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# Building a Knowledge Economy—How Academic R&D Supports High-Tech Employment

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RESEARCH

# INTRODUCTION

Increasing employment in high-tech industries is a core goal of knowledge-based economic development strategies. University research and development (R&D) has been posited as one way to support the health of regional high-tech economies, although the connection between these two elements of a local innovation ecosystem is not always well understood by policymakers.

Technology and innovation are vital considerations when exploring a region's long-term economic growth. While some regions develop new industries and prosper in the long-term, others contract as their core industries become obsolete or local firms are surpassed by competitors. As with natural, cultural, political, and geographic factors, a region's capacity for innovation and its ability to transform new ideas into economic activity can be a key differentiator in the global contest to host jobs and investment.

Universities play an important role in determining this aptitude to evolve. Not only do they educate the local workforce creating human capital, and produce intellectual property (IP), but they also contribute indirectly through their basic research activities. While not of immediate commercial value, these foundational research activities help create and advance industries in unpredictable ways. Studies of regional economic clusters suggest tacit knowledge shared through informal networks and workers moving from one job to another facilitate the recognition of the economic value of research findings and their conversion into private sector solutions or new commercial opportunities.<sup>1</sup> Understanding whether innovative industries in the high-tech sector benefit from R&D activity at regional academic institutions would be useful when assessing the tools available for technology-based economic development strategies. Our empirical analysis of the relationship between research activity and high-tech employment aims to inform

<sup>1</sup> Acs, Zoltan J., David B. Audretsch, and Erik E. Lehmann. "The Knowledge Spillover Theory of Entrepreneurship." *Small Business Economics* 41, no. 4 (2013): 757-74

Fallick, Bruce, Charles A. Fleischman, and James B. Rebitzer. "Job-Hopping in Silicon Valley: Some Evidence concerning the Microfoundations of a High-Technology Cluster." *The Review of Economics and Statistics* 88, no. 3 (2006): 472-81.

# INTRODUCTION

policymakers interested in the long-term capability of U.S. regions to sustain an economic base in knowledge-based industries.

To understand the connection between university research and regional economies, we focus on research spending at universities and its relationship to employment in the region's high-tech sector. While these variables do not capture all the ways in which university research activity can foster regional economic innovation, they serve as measurable proxies for the scale of research activity and the success of industries in the knowledge economy.

In our analysis, we control for factors that can also influence high-tech employment in a Metropolitan Statistical Area (MSA) in an attempt to isolate the effect of university research in particular. Regional characteristics taken into account include the region's working-age population, the number of graduates from local universities, the diversity of the population, and the foreign-born population. We also tested the robustness of our results by evaluating the effect of including the number of high-tech establishments or the region's female population in the model, substituting these for highly correlated variables and achieving very similar results.

The use of time series data allows us to examine the effect of university research expenditures both contemporaneously and in the longer term. This helps differentiate between effects that might share a common cause—for example a high-tech cluster and higher local university research—and a more robust relationship.

By placing the focus on academic R&D activity, the intention is not to diminish the importance of a university's contribution to regional economies through its educational activities. The value of a skilled regional workforce and the benefits to the individual graduates and their future employers of high quality higher education is well explored elsewhere, and this paper conditions for this crucial

# INTRODUCTION

contribution when attempting to distinguish the effects of university R&D by including the number of graduates.<sup>2</sup> Other aspects of a regional innovation ecosystem not analyzed in our model—such as the availability of venture funding, the entrepreneurial culture, and industry mix—may also affect the results.

In our analysis, we find academic R&D expenditures were significantly and positively correlated with regional high-tech employment in the long term, and this relationship remains intact over different model specifications and time periods.

<sup>2</sup> Bloom D.E., Hartley M., Rosovsky H. (2007) *Beyond Private Gain: The Public Benefits of Higher Education*. In: Forest J.J.F., Altbach P.G. (eds) *International Handbook of Higher Education*. Springer International Handbooks of Education, vol 18. Springer, Dordrecht

