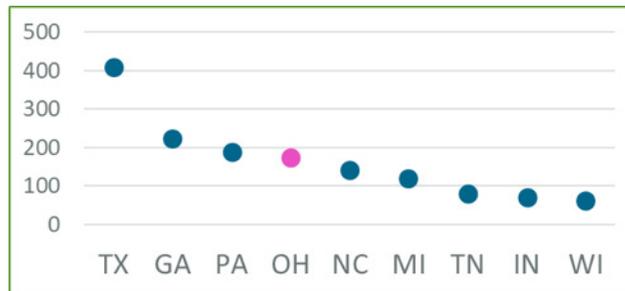
Rate of New Firm Formation as a Percent of All Firms, 2014



Avg. Number of Companies on the Inc. 5000 List of Fastest-Growing Companies, 2014–2016



Share of Employment in Firms Ages 0–5 Years Old, 2014

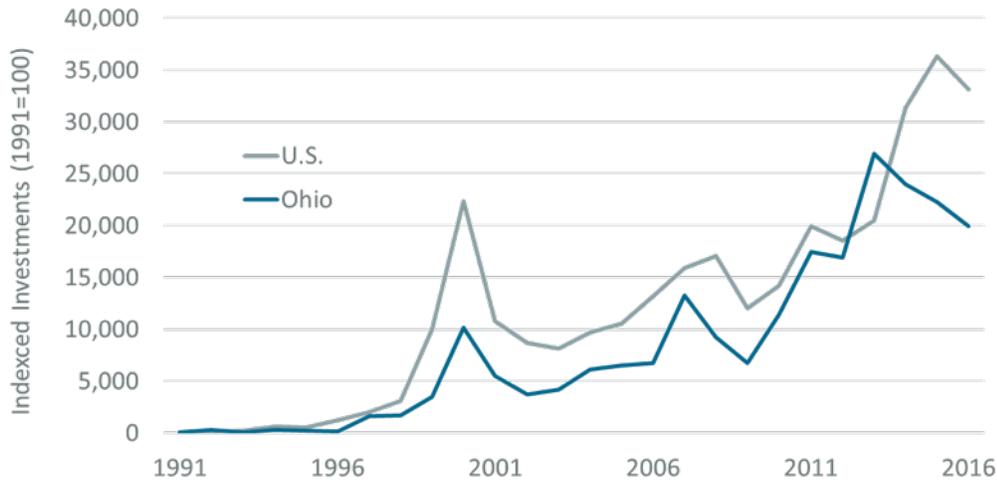


Sources: U.S. Census Bureau, Business Dynamics Statistics (BDS). The BDS data are compiled from the Longitudinal Business Database (LBD) a longitudinal database of business establishments and firms covering the years between 1976 and 2014.

Inc. 5000 Website (www.inc.com/inc5000). Ewing Marion Kauffman Foundation. TEconomy calculations.

A further concern is raised regarding Ohio's ability to scale innovative, traded-sector, entrepreneurial firms when the level of risk capital deployed across the state is examined. As illustrated in Figure 20, Ohio has lagged behind growth in U.S. investments since 1991, with the gap widening since 2013.

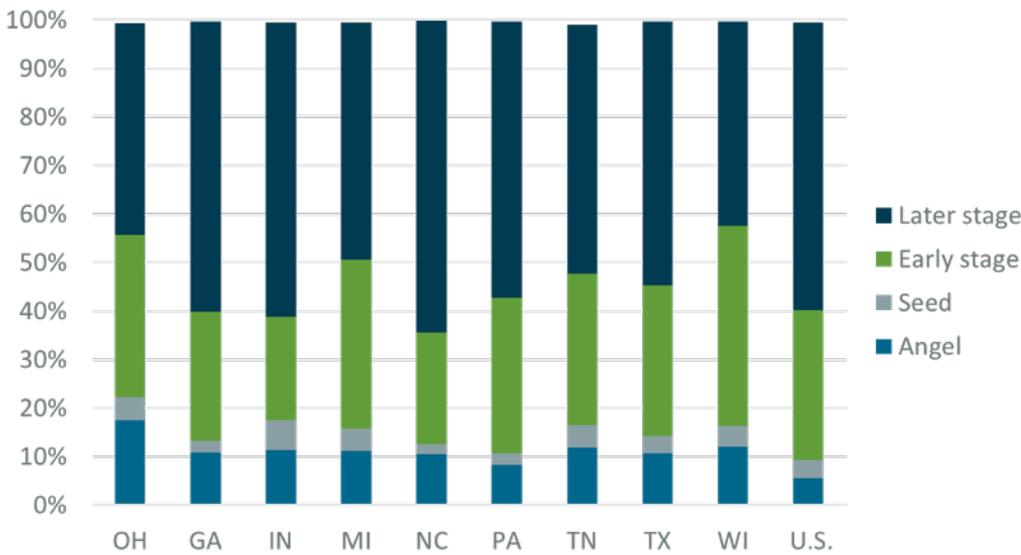
Figure 20. Indexed Venture Investments for Ohio and the United States, 1991–2016 (1991=100)



Source: TEconomy’s analysis of PitchBook venture investment database.

Interestingly, when risk capital is segmented by stage of deal, Ohio ranks comparatively low in later-stage investments but among the top in angel, early, and seed investments, providing evidence that the investments made in catalyzing early-stage capital by the Ohio Third Frontier have been effectual (Figure 21). However, while it is widely understood that the national risk capital markets have moved significantly downstream since the global recession, these statistics provide evidence of a growing concern that the level of later-stage risk capital that can scale a company is simply not being raised in nor attracted to Ohio at the level that Ohio’s deal flow would appear to demand.