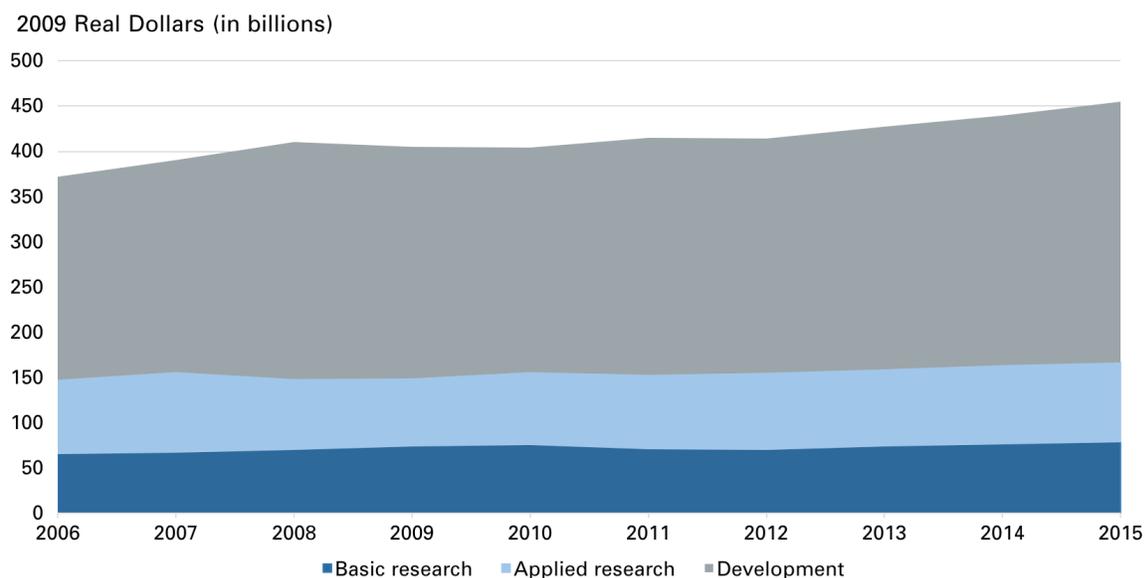
DeVol, Ross, Joe Lee and Minoli Ratnatunga. "Concept to Commercialization: The Best Universities for Technology Transfer." Milken Institute (2017).

# BACKGROUND TRENDS

As context for this discussion, it is useful to examine the scale and trends in a selection of the variables analyzed in our model.

In the United States, R&D expenditures, which include dollars spent on basic research, applied research, and development at all types of non-federal institutions, have been trending upwards in real terms. Development makes up more than half of the overall R&D outlay, as seen in Figure 1. While the private sector takes the lead on development activities, which aim to use research findings to create or improve products and processes, universities are critical sources of basic research. In real terms, university expenditures on basic research have been relatively stable at around \$38.8 billion and accounted for approximately 50 percent of the total basic research spending in 2015 (see Figure 2). This share declined in the past decade as competing budget priorities limited growth in government funding for basic research at universities and the private sector increased its spending on foundational research.

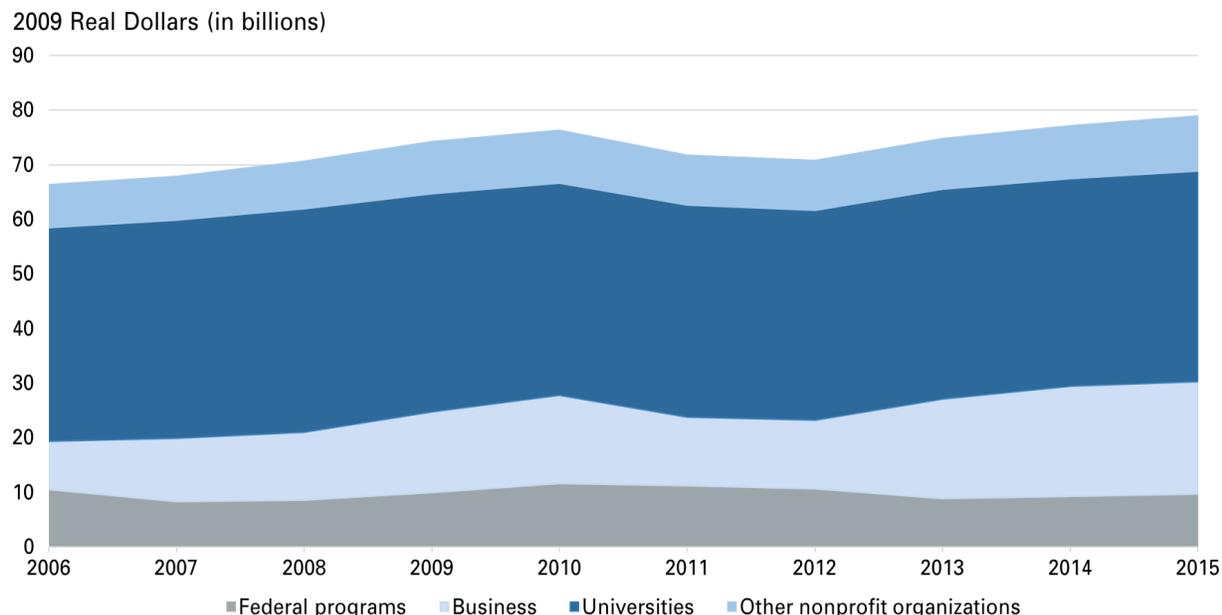
**Figure 1. Total U.S. R&D by Type in 2009 Real Dollars**



Source: National Science Foundation.

## BACKGROUND TRENDS

**Figure 2: Total Basic Research U.S. Expenditures by Source in 2009**  
**Real Dollars**



Source: National Science Foundation.

The nature of university R&D, especially basic research, can seem esoteric and unrelated to short-term market needs. However, through technology transfer and knowledge spillovers, it can pay off in future jobs and is an essential part of the innovation cycle. We examined the impact of technology transfer through patents and other IP in our 2017 paper “Concept to Commercialization.” Knowledge spillovers occur when the results of research enter the market through informal information sharing. This can happen when graduates take what they learned into the workplace, or through networking and collaborative partnerships. Entrepreneurs may recognize the market value of an idea that an academic missed, creating a start-up to commercialize the research. Since innovative approaches to exploit new technologies can be copied relatively quickly once introduced to the market, the return on research is sometimes lower than the private sector needs. However, the wider adoption of a more efficient process or higher quality product has broad economic benefits to society.

## BACKGROUND TRENDS

A university can provide a continual source of innovation that maintains a region's competitive advantage.<sup>3</sup>

A university's role in industrial clustering can benefit regional high-tech firms through alignment of specialization and creation of talent. Start-ups and established firms' choice of location can be influenced by these factors as well. Innovation and technological progress can promote economic growth and regional resilience. Using the university platform, entrepreneurship efforts can be cultivated and strengthened through the availability of concentrated expertise

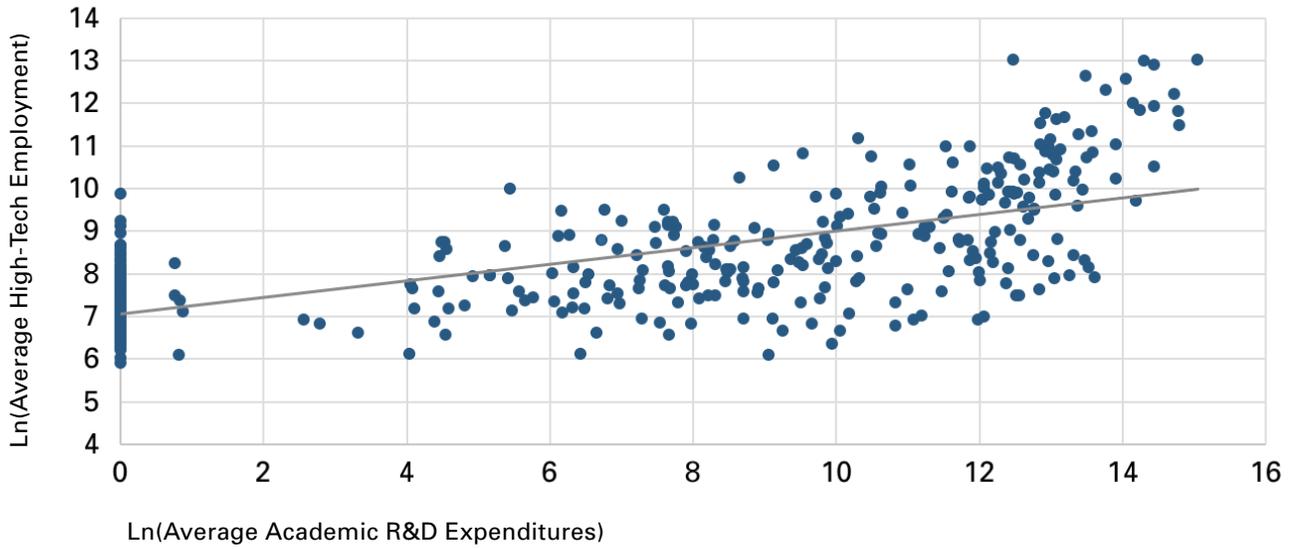
The high-tech sector is made up of industries that depend on innovation and improvement to prosper and require a larger share of workers with advanced skills. This group of industries was responsible for 6.42 percent of net new jobs created and 14.34 percent of net new wages in the U.S. between 2009 and 2015.<sup>4</sup> They are the target of technology-based economic development programs in regions around the country. Given their importance to policymakers, understanding what factors might help these industries prosper could arm local leaders with better information as they try to promote regional growth in a changing economic landscape. By matching universities that spent at least \$150,000 on R&D to their home MSAs, we were able to estimate average academic R&D expenditures by MSA over the 2006-2015 period. In Figure 3, plotting average academic R&D expenditures by metropolitan region against average high-tech employment in that region indicates a positive correlation between these two variables, pointing to a potential relationship warranting more detailed analysis. We examine continuous investment into university R&D by using panel data for our analysis, which can help demonstrate the importance of university spillover effects on regional high-tech employment.