Figure 21. Total Venture Investments by Stage for Ohio, the United States, and the Benchmark States, 2010–2016



Source: TEconomy’s analysis of PitchBook venture investment database

As Ohio seeks to further elevate the entrepreneurial/risk capital ecosystem to drive future economic growth, it will be important that programs/initiatives seek to do the following:

- **Advance entrepreneurial dynamism within the four innovation opportunity platforms;**
- **Connect increased deal flow due to seed capital with a critical mass of Series A and B funds; and**
- **Foster a more robust culture of entrepreneurship throughout the State of Ohio, building off of the success found in several regions of Ohio.**

The following recommendations seek to obtain these goals.

Strategic Recommendations

Action 3: Continue to invest in the regional Entrepreneurial Signature Programs (ESPs) and expand their role to ensure that innovation opportunities generated by the four Innovation Hubs are scaled in Ohio.

Entrepreneurial activity is critically important to statewide economic development because it drives industrial innovation and new business formation. Almost by definition, the founders of start-up companies are innovators—focused on capitalizing on commercial opportunities arising from introducing a new product; enhancing a service; and/or making a delivery system or production process more efficient, more user friendly, or less expensive. It is, therefore, not surprising that entrepreneurial activity and innovation are strongly correlated.

However, with a few notable exceptions such as Boston and Silicon Valley, the entrepreneurial climate necessary to generate high-growth enterprises has not developed fully and sustainably through market forces alone. Building a critical mass of entrepreneurial management talent in a locality depends on providing the resources that must be amassed, and the services needed to successfully scale a company.

To ensure the greatest chance of success, entrepreneurs must have access to a comprehensive continuum of programs as they progress through the stages necessary to establish a thriving enterprise. Technology entrepreneurs value the following support services:

- Business mentoring by successful serial entrepreneurial managers who have been involved in similar businesses and business models;
- In-depth counseling and advice to prepare the entrepreneur to present investment-grade plans to angel and other informal investors; and
- Assistance with forming a business team of managers to assist with market research, technical evaluations, regulatory issues, etc.

Recognizing this need, the Ohio Third Frontier has invested in six Entrepreneurial Signature Programs (ESPs) to provide at a regional level advanced entrepreneurial business services to Ohio's most promising innovative companies. **The continued investment in the regional ESPs will be critical to advancing an innovation strategy.** A fundamental

mission of the ESPs is to provide value-added entrepreneurial support services to innovative firms. While the individual mission of each organization has morphed to meet the needs of its regional community, this core mission of providing comprehensive business mentoring and access to C-suite talent will be critical to driving further innovation in the state through entrepreneurial efforts.

Additional ideas to expand the current role of the ESPs under this innovation strategy include the following:

- **Leverage the ESP infrastructure to support the efforts of the four Innovation Hubs.** The entrepreneurial expertise found within the ESPs should be leveraged to support the business creation/scale-up of emerging companies that are commercialized as a result of the activities of the four Innovation Hubs. It will be important that programs/services are not created within these Hubs that duplicate programmatic initiatives already in existence.
- **Link emerging companies to Ohio's anchor industries as first customers.** A key component of the Innovation Hubs will be the ideation of innovative solutions to meet Ohio's industrial needs. As these ideation sessions result in businesses being created to produce new products and processes that solve these problems, it will be critical for Ohio's anchor industries to serve as first customers and early adopters so that the innovations can be deployed into the field to prove their efficacy. By linking emerging companies to Ohio's industry anchors, start-ups firms will be able to firmly establish their roots in Ohio as they grow and scale at a more rapid pace.
- **Create a Serial Entrepreneur Attraction Program.** While significant strides have been made over the past decade to develop the entrepreneurial talent in Ohio, there are still not enough C-level suite managers to drive the growth of Ohio's entrepreneurial pipeline. As the four Innovation Hubs create additional deal flow in specific areas of innovation, it will be critical to be able to attract talent from outside the state to support these opportunities. Ohio should seek to attract serial entrepreneurs to the state by offering personal income tax and/or investment incentives. By working to de-risk the perceived costs of relocating to the state, Ohio will catalyze the number of serial entrepreneurs who will accept employment in critical leadership positions of its most promising emerging companies.
- **Focus additional efforts around culture-building activities.** While significant progress has been made in creating a supportive entrepreneurial culture in pockets around the state, more needs to be done to create an entrepreneurial culture across the state. By leveraging the network of ESP partners in each region, more can be done to stimulate entrepreneurial networking, hold meet-up events, and promote success stories so that entrepreneurship is more widely embraced in every region of the state.

Action 4: Continue to foster the creation of early-stage risk capital by focusing additional efforts on funding the creation of emerging firms from the four innovation platforms.

States and regions with thriving entrepreneurial sectors share one characteristic—they are home to a risk capital community that is both oriented toward early-stage financing and committed to indigenous investment. Emerging trends in innovation capital are making it even more imperative to have indigenous funds for the growth of innovative firms. These indigenous funds help to identify promising discoveries and technology advances, provide the initial funding to validate these opportunities, support the formation of new ventures, and provide the on-the-ground capacity to support these new ventures and facilitate their connection to outside venture capital.