<sup>3</sup> More detail on existing research on academic R&D and its effects can be found in the Appendix.

<sup>4</sup> The data is sourced from the Quarterly Census of Employment Wages and is calculated and distributed by Moody's Analytics.

# BACKGROUND TRENDS

**Figure 3. Average High-Tech Employment vs. Average Academic R&D Expenditures by MSA**



Sources: Quarterly Census of Employment and Wages, Moody's Analytics, Higher Education Research and Development Survey National Science Foundation.

# DATA

This analysis uses an unbalanced panel covering data from 380 MSAs from 2006 to 2015. The data was assembled from several sources. This dataset does not contain the metropolitan divisions. We selected 19 industries from the North American Industry Classification System to define the high-tech sector.<sup>5</sup>

<sup>5</sup> DeVol, Ross, Lee, Joe, and Ratnatunga, Minoli. "State Technology and Science Index: Sustaining America's Innovation Economy." Milken Institute, (2016): 16-17.

High-tech employment is the independent variable used for the analysis. Data on private high-tech employment was based on the Quarterly Census of Employment and Wages.<sup>6</sup> The data for this variable covers the time period from 2005 to 2016 for all MSAs.

<sup>6</sup> The data is sourced from the Quarterly Census of Employment Wages and is calculated and distributed by Moody's Analytics.

Academic R&D expenditures was chosen as the variable of interest to capture the scale of investment in academic R&D. Data was sourced from the National Science Foundation's Higher Education Research and Development survey. The dataset comprises expenditures from the 1,028 universities that had at least \$150,000 in R&D expenditures at some point during the period from 2006 to 2015. Universities on this list were then assigned to MSAs by mapping longitude and latitudes to yield an estimate of academic R&D expenditures in each region.

Data on the number of graduates used in the model captures graduations from 2005 to 2015. This variable counts all graduates from accredited two- and four-year non-profit public and private schools. The data comes from the Integrated Postsecondary Education Data System and has been matched to MSAs. We chose to use the number of graduates instead of the resident population with a Bachelor Degree or higher because the former measure better captures spillover effects from local universities on a metro. The number of graduates could theoretically be more easily affected by local policies, and is unaffected by inflows of highly educated people to an MSA.

**Table 1. Descriptive Statistics**

Variables	Mean	Standard Deviation	Observations	Years
High-tech employment	18,953.9	55,582.9	4,191	11
Academic R&D expenditures (USD in ths)	147,942.6	379,136.6	3,810	10
Females	34,2489.2	77,0947.9	4,484	11.77*
Graduates	23,503.7	48,645.9	4,572	12
Black population	91,706.6	26,9283.7	4,444	11.66*
High-tech establishments	858.7	2,473.9	3,760	9.87*
Working-age population	378,887.1	879,615.4	4,180	11
Foreign-born population	73,021.1	367,500.8	4,572	12
MSAs			380	

\*indicates average of time periods

Source: Milken Institute.