The analysis clearly shows that Ohio, through its support of the Ohio Third Frontier Pre-Seed and Seed funding initiatives, has made significant investments to meet the needs of early-stage funding for its most promising innovative firms. However, as deal flow continues to increase as a result of investments in this innovation strategy, Ohio should continue to catalyze early-stage risk capital by doing the following:

- **Creating pre-seed/seed/seed-plus funds specifically focused on the four innovation opportunity platforms.** Having dedicated funds that understand the technology and market opportunities of the four innovation platforms will be critical to support new product development. This is particularly true for the platforms that typically do not attract traditional forms of risk capital since the return is not always seen as significant enough. It will be critical for Ohio to stimulate investment in these nontraditional risk capital sectors to support emerging ideas that can be transformative for Ohio's industrial base.
- **Reinstating the Technology Investment Tax Credit.** Ohio had a successful tax credit program that catalyzed the investment of angel funding across the state. While some argued that these investments would have been made without the incentive, that thinking is short sighted. Risk capital investments do not know artificial geographic boundaries and can flow anywhere there are good ideas. By working to de-risk Ohio investments by providing a tax credit, the state is able to incent those dollars to remain in the state. Ohio should reinstate the Technology Investment Tax Credit to stimulate further early-stage investment in Ohio's emerging pipeline of deal flow, particularly focused around the four innovation platforms.
- **Creating an SBIR/STTR Phase III funding program.** As a source of early-stage risk capital that is nondilutive, the federal government's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, also known as America's Seed Fund, are one of the largest sources of early-stage capital for technology commercialization in the United States. The federal government provides grants to determine the feasibility of a technology (Phase I) and will then fund additional R&D to determine the commercial potential of a technology (Phase II), but will not provide funding to commercialize the technology so that it can enter the marketplace (Phase III). Ohio should create a Phase III funding program to support successful Phase II grantees in their efforts to commercialize their technologies.

- **Providing nondisputable clarification of Ohio law to allow for public universities and entrepreneurial service/risk capital grantees to take equity positions.** Differing views still exist on whether public universities and the entrepreneurial ecosystem partners can take equity positions in companies. This uncertainty is an unnecessary barrier that is limiting (or at least is perceived by some to be limiting) the ability to invest in Ohio's most promising emerging opportunities. Even if this perceived prohibition can be circumvented through the creation of other legal entities, setting up work-arounds takes time and energy, which is harmful to Ohio's entrepreneurial culture. Therefore, to settle all ambiguity so that there can be no further interpretation of the law, the state should provide nondisputable clarification to allow for public universities and entrepreneurial service/risk capital grantees to take equity positions.

Action 5: Stimulate creation/attraction of later-stage risk capital financing to ensure emerging opportunities are able to grow and scale in Ohio.

The realignment of national markets since the global recession has shifted capital markets downstream, leaving many Ohio companies without access to later-stage investments. If this investment climate is not corrected, Ohio's most promising companies are in danger of leaving the state in pursuit of capital.

States that have limited risk capital in which to invest in later stage venture capital rounds end up leaving their entrepreneurial companies on the "runway" unable to take off and reach their growth potential. States wishing to grow entrepreneurial companies have used a variety of mechanisms to encourage investment in venture capital at the later stages.

For this national problem to be solved in **Ohio, the state should create a state-sponsored and/or supported equity investment fund to create/attract Series A and B funds to Ohio (through a fund-of-funds (FoF) co-investment model) by engaging corporations, foundations and other major investors as limited partners (LPs).** Through an FoF model, investments are made in a portfolio of venture funds with the assistance of a general fund manager, who helps select those venture funds best suited for the state. The FoF approach mobilizes venture capital investors who are willing to consider investing in emerging companies located in the state.

To complement its current focus on early-stage innovation capital, it is recommended that Ohio help ensure access to follow-on venture funding by capitalizing an FoF model with strong ties to Ohio institutional investors and corporate LPs. Consideration should be given to ensuring that the fund is return driven and has guidelines in place to help ensure that capital partners have a meaningful local presence. It will also be important to consider the mixture of mid-sized versus larger-sized funds to catalyze the development of indigenous early-stage capital and leverage the relationship that regionally based funds have with the entrepreneurs, the angel investment community, and the research institutions.

As part of this effort, **Ohio should also create a Venture Capital Managerial Attraction Program.** Similar to its need for serial entrepreneurs, Ohio is also in need of serial investors. One of the entrepreneurial talent development programs that Michigan has invested in is the Executive Attraction Program managed by the Michigan Venture Capital Association

(MCVA). The Executive Attraction Program was designed to increase the number of venture-backed executives in Michigan. The program provided assistance with recruiting and first-year salary expenses associated with hiring exceptional talent at qualified MVCA member portfolio companies, with the goal of increasing the number of successful portfolio companies in the state. It is recommended that Ohio invest in a similar program to increase the investment talent in the state.

What Others Do: Models for Fund of Funds

Colorado Venture Capital Authority (VCA). The VCA was established in 2004 to make seed- and early-stage capital investments in businesses. The VCA was allocated \$50 million in premium tax credits, which it subsequently sold to insurance companies. The VCA selected fund manager High Country Venture, LLC, and established Colorado Funds I and II, each with nearly \$25 million. The minimum and maximum investment size generally ranges from \$250,000 to \$3.375 million. As of February 2015, 31 emerging companies received investments across the two funds of nearly \$46 million, leading to the creation of over 1,200 jobs.

Utah Capital Investment. Formerly known as the Utah Fund of Funds, this venture capital initiative is a \$300-million State of Utah economic-development program aimed at providing access to alternative or nontraditional capital for Utah entrepreneurs. Utah Capital Investment invests in venture-capital and private-equity funds that commit to establishing a working relationship with Utah's start-up and business community and to making investments in qualifying companies. A number of venture capital funds targeting life sciences have received funding, including 5AM, Frazier Healthcare Ventures, NEA, SV Life Sciences, TriVentures, and UpStart Ventures. To date, \$785 million have been invested in 73 Utah companies by Utah capital portfolio funds since fund inception, of which 60 remain in operation, and 4,069 new Utah jobs have been added.

New PA Venture Capital Investment Program. Authorized \$60 million as loans to venture capital companies seeking to invest in Pennsylvania firms. The New PA Venture Guarantee Program authorized up to \$250 million of guarantees on the first losses of equity investments made in Pennsylvania companies by qualified venture-capital firms to be matched 1:1 with additional investments.

The Maryland Venture Fund—InvestMaryland. Through an auction of premium tax credits to insurance companies, the State of Maryland raised \$84 million to invest in qualified private-venture funds to further catalyze the state's local venture-capital community. Those funded have committed to invest in emerging technology companies in Maryland in the areas of life sciences, software, communications, and cybersecurity, with the goal of investing in 150 or more companies and generating 5,000 jobs created or retained.

Finally, **Ohio should create venture debt funds to provide nondilutive working capital (growth capital).** The funding should be targeted at both high-growth companies that are in need of additional financing between venture rounds as well as companies that do not meet the traditional investment profile for venture capital but represent promising opportunities within the four innovation platforms. The creation of a venture debt fund could be accomplished by the following:

- Expanding the existing JobsOhio R&D Loan Fund and allowing loans to be utilized for operating expenditures;
- Leveraging the newly created federal opportunity zones incentive program that allows for significant flexibility to encourage long-term investments in struggling communities; and/or
- Leveraging the Ohio-based federal SBA loan programs to catalyze private banking efforts in the area.

Strategy 3: Develop, Retain, and Attract the Talent that Ohio's Industry Demands

Rationale

In a global economy where jobs are outsourced from one continent to another, it is appropriate to ask whether workforce is a relevant competitive factor. Is labor a commodity, and thus unable to create a significant competitive differentiation or advantage; or can it be unique to a firm, region, or state like location or intellectual property, and confer a significant competitive advantage?

Talent can and must be an essential part of any strategy to create a competitive advantage. If a firm does not use its workforce as anything more than a low-skill, low-wage, and high-turnover commodity, then it will not generate or retain any type of enduring market advantage in a marketplace that is increasingly emphasizing the use of high-tech tools that add value for suppliers and end customers. So, how does human capital factor into a state's comparative advantage?

Simply put, human capital is one of the few market factors that are locally based and have the potential to create a comparative advantage that can differentiate a state, region, or firm from its competition. A state cannot change its physical location, so its location advantages are fixed. Firms can purchase new and emerging technology; but, if these are "off-the-shelf" technologies, then they are available to the competition. In contrast, human capital is a locally provided and locally managed resource, thus able to be differentiated from other regions. In addition, human capital is an essential element in implementing advanced technology solutions. The quantity, quality, and management of human capital are competitive factors very much in local control.

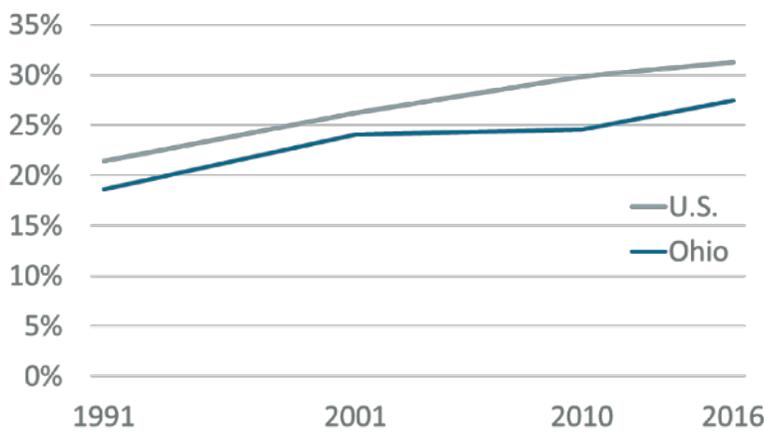
Unfortunately, in many states, human capital that meets the needs of many in its industrial base is lacking. This lack of human capital in part is driven by the lack of understanding and preparation for the jobs that are available. The historical approaches to worker training allow for minimal input into how skills are further developed and used in the workplace. Improving the effectiveness of the workforce development system requires adopting a demand-side strategy that builds on employers' needs.

Ohio's Current Situation

While it is difficult to ascertain the workforce readiness of any state because the needs of industry vary so significantly, when Ohio is compared with the nation and benchmark states across a few key innovative workforce metrics, it is quickly recognized that the state is not keeping pace.

For example, as Figure 22 illustrates, Ohio's 4-year graduation rate has not kept pace with that of the benchmarks or the United States, ranking Ohio below the nation and near the bottom of the benchmark states.