This paper utilizes several control variables for the size of an MSA. The working-age and female populations in a metro are used as demographic controls. The data is drawn from the one-year releases of the American Community Survey (ACS) from 2005 to 2015. Since a little over one percent of the MSAs have a population less than 65,000, we do not need to be concerned that the data contains detrimental bias based on the sampling of the one-year data releases.<sup>7</sup> The number of high-tech establishments in a metro is used as a control for the size of the high-tech sector, and is drawn from the County Business Patterns datasets from 2005 to 2015. This count of establishments uses the same definition of the high-tech sector as used for employment. These three variables are all highly collinear, which makes them unusable together but provides useful robustness checks.

The number of black people and total foreign-born populations in an MSA are drawn from the ACS. The purpose of the control variables is to better obtain meaningful comparisons of MSAs by reducing omitted variable bias. To this end, the choice to use the number of

<sup>7</sup> "When to use 1-year, 3-year, or 5-year Estimates." American Community Survey United State Census Bureau, (2016) <https://www.census.gov/programs-surveys/acs/guidance/estimates.html>

The inclusion of data on the foreign-born population aims to capture the high-tech industry's well-known use of highly skilled foreign labor. It also serves as a proxy for in-migration and diversity of an MSA. Additionally, the foreign-born population helps differentiate large and small metros in this estimation without increasing multicollinearity.<sup>8</sup>

<sup>8</sup> The one-year releases of foreign-born people do not cover the same number of MSAs as the five-year ACS releases. A set of T-tests of five-year 2009 (first release) and 2015 (latest release) compared to the one-year releases show non-significance with the pair of T-scores under one. This testing indicates the one-year variables show no statistically different information from the five-year data releases.

# METHODOLOGY

The empirical analysis for this paper uses an unbalanced panel data set. To estimate this data type, it follows the standard for economics by using a fixed-effects panel model. This is confirmed by rejecting the null hypothesis of a Hausman test. The model conforms to OLS assumptions of proper specification by taking the logarithm of each variable to reduce a large positive skew. Linearity is obtained based on a Link Test finding no squared relationship. The addition of the working-age population, black population, and foreign-born population are to control for differences in demographics between MSAs and reduce omitted variable bias. We have removed all large outliers based on DFFITS values. We address any remaining concerns of autocorrelation and heterogeneity in the data by using robust standard errors. Variance Inflation Factors for all variables are less than three, indicating there is no concern of multicollinearity.

While a within estimator provides a negative adjusted R<sup>2</sup>, a between estimator passes all statistical tests validating the model. However, the nature of the data and the aggregation level defining an MSA makes the traditional fixed-effects panel model assumption that the entity effects are correlated with independent variables too restrictive. The most fundamental example is the heterogeneity of research quality, which can occur not just within a region but also within a university. To take into account both assumptions for random and fixed effects, we have employed a linear mixed-effects model following Mundlak's approach.<sup>9</sup> This allows for explicitly modeling within and between effects as independent variables while being able to take into account entity-specific random effects. The variable of interest in this model is academic R&D expenditures. The other major factor in this model is the number of graduates. These two variables are both highly dependent on the number of universities in a region.

<sup>9</sup> Bell, A. J. D., & Jones, K., "Explaining Fixed Effects: Random Effects modelling of Time-Series Cross-Sectional and Panel Data." *Political Science Research and Methods* 3, no. 1 (2015) 133-153

## METHODOLOGY

The relationship between these three variables is one in which not including the relevant institutions causes omitted variable bias in the estimation and including them breaks the assumption of no multicollinearity. Due to this problem, the mixed-effects model is preferred to control for the underlying factors over both the fixed- or random-effects models due to the assumptions these models require.

Beyond accounting for bias, this model allows for a useful interpretation of R&D in which the deviations from the mean are short-run effects or within-group effects. The variable means are calculated as the means over the sample period, which yield the long-run effects or between-group effects. This is particularly useful for interpreting how academic R&D expenditures impact MSAs' high-tech employment. Equation 1 is the model used in the estimation. Equations 2 and 3 are the assumed distributions for the error terms. Equations 4 to 6 are the weights used to estimate the random effect.