Figure 22. Percent with Bachelor's Degree or Higher in Ohio, the United States, and the Benchmark States, 1991-2016

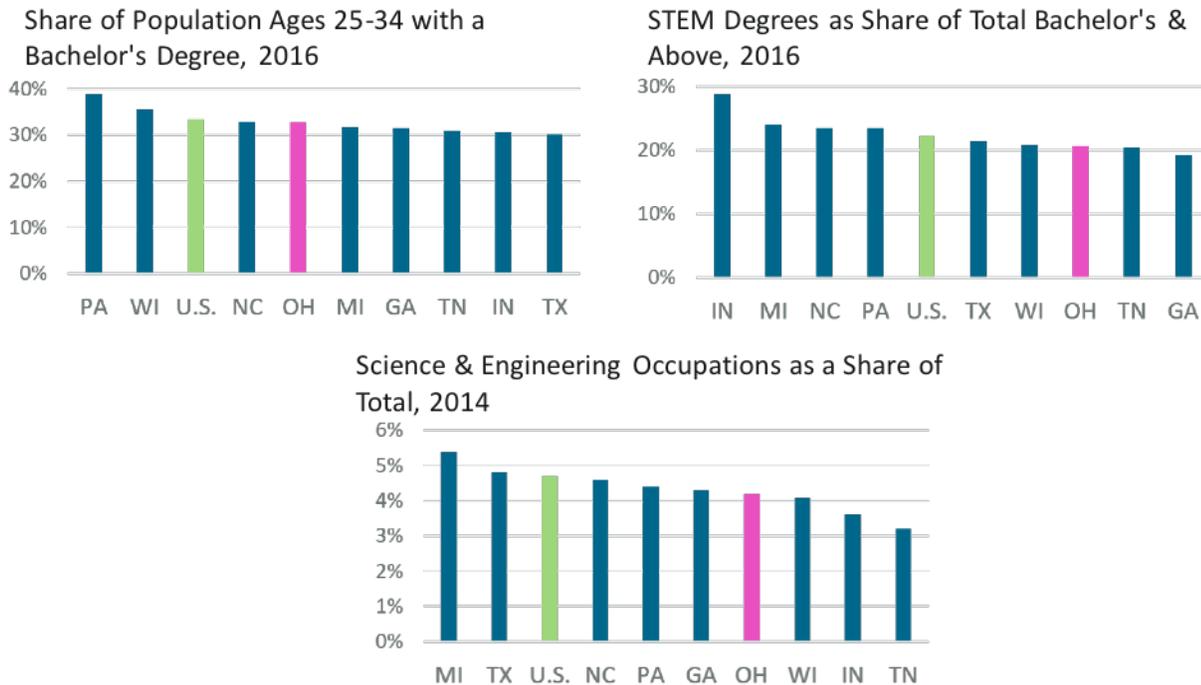


	% Bachelor's Degree or More	Change 1991 to 2016	Rank Change Since 1991
PA	30.8	12.4	6
GA	30.5	9.6	-
NC	30.4	11.9	3
WI	29.5	9.0	-1
TX	28.9	7.8	-4
MI	28.3	10.8	2
OH	27.5	8.9	-2
TN	26.1	7.3	-4
IN	25.6	10.9	0
US	31.3%	9.9%	n/a

Note: "College graduates" refers to those who have completed a Bachelor's degree or higher
 Sources: U.S. Bureau of the Census, Current Population Survey (1991 and 2001) and American Communities Survey (2010 and 2016)

Furthermore, while Ohio ranks behind the nation but in the middle of the benchmark states in terms of the share of its population that is college educated, Ohio ranks toward the bottom in STEM degrees and science and engineering occupations—key drivers of innovation (Figure 23).

Figure 23. Population Ages 25–34 with a Bachelor’s Degree, and STEM Degrees as Share of Total Bachelor’s Degrees or Higher, 2016; and Science and Engineering Occupations as a Share of Total, 2014; for Ohio, the United States, and the Benchmark States



Sources: National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS). U.S. Census Bureau, American Community Survey. National Science Foundation (NSF), Science & Engineering Indicators 2016 (for S&E Occupational Employment), derived from Bureau of Labor Statistics, Occupational Employment Statistics data. TEconomy calculations.

In interviews conducted around the state with key industrial thought leaders, concern was expressed regarding the following:

- Lack of manufacturing/skilled labor talent and the fact that most skill development programs do not place a great enough emphasis on experiential learning.
- Lack of data analytics/IT talent and the fact that most talent development programs are outdated and focused on theoretical knowledge instead of applied skills. This is further exacerbated by a lack of skill development focus at the K–12 level.
- Inability to retain top talent—brain drain is of significant concern.
- Difficulty in attracting top talent to the state.

Ohio must be able to develop, retain, and attract the talent that Ohio’s industry demands to ensure its economic drivers remain globally competitive and new industries can grow and scale. The following recommendations seek to obtain these goals.

Strategic Recommendations

The efforts, programs, and initiatives that are ongoing across the State of Ohio to address educational training, workforce development, retraining of incumbent workers, and life-long learning are overwhelming in their size and scope. It is not possible in this report to begin to address all of the shortcomings and challenges presented by the current system. Instead, the recommendations focus on near-term opportunities that leverage other recommended investments to have the most immediate impact on meeting industry's demand for an innovative workforce, particularly as it relates to data analytics and advanced manufacturing innovations—the greatest need expressed by industry.

Action 6: Encompass significant talent development efforts into the Data Analytics Innovation Hub.