$$\ln(\text{High Tech Employment})_{ij} = \beta_0 + \beta_1 \ln(R\&D_{ij} - \overline{R\&D}_i) + \beta_2 \ln(\overline{R\&D}_i) + \sum_{k=1}^m \gamma_k \ln(X_{kij} - \overline{X}_{ij}) + \sum_{k=1}^m \varphi_k \ln(\overline{X}_{ki}) + (\mu_i + \varepsilon_{ij}) \quad (1)$$

$$\mu_i \sim N(0, \sigma^2) \quad (2)$$

$$\varepsilon \sim N(0, \sigma^2) \quad (3)$$

$$\mu_i = w_i \overline{e}_i \quad (4)$$

$$\overline{e}_i = \sum_{k=1}^m \hat{\gamma}_k e_{it} \ \& \ e_{it} = \ln(\text{High Tech Employment}) - \hat{\beta}_0 - \hat{\beta}_1 \ln(R\&D_{ij} - \overline{R\&D}_i) - \hat{\beta}_2 \ln(\overline{R\&D}_i) - \sum_{k=1}^m \hat{\gamma}_k \ln(X_{kij} - \overline{X}_{ij}) - \sum_{k=1}^m \hat{\varphi}_k \ln(\overline{X}_{ki}) \quad (5)$$

$$w_i = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \frac{\sigma_\varepsilon^2}{n_i}} \quad (6)$$

# RESULTS

The results of this analysis are reported in Table 2. The first column is the base model (Base), while the second column (Extension) builds towards the main findings. The final results are reported in the third column (Main Results), while the fourth and fifth columns are robustness tests. This model captures both the short and long-run effects of each variable, shown by the deviations from the mean and corresponding mean, respectively. This model took into account the randomness of the aggregation represented by MSAs (see Methodology). The usable data for the estimations is a subset that covers 380 MSAs between 2006 and 2015. The total number of observations for the results is 3,442.

<sup>10</sup> Koller, M. "robustImm: An R Package for Robust Estimation of Linear Mixed-Effects Models." *Journal of Statistical Software* 75, no. 6 (2016): 1-24

**Table 2. Mundlak Linear Hierarchical Mixed Effects Model<sup>10</sup>**

Variables	Base Ln(High-Tech Employment)	Extension Ln(High-Tech Employment)	Main Results Ln(High-Tech Employment)	Robustness Check 1 Ln(High-Tech Employment)	Robustness Check 2 Ln(High-Tech Employment)
Ln(Academic R&D expenditures)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0002 (0.001)	-0.0002 (0.001)	-0.0002 (0.001)
Ln(Academic R&D expenditures) (mean)	0.06*** (0.008)	0.06*** (0.009)	0.06*** (0.008)	0.04*** (0.009)	0.04*** (0.008)
Ln(Number of graduates)	-0.009*** (0.002)	-0.009*** (0.002)	-0.009*** (0.002)	-0.006*** (0.002)	-0.007*** (0.002)
Ln(Number of graduates) (mean)	0.06*** (0.02)	0.06*** (0.02)	0.06*** (0.02)	0.11*** (0.02)	0.04* (0.02)
Ln(Working-age population)	0.33*** (0.03)	0.33*** (0.03)	0.33*** (0.03)		
Ln(Working-age population) (mean)	1.03*** (0.04)	0.97*** (0.05)	0.83*** (0.6)		
Ln(Total high-tech businesses)				0.01 (0.01)	
Ln(Total high-tech businesses) (mean)				0.98*** (0.08)	
Ln(Female population)					0.17*** (0.2)

# RESULTS

Ln(Female population) (mean)				1.19***	(0.07)
Ln(Black population)	0.0008	0.0008	0.002	0.002	(0.004)
Ln(Black population) (mean)	0.05**	0.05**	0.23***	-0.03	(0.02)
Ln(Foreign-born population)		-0.002***	-0.001***	-0.001**	(0.0006)
Ln(Foreign-born population) (mean)		0.04***	0.12***	-0.004	(0.01)
Constant	-5.13***	-4.82***	-3.21***	10.71***	-6.15***
Metro random effect	Yes	Yes	Yes	Yes	Yes
Year random effect	Yes	Yes	Yes	Yes	Yes
Observations	3,443	3,443	3,443	3,443	3,443

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ , (Robust Standard Errors in parenthesis).

Note: all variables without the (mean) tag are deviations from the mean. W.A.P is short for working-age population.

Source: Milken Institute.