Key Ohio industry sectors are currently in the midst of a significant transition to data-driven business intelligence products and services, and each one is at different stages of maturity in integrating analytics tools into their operations. As capital costs for deploying data analytics technologies continue to fall, the differentiating driver of innovative activity will revolve around the ability to build and maintain excellence in skilled data analytics talent bases.

As a result, the Data Analytics Innovation Hub must be focused in part on supporting the human capital that will drive the adoption of innovative processes and products. These talent bases have several segments that are all important to the overall function of analytics-focused innovation ecosystems, both within individual businesses as well as across broader industries that will become users and consumers of analytics tools. These segments of skilled talent in analytics, each of which having different strategies for growth and responding to different incentives, include the following:

- Executive management at companies implementing or creating analytics solutions that embrace the disruptive nature of data-driven technologies, understand the core concepts behind data science, and are thought leaders in one or more fields of applied analytics. Business environments without some critical mass of these leaders can struggle to transition toward data-driven environments and run the risk of underutilizing new technologies, leaving more concentrated, enterprise style business models at risk of disruption by competitive ecosystems in other regions of the country. Since these thought leaders are relatively rare, retaining and engaging these types of skilled executives in advisory roles is critical in conjunction with establishing industry networks for company management built around knowledge sharing and education in data analytics. As a result, one key goal of the Data Analytics Innovation Hub should be to develop professional networks where executive management can gain knowledge about implementing analytics solutions that drive innovation in their firms.
- Mid-career workers who have applied knowledge of legacy analytics tools and business models but have embraced the continual learning environment of data sciences and developed upgraded skill sets. This segment of a skilled data analytics workforce is critical to bridging the gap between industry's current position and future analytics-driven business ecosystems and requires investments to drive retraining and skills building. As a result, another key goal of the Data Analytics Innovation Hub should be to develop training/skill retraining programs to meet the mid-career needs of data analytics professionals. Financial incentive initiatives for companies who support skills-building investments for their mid-career workforces can prompt higher levels of reinvestment and

accelerate the process of transitioning existing workers toward new skills sets more aligned with data analytics innovation needs.

- New graduates from data analytics–related programs at research or technical institutions who have technical experience in focused industry applications areas. Employers seeking to recruit or integrate new analytics talent into their operations as a part of transitioning to new business models can find that degree programs lack applied knowledge about the specific challenges and business operations of specific industries. Initiatives to better connect industry needs in data analytics to academic programs at research and technical institutions are necessary to align applied knowledge requirements with educational experiences. As a result, another key goal of the Data Analytics Innovation Hub should be to develop the connections between industry and academia to help design specific data analytics programs to ensure that the needs of Ohio industry are met. This often includes using industry advisors to help guide curriculum requirements and integrating applied educational experiences into programs such as industry-led capstone projects and technical certification training in specific data science tools or methodologies. It could also include the creation of a Summer Institute for Data Analytics for rising college juniors to provide them with a unique experiential learning experience as well as the establishment of a statewide Data Analytics Internship/Co-Op Program.

To guarantee diversity and inclusiveness of these efforts to ensure that students across the State of Ohio participate, it will be critical to establish metric goals for minority and geographic (rural) participation in all of these talent programs.

The results of this concentrated talent pipeline development by the Data Analytics Innovation Hub should then be leveraged to create a brand for Ohio as the place for advancing careers in data analytics built around major Ohio companies. This will in turn serve as a strong attraction mechanism for companies involved in advancing innovation in data analytics as the lack of alignment between supply and demand of skilled workers is an issue found across the nation, and solving the problem in Ohio can serve as a strong competitive advantage for the state.

While it is envisioned that the Data Analytics Innovation Hub will have a strong workforce development component, it will also be critical to support these efforts with a comprehensive state focus on upgrading data analytics skilled talent pools. This will require the following:

- Leveraging the coordinating power of Office of Workforce Transformation and utilizing federal funds allocated by the Ohio Department of Job and Family Services (ODJFS) and the Ohio Department of Higher Education (ODHE), create funding mechanisms for the talent programs of the Innovation Hub as well as company-specific training programs. This will require that the Office of Workforce Transformation be charged to work with the Auditor’s office to update the 2013 audit of Ohio’s workforce programs to determine what workforce dollars can be directed to data analytics training needs.
- Expanding career center/vocational training offerings to encompass additional digital analytics/IT training and clearly articulate career pathways to students, parents, and career guidance counselors.

- Incorporating data analytics into K–12 educational requirements to ensure that the skill sets required for all industries of the future are embedded into Ohio’s core educational offerings.

Action 7: Encompass significant talent development efforts into the NextGen Manufacturing and Materials Innovation Hub.

Similar to the Data Analytics Innovation Hub talent efforts, it is envisioned that the NextGen Manufacturing and Materials Innovation Hub will be a significant provider of technical training and retraining efforts of new and incumbent workers based on the demands of industry. Leveraging the coordinating power of the Office of Workforce Transformation and utilizing federal funds allocated by ODJFS and ODHE, it is envisioned that a funding mechanism can be created to fund the talent programs of the Innovation Hub as well as company-specific training programs. This will require that the Office of Workforce Transformation be charged to work with the Auditor’s office to update the 2013 audit of Ohio’s workforce programs to determine what workforce dollars can be directed to specific innovation-based manufacturing training programs.