The main results and two robustness checks show academic R&D expenditure estimates are relatively stable in our analysis. The long-run effects of academic R&D expenditures are highly significant and maintain their directionality over all regressions. The short-term effects of academic R&D expenditures are insignificant over all estimations. The implied net effect of a one percent increase in academic R&D expenditures is a 0.06 percent increase in high-tech jobs, all else being equal. This result suggests academic R&D expenditures have no short-run effects but do have positive long-run effects on high-tech employment, in our model. The dynamic in this estimation indicates university R&D has long-run spillover effects on high-tech employment.

The number of graduates in a metro has negative short-run impacts on high-tech employment, but the long-run effects overwhelm any negatives. This could mean in the short-run during the years studied, new graduates had a hard time getting jobs in the high-tech sector due to lack of experience.

## RESULTS

In the long-run, the number of graduates had a net positive effect on high-tech employment in a metro. This could reflect that places with more graduates have more opportunities for employment. Robustness Check 1 addresses the number of high-tech establishments in an MSA and follows the same pattern as the main results. It supports the idea that metropolitan areas with more opportunities are better equipped to absorb graduates in the long run. The robustness analysis shows this dynamic is relatively stable. The net positive impact of university graduates supports the idea of positive university spillovers to the private sector.

The size of an MSA's working population has a net positive effect on high-tech employment, which is expected. The number of high-tech establishments and females in an MSA also show significant and positive long-run effects. Short-run effects for high-tech establishments are insignificant. Robustness Check 2 shows the estimation including the female population washes out the effects of most other control variables. The robustness analysis shows the effect of foreign-born populations on our model is unstable. Looking at the samples from 2006 to 2008 and 2009 to 2015, the estimation specification for Robustness Check 2 shows the foreign-born population is never significant and short-run impacts change directionality. This result is most likely due to the increased correlation between the female population and all other demographic variables.

# CONCLUSION

Using an empirical analysis of data from 380 American metropolitan regions, this paper supports interest in the role academic R&D plays in fostering high-tech industries. In our model, we found university research expenditures were significantly and positively correlated with high-tech employment in a metropolitan area, and this relationship remains intact over different model specifications and time periods. However, the effect of university R&D on high-tech employment was felt in the long term, not in the short term, indicating that policymakers should be aware the impact of investments in R&D may take years to bear fruit.

The linkage between university research and regional high-tech employment likely runs more strongly through certain industries depending on how easily research findings are formalized and transmitted, but our initial analysis looked at the relationship across the whole economy in order to yield information relevant to a broader group of policy makers. Future research could examine the relationship between particular areas of academic research excellence and activity, and the success of related local high-tech industries across U.S. regions.

Given the importance of being able to adapt to changing economic circumstances in sustaining prosperity in their communities, local leaders should invest in policies that facilitate innovation and help bring new ideas to market. University research is a key source of innovation, and our analysis suggests academic R&D could help support the vitality of the local high-tech sector in the long run as part of an overall innovation ecosystem.

# CONCLUSION

## Key Findings

- The net effects of academic R&D expenditures on a metro's high-tech employment are positive in the long run, suggesting R&D funding is an investment in the regional innovation ecosystem.
- Increasing the number of graduates from local universities has a net positive effect on high-tech employment in a metro in the long run.
- Technology transfer offices that facilitate the commercialization of academic R&D can be a mechanism to capitalize on untapped innovation.
- Funding career development centers, placement services, and collaborative partnerships may increase spillover effects from universities by creating more opportunities for informal knowledge exchange.

# APPENDIX

## LITERATURE REVIEW

Research into agglomeration suggests proximity to consumers, suppliers, larger labor supplies, natural advantages, and technology R&D all contribute to industrial clustering (Ellison et al, 2010). The positive evidence of clustering is well defined for more traditional industries (Ellison et al, 2010). When examining high-tech firms, most empirical inquiries look at entrepreneurial activity related to economic growth (Valero and Reenen, 2016, Acosta et al, 2011). There is evidence that clustering and location can positively affect high-tech start-ups, while universities can have positive effects on clusters of high-tech firms (Maine et al, 2010, Fritsch and Aamoucke, 2013, Audretsch et al, 2012). University specialization can also have positive impacts on cluster creation, specifically for science and engineering firms (Bonaccorsi, 2013). University contributions to a cluster come in many forms, the most observable being the creation of human capital. Evidence exists that graduates are the most influential factor for university spillover effects, as former students take what they learned into the workplace (Acosta et al, 2011). There is also evidence showing research universities can have significant impacts on new firm behavior (Audretsch et al, 2012).

The idea that technology is a foundational part of economic growth theory is well recorded (Mankiw et al, 1992). Innovation is at the core of how technology interacts with other inputs to create growth. One path from a basic research discovery to economic activity runs through the university technology transfer system, as explored in “Concept to Commercialization” (DeVol et al, 2017). Ideas with recognized commercial value can be patented and licensed for use by the private sector. However, the potential use and relevance of research results are not always understood initially, and the path to market for these discoveries is more difficult to track.

The Knowledge Spillover Theory of Entrepreneurship (KSTE) posits entrepreneurs' play a vital role by taking advantage of knowledge spillovers from universities, but ideas must pass through a knowledge filter to be developed (Acs et al, 2013). A knowledge filter is described as an impediment to the commercialization of ideas. This filter can manifest as legal or regulatory burdens, transaction costs, asymmetric information, etc. Universities can help ameliorate the impact of the knowledge filter by providing a platform that reduces friction through collaboration, expert knowledge, networks, or other resources. With knowledge spillovers often occurring through informal information sharing, proximity can be a crucial factor, with the effects diminishing with distance from the university (Anselin et al, 1997, Qian 2018). This highlights a potential constraint on the effects of these knowledge spillovers, depending on the regional absorptive capacity, or whether a region has sufficient resources available locally to successfully convert innovation into economic activity (Qian and Acs, 2013). The idea that knowledge spillovers have benefits can be seen in research on industrial clustering. An examination comparing private entrepreneurship to university entrepreneurship suggests larger spillover effects if the latter is involved (Link and Ruhm, 2011). Knowledge generated through R&D activity at a university can use collaborative platforms, like StartX at Stanford or the University of Washington's partnership with the Gates Foundation, to pass through the knowledge filter more easily. The direct connection to a constant flow of people entering the workforce or become entrepreneurs also expands networks and allows for the incorporation of new knowledge into private sector practices.

Research and development activities play a key role in endogenous growth. Typically, growth modeling emphasizing R&D focuses on the way it can enable increases in productivity, increases of product quality, or reduction of costs of production (Doraszelski and Jaumadreu, 2013, Thompson 2001, Cozzi and Tarola, 2006, Kretschmer, 2012).

A whole branch of the literature on R&D is related to its effect on employment. Some evidence suggests federal programs like Small Business Innovation Research (SBIR) grants have limited ability to create jobs retained after the project funding is completed (Link and Scott, 2012). Evidence also supports the claim that the impact of R&D on employment diminishes over time, which makes intuitive sense, since R&D outcomes are hard to monopolize because of externalities caused by R&D and first-versus-second-mover effects (Falk, 2012, Dasgupta and Stiglitz, 1980, Derfus and Maggitti, 2008, Campisi et al, 2001, Jones, 2000). Once an innovation has been commercialized, any rival reproduction no longer faces as many barriers to entry. New market entrants increase competition, and speed improvements and responses by rival firms. As a result of these positive externalities from R&D activity, private firms in a competitive market are likely to underinvest in R&D compared to the desired social optimum. University R&D is an important supplement to market driven R&D activity.

There is a large body of work on universities as part of regional economies and their role in the innovation process. The question being studied is, do academic R&D expenditures affect a metro's high-tech employment? This is of interest because by adopting new technology and new forms of capital, the high-tech sector can alter the share of labor needed while also creating new opportunities and efficiencies. (Mankiw, 1992). In this paper, we examine initial investments in innovation to understand their eventual impacts on a fundamental part of the economy. There is evidence research universities have positive impacts on employment during periods of economic expansion and no effect during contraction, but the combination of those time periods net to a positive impact (Lendel, 2010). Our analysis reexamines this previous work by using data covering an economic contraction and subsequent recovery using a model accounting for this reality. Evidence also exists showing R&D activity does have positive impacts on employment, but these impacts decrease over time (Falk, 2012).

## APPENDIX

The use of panel data offers a different perspective of the impact of R&D, exploring the continual investment rather than the effects of one investment over time. In this paper, we examined the impact of academic R&D expenditures and production of graduates as two of the channels through which universities spillovers can affect an MSA's high-tech employment.

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