It is envisioned as part of the Innovation Hub that a collaborative training facility, similar to the Alabama Robotics Technology Park (see side bar), will ultimately be created that aggregates industry demand for advanced skills training and provides hands-on learning. This will be done in partnership with Ohio’s community colleges, career technical centers, and other service providers. To guarantee diversity and inclusiveness of these efforts to ensure that students across the State of Ohio participate, it will be critical to establish metric goals for minority and geographic (rural) participation in all of these talent programs.

To help ensure a pipeline of workers, it will be critical for the Innovation Hub to partner with the career center/vocational training offerings around the state to expand their own next-generation manufacturing training offerings and clearly articulate the high demand for these careers, the level of pay, and the opportunity for career pathways to students, parents, and career guidance counselors.

Finally, the Innovation Hub will need to partner with educational institutions across Ohio to develop new work-school models to serve industry partners—apprenticeships, co-op programs, and working student programs. It will be important

Alabama Robotics Technology Park

The Alabama Robotics Technology Park (RTP) is a collaboration between the State of Alabama, Alabama Community College System, Alabama Industrial Development Training, and national robotics industry leaders to create the \$73 million, three-building training center facility. Its mission is to provide a technically trained, highly skilled, and educated workforce for automation and robotics; to assist public and private entities in developing new robotics systems and technologies; and to promote the creation, growth, or expansion of companies through innovative technology.

- Interfaces with industry to produce technical workforce with automation skills directly suited to company needs—serves as primary training hub for major state manufacturing companies
- Hands-on exposure to advanced robotic systems, machine vision, and company-specific customized training on modern equipment used in production lines
- Company recruitment asset for state—for use by in-state companies only

to identify those skill sets that are in the greatest demand and are serving as current workforce bottlenecks and incent individuals to pursue careers by offering free tuition for critical certificates/degrees.

Action 8: Encourage Ohio graduates to pursue careers within the four innovation opportunity platforms by offering financial incentives.

To ensure the human capital that innovative firms require, skilled graduates need to be retained in a competitive national labor marketplace, which can involve programs that give tax credits or other financial incentives to new workers who commit to local employers in roles that are in demand by the four innovation opportunity platforms.

It is recommended that financial incentives be provided for Ohio graduates with skill sets related to the four innovation platforms (including residents attending out-of-state universities) to encourage them to pursue their careers in Ohio. Incentives could be a mix of personal tax credits and tax credits to employers for tuition reimbursements.

To guarantee diversity and inclusiveness of these efforts to ensure that students across the State of Ohio participate, it will be critical to establish metric goals for minority and geographic (rural) participation in all of these talent programs.

To ensure that graduates understand the plethora of career opportunities that exist in Ohio, it will be critical to leverage the Ohio Third Frontier Internship Program and Ohio Means Internships & Co-ops Initiative and innovate programs such as INNOVATE-O-Thon that introduce companies and students to one another for a trial-period.

Action 9: Offer financial incentives for senior and mid-level professionals to relocate to Ohio for careers within the four innovation platforms—create an Ohio Alumni Outreach Program.

Similar to the recommended Serial Entrepreneur Attraction program, it will also be important to attract to Ohio senior and mid-level professionals demanded by industry being impacted by the four innovation platforms. As the four Innovation Hubs help drive innovation into Ohio’s industrial base, it will be critical to be able to attract talent from outside the state to support these opportunities. Ohio should seek to attract talent to the state by offering personal income tax and other incentives. By working to de-risk the perceived costs of relocating to the state, Ohio will catalyze the amount of talent in critical leadership positions in its most innovative firms.

Tax Credit for Aerospace Engineers in Oklahoma

A complex financial incentive has been developed that includes the following:

- A personal tax credit to the aerospace engineer of up to \$5,000 per year for a maximum of 5 years.
- A tax credit to the employer for tuition reimbursements they make to their newly graduated engineers. The credit would apply to up to 50 percent of the average annual amount the engineer paid to earn his or her degree.

A review showed they had generated \$1.4 billion in economic output, \$287 million in employee wages, 4,200 new jobs, and a 16.7 percent growth in aerospace engineer employment in Oklahoma.

Key to the success of this attraction program will be to create an Ohio Alumni Outreach Program, utilizing the vast alumni networks of Ohio's higher education institutions and serving as an immediate connection point to the State of Ohio.

Sources of Funding

While the funding requirements for these critical statewide initiatives will be significant, they will also be transformative for Ohio's economy—developing an innovation ecosystem structured to leverage disruptive change and adapt to it. It is important to note that, within the State of Ohio, funding streams already exist with significant revenue to provide the vast majority of the resources required for these efforts. It is simply a matter, in some cases, of reprioritizing the focus of these existing revenues on these transformative new activities, and in others, of renewing their original purpose/mission. These existing sources of funding include the following:

- **R&D Bond Funding:** The R&D Bond fund has been used to fund the Ohio Third Frontier for over a decade. Utilizing this revenue source, the Ohio Third Frontier has funded a number of innovation-based programs over the years, including efforts to enhance the commercialization of near-market technologies, the advancement of specific industry clusters, and the formation of Wright Centers of Innovation. Since 2008, the bond funding has also provided revenue to support the operations of six ESPs across the state as well as helped capitalize numerous pre-seed and seed funds. The current fund, approved by the voters in 2010, has more than \$225 million of unencumbered funds remaining that could support the regional ESPs and help expand their role to ensure that the innovation opportunities generated by the four Innovation Hubs are scaled in Ohio. In addition, remaining funds could be used to continue to foster the creation of early-stage risk capital funds focused on emerging firms from the four innovation platforms. Further, it is recommended that voters be asked to renew the R&D bond fund at the earliest possible time to provide additional and sustained dollars to fund the other strategic efforts outlined herein.
- **Liquor proceeds:** JobsOhio was created in 2011 as a private corporation funded through the purchase of the state's liquor business. JobsOhio paid the state \$1.4 billion to purchase the liquor enterprise and makes supplemental purchase payments to the state every year based on the total net liquor revenues it receives. JobsOhio has significant discretion in the use of its funds to advance economic development efforts in the state. While the entity's primary focus should remain on its core mission of attraction and expansion of corporate entities to and within the State of Ohio, JobsOhio has sufficient resources and should consider dedicating annually a meaningful portion of the liquor proceed revenues to fund the strategic efforts outlined herein.
- **Federal workforce dollars:** As a result of the Federal Workforce Innovation and Opportunity Act, the State of Ohio receives more than \$150 million a year in federal funds to apply to workforce efforts. While restrictions exist on how the money can be applied, it is recommended that a portion of these dollars be focused on advancing the NextGen Manufacturing and Data Analytics skill sets of Ohio's workers in partnership with the Innovation Hubs.
- **Private capital investments:** It will be critical to engage Ohio's industrial community in these strategic actions to catalyze their own investments in technological development within their own firms that are advanced by the

Innovation Hubs, as well as advancing Ohio's innovation economy through investments in later-stage risk capital financing mechanisms.

By targeting existing revenue streams to these focused initiatives, Ohio will be able to accelerate its economy in new and bold ways.

Summary

The acceleration of Ohio’s economy will require that the State of Ohio focus its innovation investments on three strategic priorities that leverage and complement existing efforts while catalyzing long-term economic growth across the state (Table 13).

Table 13. Recommended Action Plan: Accelerating Ohio’s Economy

Strategy	Baseline Action for Ohio to Consider
<p>Strategy One Foster the Infusion of Advanced Innovation Processes, Products, and Techniques throughout Ohio’s Industrial Base</p>	<p>Action 1: Create four statewide Innovation Hubs that focus on the innovation opportunity platforms and represent public-private partnerships.</p> <hr/> <p>Action 2: Review and update Ohio tax code to create additional ways to incent Ohio companies to invest in new products and process improvements.</p>
<p>Strategy Two Further Elevate the Entrepreneurial/Risk Capital Ecosystem to Drive Future Economic Growth</p>	<p>Action 3: Continue to invest in the regional Entrepreneurial Signature Programs (ESPs) and expand their role to ensure that innovation opportunities generated by the four Innovation Hubs are scaled in Ohio.</p> <hr/> <p>Action 4: Continue to foster the creation of early-stage risk capital by focusing additional efforts on funding the creation of emerging firms from the four innovation platforms.</p> <hr/> <p>Action 5: Stimulate creation/attraction of later-stage risk capital financing to ensure emerging opportunities are able to grow and scale in Ohio.</p>
<p>Strategy Three Develop, Retain, and Attract the Talent that Ohio’s Industry Demands</p>	<p>Action 6: Encompass significant talent development efforts into the Data Analytics Innovation Hub.</p> <hr/> <p>Action 7: Encompass significant talent development efforts into the NextGen Manufacturing and Materials Innovation Hub.</p> <hr/> <p>Action 8: Encourage Ohio graduates to pursue careers within the four innovation opportunity platforms by offering financial incentives.</p> <hr/> <p>Action 9: Offer financial incentives for senior and mid-level professionals to relocate to Ohio for careers within the four innovation platforms—create an Ohio Alumni Outreach Program.</p>

While the funding for these critical statewide initiatives will be significant, they will also be transformative for Ohio’s economy—developing an innovation ecosystem structured to leverage disruptive change and adapt to it.

A Call to Action for Ohio

This report outlines a blueprint to accelerate Ohio's economy through a focus on driving innovation into the state's industrial base, both existing and emerging, to ensure future global competitiveness. The ability to create the envisioned innovation ecosystem has high stakes for Ohio's future. First movers in creating next-generation environments based around innovation platforms will enjoy disproportionate competitive advantages and economic growth compared with competitors. Failure to advance the four innovation platforms identified has significant long-term ramifications:

- Ohio manufacturing and production industries are especially vulnerable to disruption by new technologies and automation and represent a sizable portion of the state's industry strength. Failure to innovate will leave these companies, and hence a large portion of Ohio's economy, at great economic risk.
- The ability to serve populations with modern, innovative healthcare models has significant stakes in the state's quality-of-life attractiveness versus other states adopting novel integrated healthcare models. Failure to innovate will not only leave Ohio's emerging Future Health industrial base at risk, but will also not advance Ohio's clinical care excellence, a positive quality-of-life factor to which Ohioans currently have access.
- Smart infrastructure leadership will be a key attribute in the branding of future attractiveness of Midwest states. Failure to obtain a leadership position will put at risk Ohio's ability to compete for quality of place.
- Other regions are ahead in realizing the importance of their data analytics talent bases to long-term success, and Ohio risks falling further behind without concerted effort in this area.

The stakes are high for Ohio; but, by supporting broad-based **innovation** platforms; further elevating the **entrepreneurial/risk capital ecosystem**; and developing, retaining, and attracting the **talent** that Ohio's industry demands, Ohio can turn innovation into economic growth.



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